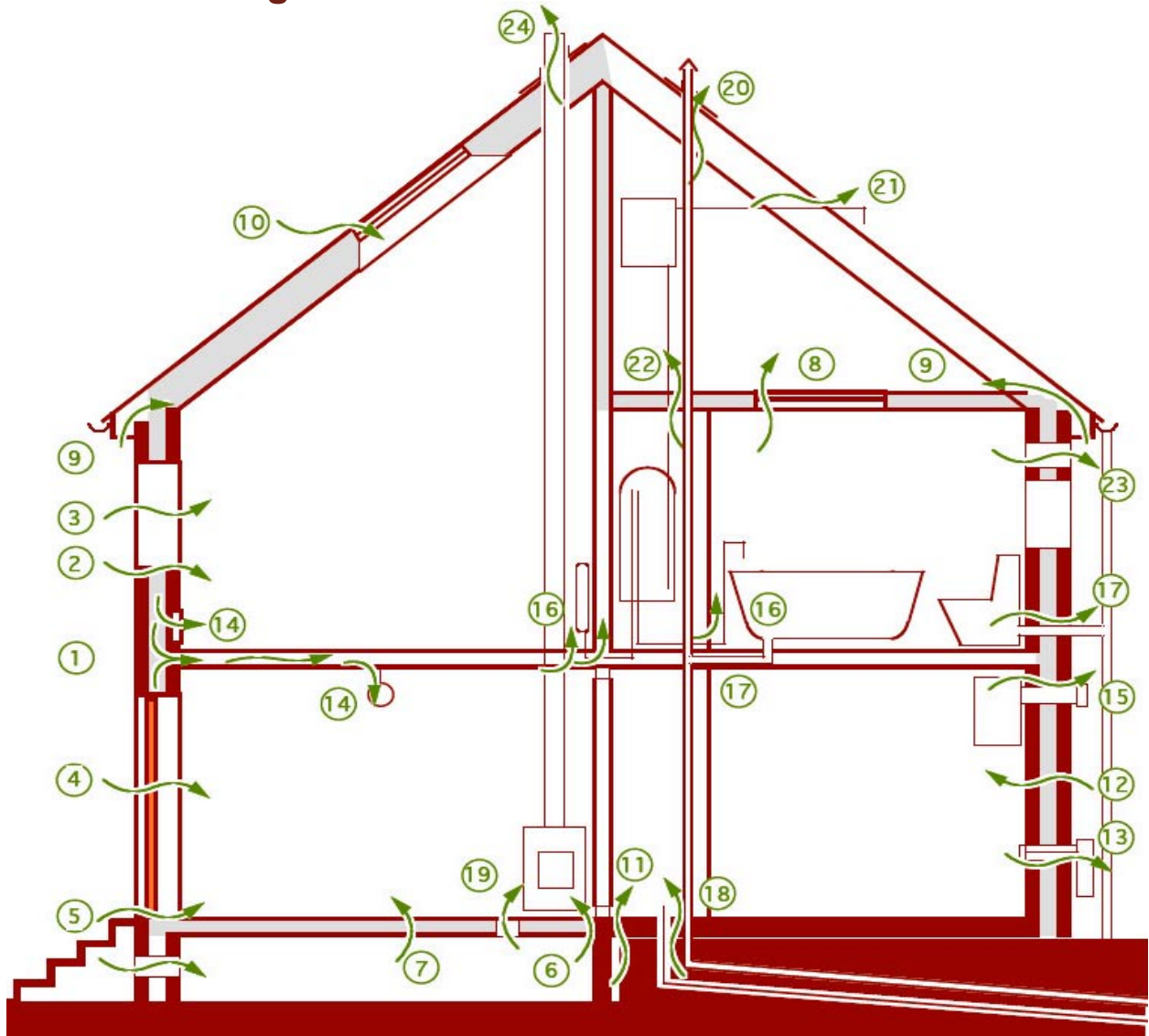


Design and Detailing for Airtightness

SEDA Design Guides for Scotland : No. 2



Chris Morgan



SCOTTISH EXECUTIVE



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1 Introduction

As thermal insulation levels have risen in the last few years the proportion of energy lost to draughts has increased to the extent that now in some cases around half of all heat losses are due to air leakage across the building fabric ⁽¹⁾. Given that approximately half of all energy used in the UK is in buildings ⁽²⁾, it is not hard to see that draughts account for a staggering amount of energy - and therefore cost - wastage.

The situation is such that further increasing thermal insulation levels would be largely unproductive unless airtightness is conscientiously addressed. Air leakage has been shown ⁽³⁾ to reduce the effectiveness of thermal insulation by up to 70% and so it is clear that if energy efficiency is to be improved in buildings, the next efforts will have to focus on airtightness.

Many people make the mistake of thinking that an airtight building is necessarily a 'stuffy' building. This is not the case. All buildings have to be ventilated for health and comfort and airtight buildings are no different. An adequate ventilation system (which may well include openable windows as well as fans etc.) has to be planned for every building. The difference will be that a great deal of unplanned air leakage needs to be stemmed (see right).

As described in Chapter 6, the additional costs of creating an adequately airtight building can be negligible, but even where costs are increased, these can be more than offset by a reduction in the capital cost of heating and ventilation equipment, not to mention the long term savings in energy.

Given that the vast majority of building stock is existing, a great deal of attention will need to be given, in the foreseeable future, to remedial works to existing buildings. This guide specifically includes examples of good and best practice remedial work in terms of airtightness and shows that such works can offer substantial benefits without undue disruption or cost.

The Scottish Ecological Design Association (SEDA) has commissioned this Guide to help address the above problems and provide practical guidance on how to save energy and costs and protect building fabric. On the basis that prevention is cheaper and easier than cure, one purpose of this guide is to enable Designers to design inherently more robust and durable solutions which avoid costly and time consuming remedial works on site.

The general guidance here is firmly focused on the idea of practical design and detailing, and should be read in conjunction with other guidance on sustainable design, energy efficiency and airtightness where necessary to provide an overall design framework. The details provided have been fully costed, tested and subjected to a Defects Liability insurance assessment. They are offered as viable alternatives to standard details, and illustrate the possibilities that exist. It simply remains for you, the reader, to apply them



Snow melt on the roof of the Sheffield University Student Union Building showing the effects both of thermal bridging and (warm) air leakage. Source: Prof. R. Lowe.



Undergoing a smoke test under pressurisation exposes this building's frightening lack of airtightness! Source: A. Leaman & W. Bordass, www.usable-buildings.co.uk



A thermographic image of heat loss through a Sports Centre, indicating a couple of potential air leakage sites. Source: P. Jennings.



This Glasgow tenement was refurbished using a variety of energy efficiency measures including airtightness. Source: J. Gilbert.

1. BRE, *Airtightness in Commercial and Public Buildings* 2002, p.3
 2. See, for example p2 of the final report of the Sustainable Buildings Task Group, available at <http://www.dti.gov.uk/sustainability/>
 3. For a detailed analysis of the problem, generally termed 'convective bypass and blow-through' refer Lowe R, *Impacts of construction defects on heat loss and CO2 emissions from dwellings*

appropriately in the context of your next project...

1.1 Aims of this Guide

- To highlight benefits of airtightness which include both energy and cost efficiency, improved comfort and reduced risks of damage to building fabric
- To improve awareness of the need for airtightness in construction
- To promote detailing and specification solutions which create airtight and efficient buildings thus reducing the need for remedial works - 'prevention rather than cure'
- To show that new build and remedial airtightness are achievable without undue cost penalties to construction works
- ... and in this way to help to 'mainstream' the good and best practice outlined in the document.

1.2 Target audience

This Guide will help all those who wish to improve the airtightness and energy efficiency of buildings through their construction, e.g:

- clients –building owners and users,
- principal and specialist contractors,
- interior designers
- architects and technicians
- structural engineers
- building service engineers
- building surveyors
- quantity surveyors/ cost consultants
- maintenance and facilities managers
- project managers
- planning officers and building control officers
- funding bodies and their professional advisors
- government and non-governmental agencies,

1.3 How to use this Guide

This Guide is divided into six sections. The first two sections provide an overview of the issues surrounding airtightness. Sections Three, Four and Five describe the requirements for the design process, the procurement and the testing involved in designing for airtight buildings.

Section Six provides a number of representative details which have been optimised in terms of airtightness. These are compared with standard details for a variety of construction types, and costed. This section will be primarily of interest to the design team. It should be read in conjunction with sections Three, Four and Five in particular, as all details must be placed in a suitable context.

At the end of this Guide there is an annotated list for further reading, as well as a list of useful contacts and websites.



In the few cases where airtightness is currently taken seriously in Scotland, it is often a story of time consuming application of mastic. Much of this effort can be designed out and more durable, effective solutions designed in from the start. Source: C. Morgan.



As part of the EU 'Shine' projects ⁽⁴⁾, this housing in London was retrofitted with a range of energy efficient measures including airtightness improvements and testing. Heating requirements were reduced by three quarters, with significant benefits for tenants and implications for fuel poverty generally. Source: N. Beddington.

4. EU Energie "SHINE" projects. UK involvement by Hyde Housing Association (0208 297 7500, Contact Sally Buckley), Ecological Development (0207 837 6308) Dyke Coomes Associates (0207 702 7558)

2 The Context

Key Principles

1. Most UK construction is 'leaky' and wastes energy and money. Building airtight buildings can save energy and money, improve comfort and reduce the risk of damage to building fabric.
2. Airtight building will NOT mean 'stuffy' buildings. Good ventilation is vital for health and comfort - it is the UNPLANNED leakage of air that we are aiming to stem.
3. Legislation is slowly catching up with best practice in Scotland, the UK and elsewhere and we can expect a greater emphasis on airtightness in all types of construction in due course.
4. Good and Best Practice Targets have been set for many types of buildings and are easily achievable.

2.1 Infiltration, Ventilation and Airtightness

Air infiltration is the uncontrolled flow of air through gaps in the fabric of buildings. It is driven by wind pressure and temperature differences and as a result is variable, responding in particular to changes in the weather. Infiltration levels are strongly affected by both design decisions and construction quality.

Ventilation, on the other hand, is the intended and controlled ingress and egress of air through buildings, delivering fresh air, and exhausting stale air in combination with the designed heating system and humidity control, and the fabric of the building itself.

Whilst some unwanted air infiltration will at times aid comfort levels, it is not reliable and moreover brings with it a range of significant disadvantages such as high levels of heat loss, reduction in performance of the installed thermal insulation, poor comfort, poor controllability and risks to the longevity of the building fabric itself. It cannot be considered an acceptable alternative to designed ventilation. Infiltration needs to be reduced as much as possible if we are to create efficient, controllable, comfortable, healthy and durable buildings. This can be achieved by delivering airtight buildings.

Airtightness is a term used to describe the 'leakiness' of the building fabric. An airtight building will resist most unwanted air infiltration while satisfying its fresh air requirements through a controlled ventilation strategy. Most existing buildings, even those built recently, are far from being airtight and because of unwanted air infiltration generate huge costs to owners and occupants, in environmental, financial and health terms.

It is important to emphasise the distinction between infiltration and ventilation, because while the primary purpose of this document is to show how buildings can be designed and constructed to be airtight, it is equally important to stress that good levels of ventilation and a clear ventilation strategy will be required in every case. As the saying goes: 'build tight, ventilate right.'



The difference between ventilation and air leakage is illustrated here. A ventilation duct has been designed to extract air from the building. Meanwhile, warm air is escaping, and cold air seeping in through the unsealed gap around the duct as it passes through the wall. It is these gaps, and this infiltration that needs to be plugged. Source: P. Jennings.

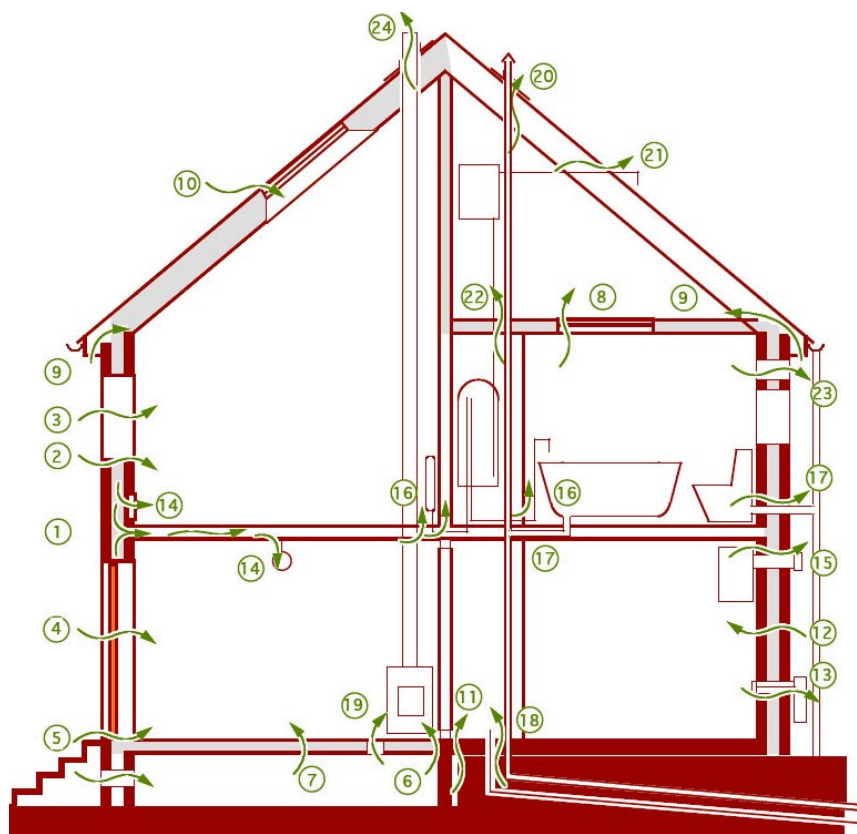


Diagram indicating some of the many myriad ways in which air can infiltrate a building fabric, key to the numbers to right

1 gaps between floor joists and inner leaf of external wall can connect with gaps through-out the building

2 gaps and poorly sealed membranes around, but especially beneath windows and window cills, leak direct to the outside or into the cavity

3 leakage through window openings due to ineffective or missing draughtproofing, through hollow (plastic or metal) frames themselves

4 leakage through doors, especially the meeting stiles of double doors

5 gaps beneath and around doors

6 cracks around skirting boards linked to gaps around the edges of suspended floors

7 leakage through suspended floors, typically bare timber floor boards

8 gaps around loft hatches

9 leakage from eaves into attics often via cavities and behind plasterboard, indirectly into rooms

10 gaps around rooflights, eg where the rooflight frame is not sealed to the adjacent rafters

11 cracks where dissimilar structural elements such as columns meet floor slabs

12 leakage through porous masonry leaves, eg perpendents not filled, often linked to gaps behind drylining. In timber frame building eg where a vapour check is torn or not sealed.

13 gaps in the external wall at services entry

14 leakage around ceiling roses, recessed spotlights and pullcord switches between a warm room and roof space or intermediate floor

15 gaps around boiler flues (in walls and roofs)

16 small gaps where water / heating pipes enter rooms from floors, walls and boxed in spaces

17 gaps around waste pipe penetrations eg behind toilets, baths and kitchen sinks

18 service entry points, even in concrete slabs within a larger diameter pipe

19 airbrick / air entry to open-flued fires required by the regulations admit air at all times, not just when the fire is on use.

20 large gaps where soil pipes / ventilation flues penetrate the roof

21 other roof penetrations eg overflow pipes

22 gaps between heated spaces and a cold loft where water pipes and cables pass between, often in airing cupboards

23 poorly sealed wall mounted extract fans, also ducted extract from cooker hoods, tumble driers etc allow air directly into and out of the room, but also into the cavity

24 chimneys and flues, if not sealed properly will allow leakage at all times

2.2 Why Build Airtight?

Legislation

At a rather prosaic level, the issue is important because it is now part of the Building Regulations in England and Wales concerning non-domestic new buildings over 1000 sqm in area, and is likely to affect a wider range of buildings soon. Whilst the initial targets set for airtightness of buildings are easy to achieve (see 2.5), it is equally likely that once in place, those targets will be ratcheted up to create ever more airtight and efficient buildings in Scotland and the rest of the UK, in line with many of our European neighbours.

Energy and Cost Saving

Typically, the largest heat losses in most buildings are related to levels of thermal insulation, followed by those related to infiltration, followed by those related to inefficient plant. Quite rightly therefore, most efforts to save energy and costs have until recently been directed at increasing thermal insulation levels. But as these levels have risen, so the relative contribution of infiltration has increased to the point where it can represent around half of all heat loss in a building. In highly insulated buildings, the percentage may be higher.

This is reflected in the fact that total space heating costs in an airtight building may be as much as 40% less than in a leaky one ⁽⁵⁾.

5. BRE, Airtightness in Commercial and Public Buildings 2002, p.3

We are at the stage where it is likely that any further increase in thermal insulation levels would be ineffective until levels of airtightness in construction have improved considerably.

Space Heating System Reduction

Clearly there is potential to reduce the capacity of space heating systems sized to cope with current levels of heat loss if those levels can be reduced by a half or more. In addition, airtight buildings are more predictable in terms of environmental control and the capital cost savings of installing smaller heating plant may be augmented by reduced plantroom sizes in certain cases, and particularly by reduced running costs in the longer term.

As well as reducing the need for heating plant, airtight buildings offer much greater potential to respond positively to the local external climate through passive, or climate responsive design strategies such as natural ventilation, daylighting, the use of thermal mass and passive solar gain. Energy savings, capital and running costs, along with CO₂ emissions can thus be further reduced.

Comfort and Control

As noted above, airtight buildings are not as affected by variations in external conditions. This makes them easier to control from an Engineer or Designer’s point of view, but it also makes them more comfortable from the point of view of the occupant.

In buildings with high levels of infiltration those occupants near draughty windows, for example, will suffer the cold, particularly on windy days, whereas those elsewhere may well suffer from too much heat locally as the system tries to raise the temperature overall. Those who try to achieve comfortable levels through the use of the provided ventilation controls will find these to be relatively ineffective, whereas in more airtight buildings greater levels of control and comfort generally are achievable and local control and variation by occupants can have a more direct effect. In one example of an existing superstore, the ambient temperature in the store was raised by 5°C after the store had been sealed ⁽⁶⁾.

Complaints by occupants in leaky buildings are common, and remedial measures are usually difficult and expensive.

Deterioration of Fabric

Leaky buildings allow cold air in through the construction causing discomfort, they also allow warm (and often moist) air out, causing heat loss. This warm and often moist air can find itself in colder parts of the outer construction where it can cool, and the moisture in the air can condense, leading to a build up of moisture. This in turn can lead to:

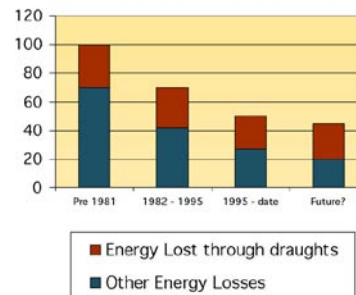


Figure of heat losses per P. Jennings, 'Airtightness in Buildings' Building for a Future Winter '00/'01



Buildings using slow response heating systems such as storage heating or underfloor heating can be vulnerable to discomfort caused by air leakage during certain weather conditions if they are not well insulated and carefully sealed. Source: C. Morgan.

6. Quoted by HRS Services in their Airtightness Information Pack, p.5 - see www.air-tightness.co.uk or 0114 272 3004.

- decay of organic materials such as timber frames
- saturation of insulating materials thus reducing their insulative effect (which increases heat loss further)
- corrosion of metal components
- frost damage where moisture has accumulated on the cold side of the insulation.

2.3 Legislation

In England and Wales the relevant regulation on airtightness is contained within Approved Document L1 for dwellings and L2 for non-domestic buildings (2002). There is general encouragement to consider airtightness issues, with a target air permeability for all buildings of $10 \text{ m}^3/\text{hr}/\text{m}^2$ envelope area at 50 Pa. In L2, buildings with a floor area of greater than 1000 m² are required to be tested if approved details are not used. Further tightening of the regulations are due in 2006 and 2010.

In the new Scottish Building Standards, the relevant section is 6.2.5 for both domestic and non-domestic buildings. In the domestic version, Designers are directed to Building Research Establishment (BRE) Report 262 – “Thermal insulation, avoiding risks” 2002 edition, and in the non-domestic version, to the BRE document BR 448: Airtightness in Commercial and Public Buildings but it is stated explicitly that “within the Building (Scotland) Regulations 2004 there is no requirement, mandatory or otherwise to test buildings”.

Proposals for changes to the Energy standards were issued to public consultation in March 2006, including guidance that air tightness testing would be required if the calculation of energy performance included air permeability rates lower than $10 \text{ m}^3/\text{m}^2\text{h}$ at 50 Pa.

2.4 Measurement

A range of units for measuring airtightness have been used in the past and this can complicate matters. However, one method only – “air permeability” - is the measure used in European Standards, the new editions of the various UK Building regulations and in CIBSE’s TM23 Testing methodology and has been used throughout this document. The Air Permeability is defined as the volume flow in cubic metres of air per hour per square metre of the total building surface area (including the floor) at 50 Pascals pressure differential, expressed in $\text{m}^3/\text{hr}/\text{m}^2 @ 50 \text{ Pa}$.

The main difference between the air permeability and previous practice in the UK is the inclusion of the non-exposed ground floor in the calculation of the ‘total surface area’ of the building. The difference between the new measurements and older ones tend only to be marked therefore where there are large volumes and ground floor areas.

Of the range of measurements used previously, the “Average Air Leakage Rate (or Index)” is similar to the “Air Permeability”



The Elizabeth Fry Building at the University of East Anglia was designed as an extremely low energy building, with airtightness measures, and testing an integral part of the strategy. Designed by John Miller & Partners. Source: John Miller & Partners / www.johnmillerandpartners.co.uk



This Leisure Centre in Lochinver, Sutherland was pressure tested to ensure that the designed energy efficiency measures would lead to the anticipated energy savings for the Client. Design: Gaia Architects. Source: C. Morgan.

except that non-exposed floors are excluded from the measurement. Another common expression is the “Air Changes per Hour at 50 Pascals (ACH @ 50 Pa). This is a useful measurement in particular because, when divided by twenty, it gives an approximate value of the natural infiltration rate of the building at normal atmospheric pressure, which can then be used to help size heating and ventilating plant etc.

Yet another measurement is the “Equivalent Leakage Area” (ELA) at 50, 10 and/or 4 Pascals. This figure gives a representation of the sum of all of the individual cracks, gaps and openings as a single orifice and helps to visualise the scale of the leakage problem. The main problem of changing the measurement technique is the ability to compare data. See P Jennings, *Airtightness in Buildings in ‘Building for a Future’* for a good account of the issues.

The standard pressure differential used is 50 Pascals. This is not in fact a very large pressure differential and corresponds to the pressure exerted by a column of water 5mm high. Compared to the fact that buildings can withstand wind induced pressures of at least 500 Pascals, this seems insignificant, but it is larger than wind induced pressure on a calm day, and by testing and quoting air leakage figures at 50 Pascals, inaccuracies are reduced and repeatability is improved. See Chapter 4 for more on this.

2.5 Targets

As noted above, the only ‘official’ guidance in the UK applies in England and Wales and relates to non-domestic buildings over 1000 sq.m in area. As can be seen from the table below, the target of 10 m³/hr/m² at 50 Pa. is relatively easily achieved compared to the good and best practice noted in the 2000 document by CIBSE, TM23. This sets out the testing methodology which is the de-facto methodology now followed in the UK.

Building Type	Air Permeability (m ³ /hr/m ² at 50 Pa)	
	Good Practice	Best Practice
Dwellings	10.0	5.0
Dwellings (with balanced mech. vent.)	5.0	3.0
Offices (naturally ventilated)	7.0	3.5
Offices (with balanced mech. vent.)	3.5	2.0
Superstores	3.0	1.5
Offices (low energy)	3.5	2.0
Industrial	10.0	2.0
Museum and Archival Storage	1.7	1.25
Cold Storage	0.8	0.4

Air Leakage Standards, based on CIBSE TM23 2000 (upper five), BSRIA Specification 10/98 and BRE BR448, 2002 (lower four).

A number of airtightness experts believe the stated targets are inadequate when compared with the overwhelming need to address carbon emission reductions, and the potential to do so through airtightness measures. For example, the house illustrated to the right was built in 1992 for the same cost as nearby houses and improved upon the standards noted above by two thirds.



Air leakage measurements for large single storey buildings with non-exposed floors like the one above are more noticeably different because one of the previous expressions of airtightness excluded non-exposed floors from the measurement. Source: C. Morgan



In Canada, ordinary dwellings are routinely built to an airtightness of around 3 m³/hr/m² at 50 Pa (BRE IP 1/00). Even in the UK, the house above, by David Olivier of Energy Advisory Associates achieved a monitored airtightness of 3.3 m³/m²hr @ 50 Pa, before remedial works. Source: D. Olivier.

3 Designing for Airtightness

Key Principles

1. A Performance Specification is a crucial document for establishing the appropriate targets for airtightness, along with the methodology for achieving it, and the roles and responsibilities of those involved.
2. Conceiving of a building in zones and air barriers will help all involved to visualise the task.
3. Air barriers must be impermeable, continuous, durable and accessible. They should be supported by positive mechanical seals where possible.
4. The simplest solutions will be the most buildable and durable.
5. A culture of airtight construction does not yet prevail and until it does, it may be necessary to follow up targets with specific details and specifications, along with guidance on the process of implementing the necessary level of co-ordination and attention to detail.

Unlike design for deconstruction (the subject of the first in this series of SEDA Guides) and the forthcoming guide on chemical-free design, the design of airtight buildings cannot be left to the specification and details, at least, not until the industry as a whole recognises the need and has sufficiently widespread experience. For the next few years, it will be necessary not only to provide careful details and performance specification, but also to develop thorough inspection and testing regimes, hence the need for Chapters 4 and 5 of this guide.

3.1 Performance Specification

The Performance specification may be the only document needed by the Architect / Designer / Client if the building is to be procured through Design and Build or similar route. However, it is more likely to be part of a suite of documents including detailed drawings.

The performance specification allows appropriate targets to be set for the project, along with a description of how the process is to be conducted, in terms of scheduling, audits and testing, and potentially remedial works. Given the increasing use of specialist subcontractors, particularly in larger projects, it is also critical that the performance specification sets out both the responsibility for, and constructive guidance regarding the co-ordination of trades with respect to the final air permeability of the completed envelope.

A sample specification clause is shown on page 12, which could be adapted for specific use.

3.2 Zones and Barriers

Once appropriate targets have been set for the project, the next task is to identify zones which require greater or lesser airtightness levels. Ideally, these zones need to be identified on a drawing which also identifies the specific air barriers in red.

Sample Specification Clause

- 0 The contractor shall appoint specialist consultants who are members of the Air Tightness Testing and Measurement Association (ATTMA) to carry out the following works. (delete as appropriate)

Design Review – to identify the air tight envelope and highlight any elements of work which may present a risk to the final air test failing.

Site Audits - A minimum of [____] site audits with the last site audit carried out 1 week (or more, as agreed) prior to the air tightness test

Air Leakage tests – A minimum of 2 tests; the first upon completion of a weathertight envelope, the last one week before practical completion

Suggested Specialists: [____]

- 1 Prior to the air tightness test, the Architect shall work out the envelope area as set out in BS EN 13829:2001(1)⁽⁷⁾.
- 2 The air tightness test shall be carried out in line with BS EN 13829:2001(1).
- 3 The air tightness test result shall be expressed as an Air Permeability (units $\text{m}^3/\text{h}/\text{m}^2$ of total surface area @ 50 Pa) and shall not exceed [____] $\text{m}^3/\text{h}/\text{m}^2$ @ 50 Pa.
- 4 The following conditions shall be met during the test;

External envelope shall be complete when the test is carried out. Raised floors and suspended ceilings shall have sufficient panels removed by the contractor to allow the free flow of air through them. Internal doors shall be wedged open.

All doors, windows and fixed vents shall be closed throughout the test.

Mechanical ventilation systems shall be temporarily sealed.

Smoke extracts and lift shaft vents shall not be sealed.

Drains and water traps shall be filled with water.

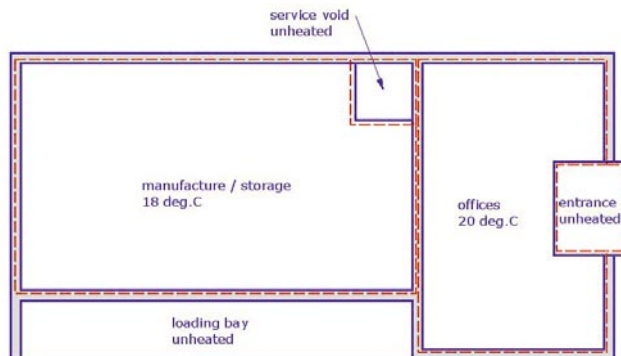
Any areas of temporary sealing or other deviations from the standard test procedure to be recorded in the test report.

- 5 If the building air leakage rate is $>$ [____] $\text{m}^3/\text{h}/\text{m}^2$ @ 50 Pa, [the contractor shall arrange / the CA and Contractor shall agree] (delete as appropriate) for appropriate remedial action to be taken which could include; A site audit of the air tight envelope, while de-pressurised, localised smoke leakage test, full scale smoke leakage test, thermographic survey, reductive sealing of components and building areas / elements to record their contribution.
- 6 Further tests shall be carried out until the air permeability is $<$ [____] $\text{m}^3/\text{h}/\text{m}^2$ @ 50 Pa.
- 7 The contractor shall arrange for a suitably competent specialist to carry out a thermographic survey to BS EN 13187:1999, to establish that insulation is continuous. (if appropriate for the construction type)
- 8 The contractor shall bear the cost of all air tightness works, tests and any remedial works.
- 9 The contractor shall operate a Quality Management System and be registered with a relevant body.
- 10 The contractor shall hold Professional Indemnity Insurance.

[Adapted from Information supplied by HRS Services, Sheffield]

7. It is likely that TM 23 is going to be revised and in the meantime UKAS approved testers (which must include ATTMA members) are testing instead to BS EN 13829:2001(1) Thermal Performance of Buildings: Determination of Air Permeability of Buildings - Fan Pressurisation Method.

For example, in the diagram below, an industrial unit with office space is divided into five separate zones, and air barriers are identified as required. Such a drawing, however diagrammatic initially, helps to conceive of the subsequent specification and detailing needs, giving an overview of the problem.



Showing conditioned (heated or cooled) areas as distinct from unconditioned, with overall airtight separation highlighted in red dashed lines. The example highlights the value of simplicity at an early stage; allowing unheated spaces to project into heated ones like this will complicate the process of constructing effective air barrier layers later.

Heated zones need to be kept separate from unheated zones such as roof voids, delivery bays etc. whilst service shafts may require particular attention. Boiler rooms with large flues and intake vents may need to be separated.

Entrances are often significant sources of draughts. Lobbies with doors set apart by around 4m, so that one door closes before the second is opened, can be effective, whereas in highly trafficked areas revolving doors are likely to be preferable. Tall buildings, with atria, stairways and service shafts all of which rise through the building can be prone to 'stack effect' air movement whereby warm air rises, dragging in cooler air from outside at the lower levels creating more acute air leakage problems. A number of tactics may be employed to reduce the effects, but in any event issues of airtightness are likely to be highlighted in these cases.

3.3 Design

With the zones and air barriers located, it is necessary to design the air barriers themselves.

To be effective, the air barrier must:

- be made of suitably air impermeable materials;
- be continuous around the envelope or zone
- have sufficient strength to withstand any pressures created by wind, stack effect or air control systems
- be easily installed
- be durable
- be accessible for maintenance / replacement if appropriate

The last of these is important since there is evidence that the airtightness of some constructions will tend to decrease over time, and in particular the first period after completion.



Above the suspended ceiling, the plasterboard is not continuous nor sealed, and mineral wool has been used which is not in itself airtight. Source: A. Leaman & W. Bordass, www.usablebuildings.co.uk

There are a number of strategic measures which can be employed to simplify the business of designing an airtight building. Since service penetrations in and out of a building provide a major source of air leaks, one strategy is to collect all such penetrations into one accessible area, see right.

In construction types such as steel and timber frame, it is usually wise to employ a specific membrane or layer as the air barrier, rather than rely on sealant between, for example, the sheathing boards. Such a membrane can usually double up as the vapour barrier if used internally and gives the Designer the opportunity to consider and address airtightness explicitly, rather than as a function of other elements. Bear in mind that most membranes are flimsy and will need support in all areas.

Another strategy is to employ service voids. Creating a service void internally allows for alteration and maintenance of services and finishes without recourse to penetrations through the air barrier. This allows for long term good performance in contrast to membranes which are liable to penetration at all service points, necessitating careful sealing of each and every penetration, not only initially, but over the years of alterations and maintenance to come.

Generally, it is better to conceive of the joints in airtight layers as 'positively' connected, anticipating differential movement and decay of adhesive or chemical bonds. For example, where different components of a curtain walling system are liable to differential movement, it is clear that a joint whereby the two components are held together with a positive mechanical connection across a compressed gasket is likely to remain airtight longer than a simple butt joint with a mastic sealant between.

Finally it is clear that complex solutions to airtightness are likely to be more prone to poor execution and potentially to greater vulnerability to differential movement, failure of sealants, dislocation of components and so on. It is important therefore to aim for the simplest solutions to providing an airtight layer, using the fewest separate materials, junctions and penetrations, and the easiest installation and maintenance.

It is worth making a point of considering each and every specified component with regard not only to its own intrinsic airtightness characteristics, but with regard to the connections between it and adjacent components. It is important to provide explicit details and guidance at specific, and particularly tricky detail areas. On design and build contracts it may be necessary to allow for some form of review of proposed solutions and procedures.

The following provide a few examples whereby airtightness can be simplified at the earliest design stages.

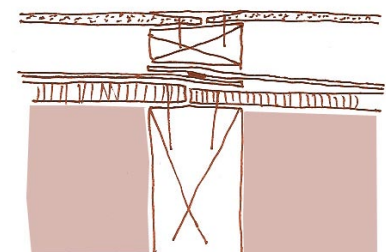
However good the workmanship, blockwork on its own can never be considered airtight. Once plastered, on the other hand, it may be considered extremely airtight, with concern only for those edges and corners where cracking or gaps can appear. This may be contrasted with the more common practice of drylining block walls with plasterboard on battens or dabs. In addition to the in-



Services Zones or Rooms enable a range of services to be collected together before exiting the building, allowing most of the penetrations in the external fabric to be grouped and sealed effectively. Source: C. Morgan



Service voids enable cables and pipe-work to be installed and altered without needing to penetrate the air barrier. Note however that if they are not run in conduit, protection may be needed against subsequent fixings. Source: C. Morgan



Positive physical connections are to be preferred over any other joint such as one relying on adhesives. In the timber frame example shown the air barrier membrane is shown lapped and sealed with mastic over a firm background (boards with stud behind) and with a positive mechanical fix - a batten - fixed over the top and through to the stud. Source: C. Morgan.

trinsically non-airtight block wall behind, this form of construction typically gives rise to a wide range of air leakage paths behind the boards and into floor, partition wall and ceiling cavities. From the perspective of airtightness, drylining should be avoided unless great care is taken. See right.

Similarly, timber floors are difficult to seal well without a good deal of care. On the continent - and to an increasing extent in the UK at large - concrete floor systems are being used for both ground and first floors (often for other reasons such as acoustics, fire and the desire for underfloor heating) and these are easier to make adequately airtight. Hollow planks however can leak into cavities and require to be sealed at their ends.

One important and often quoted example is the timber first floor connection with a block wall inner leaf. Who is responsible for ensuring absolute airtightness when the timber joists rest on the wall and are infilled between with block and mortar? Presumably the bricklayer, but is it then his fault if the timber is installed at the wrong moisture level and subsequently twists and warps, leaving cracks around every joint? Is it really feasible to attempt to tape or mastic seal around them all, and what if the underside of the ceiling is to be exposed? (See right)

Far better perhaps, to do away with the joist-onto-wall detail altogether and replace with joist hangers⁸. Increasingly, the designer should be seeking solutions which are intrinsically airtight because of the design, rather than continuing as before while accepting an increased use of duck tape and mastic on site! Whilst these may get you through the initial airtightness tests, they are sort term solutions and not likely to lead to the anticipated energy savings for the Client in the long term.

A good review of the various materials and components which allow the Designer to create an air barrier may be found in the BRE Report BR448: Airtightness in Commercial and Public Buildings.

3.4 Detailed Specification

Beyond the performance specification illustrated earlier, it is important that the issue of airtightness becomes embedded within the standard specification vocabulary.

Where an equal or approved alternative may be allowed, it is critical that an airtightness performance specification is part and parcel of that equality of performance. For example, it may no longer remain satisfactory merely to specify a membrane, but in addition to specify the fairly precise nature of the sealing, overlapping and potentially the subsequent layers as well. Simply offering a performance specification and ensuring the responsibility resides with the Contractor is all very well, but it is important too to offer solutions that will enable a satisfactory outcome to be achieved.



In addition to the intrinsic lack of airtightness, a problem of drylining is that it can create hidden pathways for air, as above, into the void above suspended ceilings and elsewhere throughout the building. Source: P. Jennings.



Timber joists built into a block wall - a poor detail for airtightness. Far better to use joist hangers and avoid the problem. Source: P. Warm.



Concrete planks are not free of problems either. here, hollow planks have been left ungrouted where they meet the external wall, which could lead to extensive air leakage internally. Source: P. Jennings.



If not designed to be airtight in the first place, ad hoc solutions on site are not likely to be durable - or elegant! Source: C. Morgan

8. Manthorpe Building products (01773 514 200) and www.manthorpe.co.uk produce a 'joist seal' or boot which allows joists to be built into block walls without the attendant disadvantages noted above.

4 Implementing Airtightness

Key Principles

1. The Contractor or Project Manager must be made responsible for achieving the airtightness levels set. In particular, this will involve co-ordinating between trades.
2. Inspection remains an integral part of achieving airtightness.
3. Ideally at least 2 pressurisation tests will be undertaken; the first when the building is weathertight, and the second a couple of weeks or so before handover.
4. Experience suggest that making one person (or team) responsible for airtightness is the most effective way to tackle the issue.
5. Remedial airtightness works to existing properties can reap substantial benefits without undue disruption.

It is not yet generally possible within the UK to specify that a building shall be airtight and leave it to the Architect or Contractor to sort out. There is not yet a culture of airtight construction, except perhaps, amongst those who construct superstores.

The responsibility of the Designer cannot be overestimated, for if airtight buildings are to become mainstream, as they are elsewhere in the world, the techniques must be above all simple and buildable, with most if not all of the 'tricky' areas designed out from the start. In this way, such techniques can become 'second nature' to Contractors and there is less reliance on potentially adversarial inspection and testing.

Ideally too, the Designer will understand the issues sufficient to prepare a sound performance specification – giving achievable targets for airtightness as well as a clear description of responsibilities and procedures, and a clear and practical set of overall and detail drawings, along with a detailed specification.

In the meantime, and even with good documents, there is likely to be a need for effort and vigilance by both the Design Team and the Main Contractor or Project Manager on site. This chapter briefly describes this effort, while the next describes in more detail the actual test procedures and auditing techniques used.

4.1 Plan of Work

The RIBA Plan of Work provides a framework for the entire design and construction process. The table on the next page allocates specific tasks relating to airtightness to each Work Stage to enable a schedule of tasks and responsibilities for the Design team to be prepared according to each project.

4.2 Roles and Responsibilities on Site

Designer / Design Team

The responsibilities of the Design Team are detailed on the following page, showing all stages including site works and beyond.



Buildings usually comprise a number of different components, creating a myriad of routes through which air can escape if not carefully sealed at each and every junction. The Designer's role is to simplify these details to reduce difficulties on site. Source: C. Morgan

RIBA Work Stage	Design Team Tasks
A Appraisal	Establish appropriate air permeability rate
B Feasibility / Briefing	Note Microclimate Test existing buildings / building to be refurbished Identify procedure for review and testing
C Outline proposals	Consider a/t issues in relation to decisions about form of construction Identify zones and layers
D Detailed Proposals	Identify requirement of additional consultants / design by specialists
E Final Proposals	Ensure co-ordination between DT to ensure a/t envelope & penetrations Detailed application of airtight materials, junctions, service penetrations
F Production Info	Select sub-contractors for specialist works (incl. testing) Careful specification of components, membranes, materials Emphasise methods for airtightness on documentation Careful specification of components, membranes, materials Emphasise responsibilities in specification for dealing with 'loose ends' between sub-contractor interfaces
G Tender Docum'n	Define Contractors' responsibilities for co-ordinating work sequences
H Tender Action	Ensure selected tenders include adequate airtightness procedures
J Mobilisation	Brief all involved in areas critical to air infiltration before work starts Preparation of samples, training, testing and QA procedures
K-L Site Works	Co-ordinate inspection with Building Control if required Ensure inspection of areas to be covered Ensure audits and testing schedule is adhered to Ensure design changes do not compromise airtightness performance
M Post Completion	Obtain feedback from concerning comfort and energy consumption Carry out remedial work as required at end of DLP.

[Based on BR 448: Airtightness in Commercial and Public Buildings, by BRE 2002]

It is critical that the purpose of pursuing airtightness is explained so that all concerned understand why they are being asked to attend to these issues. The initial briefing of key personnel at mobilisation stage – whether or not this involves the airtightness specialist – is also critical in determining the approach to conducting the works, inspection, testing and auditing etc. which will need to be dovetailed into the many other concerns on site.

On large projects it may be useful for one member of the Design Team to take special responsibility for airtightness issues.

Contractor

The Main Contractor's principal responsibility is to deliver the airtightness performance overall and the most likely task on any but the smallest jobs will be that of co-ordination between the sub-contractors. The Main Contractor must be clear that he carries responsibility for the overall airtightness and in turn must ensure that all subcontractors are clear about the extent of their responsibilities. This is important since there may be some deviation to conventional practice in order for airtightness to be achieved.

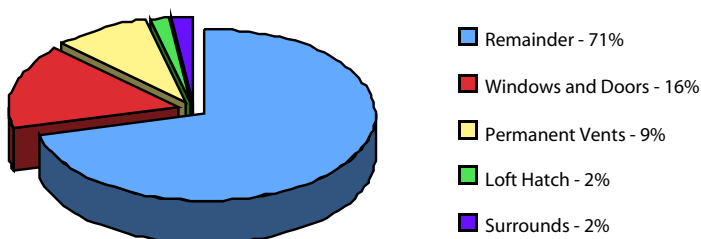
As with the Design Team, experience suggests that the best performance has been achieved by Contractors who employ a dedicated individual (or team) to carry responsibility for airtightness, to inspect the works and instruct as required.

For Contractors, the issues of airtightness are intimately linked to issues of good or bad workmanship in general and this can make the issue both more sensitive, but also more difficult to control. Even simple buildings are immensely complex and so the most important aspect of all is the creation of an overall culture of careful, tidy, accurate and airtight construction, something which cannot be simply forced through with a performance specification.

It is easier to specify and draw an airtight detail than to build it, and so the emphasis on inspection and Contractor responsibility has not developed from a prejudice against Contractors, but from a realistic appreciation that this issue cannot be entirely resolved 'on paper.' It is genuinely about a culture shift (at least for many in the industry) and this is where the real challenge lies.

4.3 Inspection

The pie chart, below, indicates the disposition of air leakage found in dwellings according to studies undertaken by BRE ⁽⁹⁾. The studies offer a range of conclusions, the most significant of which is that the greatest volume of air leakage is occurring in areas outwith the 'normal' consideration of ventilation, through the myriad of cracks and openings all over the building which is described as 'background air leakage.'



Pie chart indicating the disposition of air leakage found in dwellings by BRE.

Of the background air leakage subsequently investigated, the principal leakage routes were noted as being:

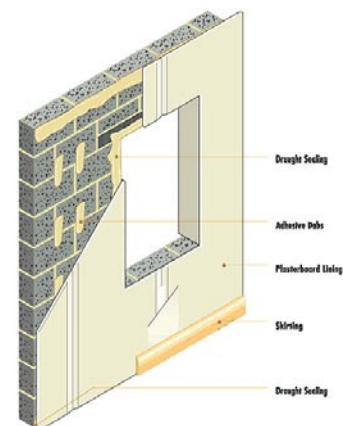
- Plasterboard dry lining on dabs or battens, often linked to routes behind skirtings etc.
- Cracks and joints in the main structure; open perpend, shrinkage & settlement cracks
- Joists penetrating external walls, esp. inner leaf of cavity walls
- Timber floors, under skirtings and between boards
- Internal stud walls, at junctions with timber floors and ceilings
- Electrical components, sockets, switches and light fittings
- Service entries and ducts
- Areas of unplastered masonry walls; intermediate floors, behind baths, inside service ducts



Some forms of construction cannot be reasonably expected to be airtight, so airtightness measures have to be 'designed in' from the start. Source: C. Morgan.



On the other hand, much work on site is unacceptable and so inspection and testing remain important ways to drive through better workmanship generally. Source: P. Warm.



Dry lining can lead to extensive air leakage through a building if not carefully sealed around openings and at the all wall edges, as shown above. Source: www.southerndrylining.co.uk

9. BRE Information Paper 01/00, January 2000.

It is perhaps worth mentioning that the BRE results were based on buildings using dry lining on masonry walls and timber floors. Had the masonry walls been plastered, if concrete floors had been used, and if basic airtightness measures were taken, it is likely that the principal problems would occur around service penetrations, and, to a lesser extent, around windows, doors and rooflights. This is the experience of countries where envelope airtightness generally is more developed.

The following table lists many of the most common infiltration problem areas. On larger projects, common problems include:

- Incomplete bulkheads at eaves;
- Gaps where blockwork abuts to steel columns or beams (right);
- Uncapped cavity walls, at eaves (right) and mid-points where cavity walls change to composite panels;
- Gaps along the underside of corrugated roof linings - even if



Gaps between blockwork and steel, above, and uncapped cavity wall at join with composite panels, below. Source: P; Jennings



Common Locations for Inspection (Applicable to all types of Construction)

Foundation / Ground Floor

Check wall and floor dpcs form an adequate air tightness layer, is a separate layer needed?
 Check gaps at perimeter insulation strips
 Check potential movement gaps between loadbearing structure such as columns and adjacent non-loadbearing slab

First and Intermediate Floor Levels

Concrete floors: Check joint between the floor and plasterboard to walls
 Check gaps between concrete planks, or beam & blocks are sealed at the wall
 Check voids under floor finishes and service run penetrations

Timber floors: Check a membrane seal has been incorporated if required
 Check any membrane used is supported between joists

Eaves and Verge

Check continuity of airtight layer between wall and roof / ceiling

Ceiling level beneath the roof

Check for separation between deliberate roof ventilation and the conditioned zone
 Check for service penetrations and hatches which pass across the airtight layer

Boundaries between different wall envelope systems

Check all systems have a dedicated airtightness layer assigned, and that these can be constructed to be continuous across dissimilar elements

Windows and Doors

Check that the frame to wall junction is properly sealed and continuous with the wall airtight layer, particularly at cills
 Check the windows and doors have appropriate weather seals between the opening unit and the frame

Services penetrations

Check for proper seals at service entry points, and at points of entry into conditioned zones. These may also require fire protection

Main Entrances

Check that the whole entrance area is separated from the conditioned zone by an inner airtight layer

Lift Shafts, Service Cores, Delivery Areas / Car Park

Check these have been separated from conditioned zones with air barriers and draughtproofed access doors

[Based on Notes produced in BRE BR448: Airtightness in Commercial and Public Buildings.]

- profile fillers are used poor workmanship is common (right);
- Perforated (acoustic) roofs, where the unsealed mineral fibre acoustic layer bridges the eaves of the building, constituting a major leakage point (right) ;
- Gaps where plasterboard or wall linings are incomplete, commonly above suspended ceilings and to the underside of beams (eg. p13);
- Incomplete door and window reveals (right)
- Services Penetrations into the building, and between zones inside the building (lower right).

Another common issue is porous blockwork, particularly when internal walls are drylined rather than plastered or painted. Where this is likely to be unavoidable, it may be worth requiring blockwork to be tested for air permeability, and to have an AP value (by an accredited lab) that is no more than 50% of the target Air Permeability for the overall building.

4.4 Testing and Audit Schedule

In many cases to date, an air leakage test has been carried out a week or so before practical completion. If the result is poor – a high rate of leakage – then a great deal of work suddenly needs to be done, often to areas which have been covered up and the whole business can be both costly and time consuming, just at the point where in many contracts there is already considerable pressure on Contractors.

Far better therefore to schedule the air leakage test at a time where remedial works are relatively simple to perform. On the other hand, it is important that a test is undertaken close to hand-over so that the Client and Design Team can be sure that the completed building accords with the performance specification.

Ideally therefore, two tests at least should be carried out. The first should be undertaken as soon as a meaningfully air- and weathertight envelope has been installed. Ideally, all air barriers are still accessible and any defects can be readily put right. This test, plus the audit techniques which are likely to accompany it, may be used to ensure an acceptable airtightness performance and give a good indication of where subsequent works may advantageously targetted.

In this way, the second and final test serves simply to confirm the performance of the building, hopefully at a slightly improved level from the first test, without the need for costly and complex operations late in the day.

Such a test schedule is nonetheless costly in itself, but for those who have been involved in such testing schedules, experience suggests that this remains the most cost effective way to deal with the issue. Certainly it is worth avoiding excessive remedial works at the eleventh hour. With a sufficiently good first test performance, it may even be possible to dispense with the final test, if this is deemed acceptable to the Design Team Leader or Client.



Missing profile fillers, top, and perforated liner sheets which extend through into the cavity at the verge, above. Two examples of gaps around windows, below and bottom, two examples of gaps around services penetrations within the building. Source: P. Jennings.



It is often the case that the envelope is not sufficiently complete on the due date for testing. This then necessitates a complex process of temporary sealing of the incomplete areas. It is harder then to ascertain the location of the leaks and allowances are made which may prove misleading. Experience suggests that this is not ideal and it would be better to put off the test for a week and carry it out when the envelope is complete and 'as intended'.

On larger projects, more tests may be needed, or more specific tests of individual areas required. Large projects with multiple units of a similar nature may benefit from either pre-installation component testing, or insitu testing of one installed component to establish acceptable airtightness levels early on. See also Section 5.4.

4.5 Remedial Airtightness Works

With airtightness testing and a general awareness of airtightness issues developing around new build situations, the principal area of concern, as with energy efficiency in general is the existing building stock. In terms of airtightness, the UK building stock is considerably worse than comparable northern latitude countries ⁽¹⁰⁾ and there is a good deal of room for improvement.

Either as a stand alone measure, or as part of a package of energy efficiency measures generally, there is scope for remedial works to most of the existing UK building stock. Relatively simple measures may in many cases be sufficient, using a wide range of sealants to control air leakage. However, it is important that such measures are combined with attention to the ventilation requirements of buildings where, to date, insufficient ventilation has been 'augmented' by infiltration and exfiltration which, if reduced, could lead to other problems.

As with thermal insulation, there is an extent to which controlling some of the air leakage merely diverts the flow of air, inward or outward, to another defect or gap, but there is such scope for improvement that even fairly basic efforts are likely to reap substantial environmental, financial and comfort benefits for owners and occupiers alike.

There are many examples of remedial works described in the various publications noted in the references. Some of the more successful measures included carefully sealed secondary glazing installed where old windows had to be kept for conservation purposes, draughtproofing of doors and entranceways generally, and installation of lobbies in well trafficked reception areas, attention to draughtproofing of existing windows and targeted use of flexible sealants to ill fitting components and joints between different construction types.



This building is almost ready for its first test. The vapour check is complete and accessible, before the plasterboard is fixed over, all windows and doors are in, but note that the gaps around the windows have yet to be sealed. Source: C. Morgan.



Older properties tend to suffer in particular from draughty suspended timber floors and gaps within, and around windows and doors. Source: C. Morgan.



This refurbishment of 1950s tenements in Fife by John Gilbert Architects included airtightness measures as part of overall energy efficiency improvements. Source: J. Gilbert.



New houses tend to suffer in particular from timber floors and dry lining, service ducts and areas of unplastered blockwork, along with simple shrinkage cracks associated with the initial drying out period. Source: www.dilwyn.org.uk.

10. See, for example, BRE Information Paper 01/00, January 2000 and Limb, M.J. Ventilation and Building Airtightness: an international comparison of standards, codes of practice and regulations. AIVC Technical Note 43, Coventry February 1994.

5. Testing Airtightness

Key Principles

1. Testing procedure is set out in CIBSE TM 23 and in BS EN 13829: 2001.
2. A pressure test involves sealing all 'normal' gaps such as vents and pressurising or depressurising the building. The level of fanpower required to maintain the pressure differential indicates the 'leakiness' or 'permeability' of the building.
3. Pressure tests are typically followed by an audit (using smoke pencils, for example) to expose and make visible the various air leakage routes.
4. Where projects comprise large quantities of a single component, component testing in the laboratory may be appropriate as well as on site element testing.

5.1 Climatic conditions

As mentioned in Chapter 1, the raised pressure differential of 50 Pascals created during an airtightness test is quite small. Whilst this is adequate to overcome most of the common pressure differential anomalies, such a small differential is vulnerable to larger pressure differences created by climatic conditions.

Air leakage tests require calm days – i.e. a reading on the Beaufort Scale of 3 or less (3.4 to 5.4 metres per second wind speed at 10 m above ground) This corresponds to a gentle breeze with leaves and small twigs in constant motion. In winter conditions, and on exposed sites therefore testing may not be possible, although it is often possible to make allowances, so long as these are carefully recorded.

5.2 The Test itself

Guidance on testing buildings for airtightness is contained in CIBSE Technical Memorandum TM23 Testing Buildings for Airtightness and in BS EN 13829: 2001. All UKAS accredited testers test to the guidelines contained in the BS EN.

Essentially the process is one of de-pressurising or (less commonly) pressurising the inside of the whole building, and of measuring the rate at which air needs to be blown or sucked to maintain that pressure differential; a leaky building will equalise readily and require a greater measurable effort to maintain the 50 Pascal differential, while a tight building will easily contain the enforced differential and require little additional input.

The pressure difference is induced by one or more calibrated fans that are normally mounted within a suitable doorway. An adjustable door panel system, sealed around the edges is used which can also be connected to large external fans via collapsible ductwork if required. The rate of the fan, or the volume flow of air through the fan can be understood as the rate of air entering / escaping throughout the remainder of the building envelope. Buildings are tested in such a way as to recreate 'normal' condi-



An example of a door fan within a panel affixed to the main entrance door of a new built house. Source: P. Jennings.

tions. Doors and windows are closed, trickle ventilators closed, extract fans and such like are closed but not sealed. Internal doors are wedged open.

If the building is under construction, testing is ideally undertaken outwith working hours, but sometimes this is not practical so some scheduling of work needs to be thought through in advance. With all external doors and windows sealed shut, some work becomes impossible (such as work with solvents requiring ventilation) and internal trades are normally 'sealed in' for a short time, where they can carry on undisturbed.

In existing buildings, tests are normally carried out when the building is unoccupied if possible because of the disruption.

5.3 Air Leakage Audits

The air leakage test quantifies the rate of air leakage through the envelope as a whole, but it cannot locate the air leakage paths. Where remedial work is required therefore, tests are followed by a range of auditing techniques designed to identify the specific places where air is leaking.

In many cases a simple visual inspection may be sufficient – especially if undertaken by someone with experience of the likely locations of leakage.

However, most leakage routes are difficult or impossible to spot without visual aids. One common technique is to use smoke tracers – smoke pencils or smoke machines. These render the air paths visible in certain situations. The building may be positively pressurised and the leaks witnessed externally, or, more usually, negatively pressurised while a smoke pencil is drawn over likely gaps and defects which become visible as the smoke is sucked inwards.

Another technique, which has certain advantages and disadvantages compared to smoke tracing, is the use of an infrared camera. (see page 4) Used either externally or internally, these thermographic cameras register the radiant heat levels of surfaces and so are able to 'see' for example, where cold air is cooling the fabric around a gap internally, or conversely where warm air is escaping and heating the colder materials on the external face.

To work effectively, there needs to be a recognisable difference between the internal and external ambient temperature, so before any heating has been installed and on a warm summer's day thermography may not be effective. Similarly on warm and sunny days, sunshine on external surfaces can distort the true situation so it is better on such days to wait until early evening. Conversely, rain on external surfaces can be equally distorting of the true thermal situation. However, these cameras are useful in identifying problems at high level or difficult to reach areas, and are also very helpful in identifying other construction defects such as poorly installed (or non-existent!) insulation within the fabric.



An example of a very large fan being used to test an Ikea Store. Source: HRS Services Ltd. www.air-tightness.co.uk



With a building pressurised, smoke can be let off to see if there are any leaks... Source: HRS Services Ltd. www.air-tightness.co.uk



... which are then immediately visible! Source: HRS Services Ltd. www.air-tightness.co.uk



A smoke tracer allows for a view of the air leakage around the edge of this window frame while the building is depressurised. Source: A. Leaman & W. Bordass, www.usablebuildings.co.uk

On larger commercial buildings, airtightness testing may be undertaken at the same time as 'standard' ventilation system commissioning and associated studies, but these are not discussed as part of this guide.

5.4 Component Testing

A distinct aspect of overall airtightness testing is the individual component test. This may be undertaken quite separately, in the laboratory or by the manufacturer of a particular component. Such tests may be deemed necessary on a large project where large areas of one particular type of component, for example curtain walling, are to be specified,

In situ element testing involves isolating the area within a temporary sealed compartment, which is then pressurised, and the air leakage related to the area of interest assessed. In this way sample areas of a building may be pressure tested using smaller fans as required.

6. The Details

Caveat

It is important to emphasise the scope and purpose of the following drawings and specifications.

They are included solely to show practitioners the sort of alterations that can be made in order to enable buildings to be much more airtight in general.

Their purpose is not to offer approved details in any sense, but to illustrate the difference between details and specifications which do not address airtightness issues, and those that do. It is the differences between the originals and alternatives which is intended to be illustrative, not necessarily the alternatives themselves.

The original details have been taken from conventional details and specifications we believe to be broadly representative of their construction types. We hope the principles shown, and the specific references made will assist designers in making similar changes in their own work, but it goes without saying that SEDA cannot take responsibility for any work undertaken as a result of the use of these details.

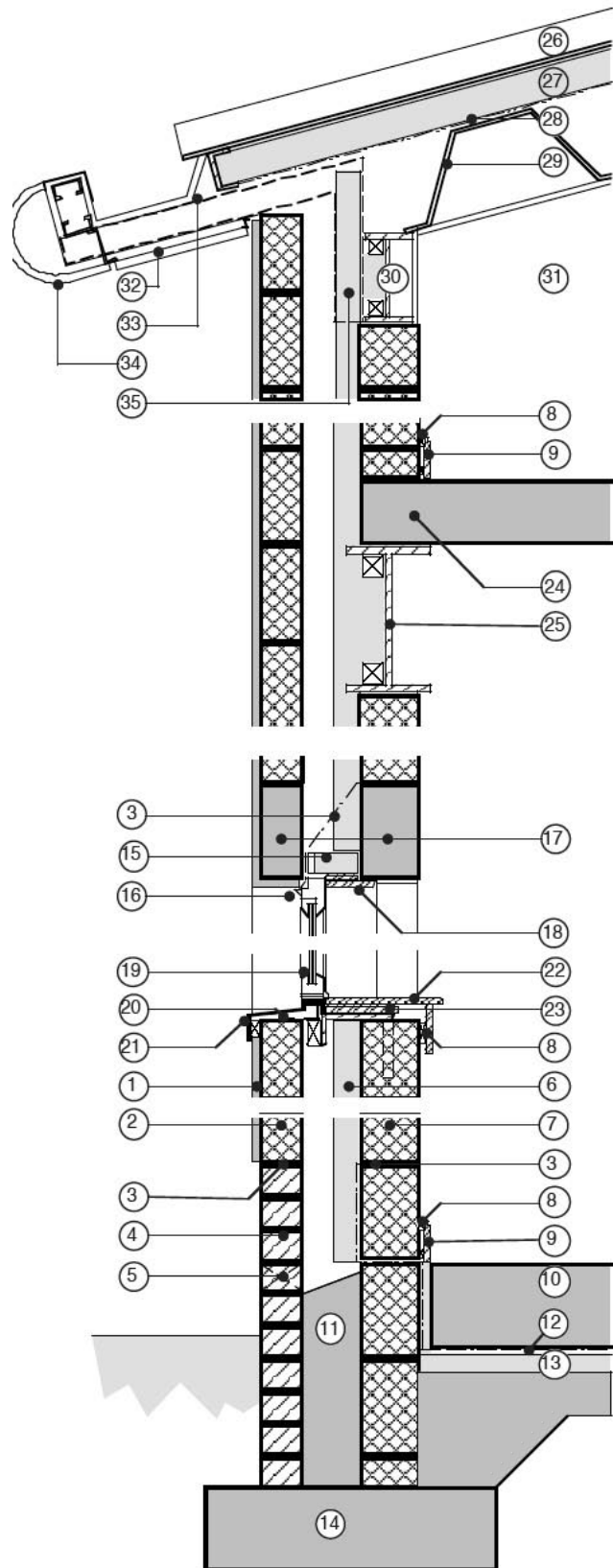
Specifically, these details are not intended to show best practice in any sense, nor are they even intended to be up to date. We have striven in the preparation of these details and specifications to keep as close to the original as possible. We have done this in order to show that some quite fundamental alterations – in terms of airtightness - may be made with the minimum of visual or functional impact on the original. Where these original details and specifications do not meet current standards or aspirations, the alternatives given are likely to be similarly wanting. To re-iterate, the purpose is not to produce approved details, but to illustrate the process of improvement – in terms of airtightness only – that may be made.

Consideration of priorities in airtightness design and specification is potentially misleading since, in effect, all gaps, cracks or tears let in air and the sealing of one simply redirects infiltration to somewhere else. Like thermal insulation, what is important is the level of continuity generally, not any particular detail on its own. Nonetheless some prioritisation has been attempted in order to help Designers to prioritise their own efforts since not all measures may be necessary.

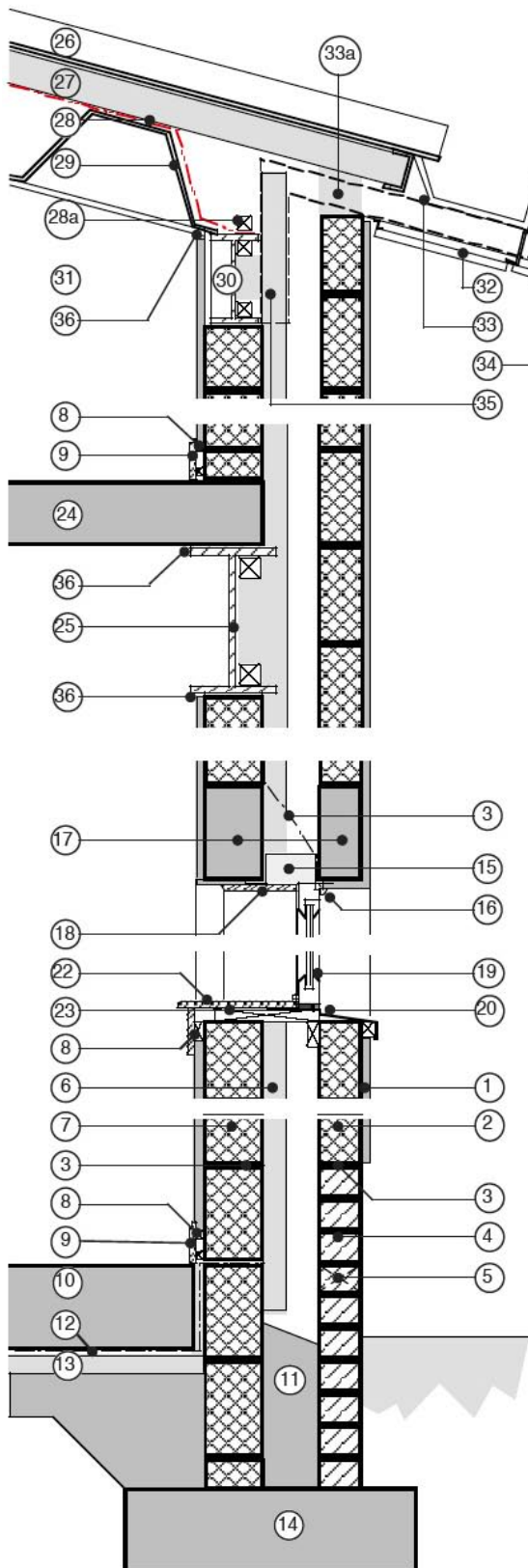
6.1 Steel Frame + Concrete Block Cavity Wall

Original Specification

1. Drydash, cement: lime: sand render to BS 5262 with drips
2. 100mm dense concrete blockwork in 1:1:5 mortar
3. Damp proof course (also as cavity tray)
4. 100mm facing brickwork in 1:1:5 mortar
5. Perpend weep slot @ 900mm centres
6. 60mm butt jointed mineral fibre slab insulation held to wall @ 600mm centres
7. 140mm concrete blockwork in 1:1:5 mortar with 2 coats matt emulsion paint finish
8. Soft wood timber packer nailed to wall
9. 15mm MDF skirting board nailed to packer, both with 2 coats satin emulsion paint finish
10. 200mm Insitu concrete reinforced slab, float finish, perimeter insulation
11. 140mm wide standard mix ST2 concrete fill
12. Polyethylene damp proof membrane dressed up and lapped with DPC
13. 50mm rigid polystyrene eps butt jointed insulation
14. Trench foundations
15. 40mm mineral fibre slab compressed into void
16. Polysulphide sealant
17. Reinforced Concrete lintols to Structural Engineer's specification
18. 15mm MDF surround nailed to packer, with 2 coats satin emulsion paint finish
19. Proprietary aluminium double glazed window unit screwed to masonry or support steelwork
20. Mastic tape
21. PPC pressed metal cill glued to packer
22. 15mm MDF cill and apron nailed to packer, with 2 coats satin emulsion paint finish
23. Secondary steel support angle to structural engineers specification
24. 150mm insitu reinforced concrete slab, float finish
25. Steel beam to structural engineers specification
26. Standing seam roof mechanically fixed to support structure
27. 100mm butt jointed mineral fibre slab insulation mechanically fixed
28. Reinforced polyethelene vapour barrier laid loosed with lap joints
29. 200mm structural metal deck
30. Eaves beam to structural engineers specification
31. Raking rafter to structural engineers specification
32. PPC metal soffit bolted to outrigger
33. Preformed gutter and single ply lining mechanically fixed
34. PPC bullnose gutter mechanically fixed to roof structure
35. Cranked galv. mild steel outriggers bolted to eaves beam



Alternative Specification



1. Drydash, cement: lime: sand render to BS 5262 with drips
2. 100mm dense concrete blockwork, perpends fully filled (a)
3. Damp proof course, lapped and sealed (b) also as cavity tray
4. 100mm facing brickwork, perpends fully filled (a)
5. Perpend weep slot @ 900mm centres
6. 60mm t&g or shiplap jointed and taped xps batt (c) insulation held to wall @ 600mm c/c. Wall ties as required, not shown
7. 140mm concrete blockwork, perpends fully filled (a) to maximum air permeability by component test of [5] m³/hr/m² (aa)
- 7a. Internal wet plaster skim finish to blockwork (d) with 2 coat emulsion finish.
8. Soft wood timber packer nailed to wall
9. 15mm MDF skirting board nailed to packer continuous mastic seal to both ends before installation (e), 2 coats paint finish
10. 200mm Insitu concrete reinforced slab with float finish, perimeter insulation (f)
11. 140mm wide standard mix ST2 concrete fill
12. Polyethylene dpm x dressed up and lapped with DPC (b)
13. 50mm rigid eps t&g jointed and taped (c) insulation
14. Trench foundations
15. Insulated and Robust Cavity Closer between Lintols (g)
16. Polysulphide sealant
17. 2no RC lintols, to structural engineers specification
18. 15mm MDF surround nailed to packer, continuous bed of mastic to both adjoining edges (e), with 2 coats paint finish
19. Proprietary aluminium double glazed and draughtstripped (m) window unit screwed to masonry or support brackets
20. Proprietary Metal Cill with upstand on packer with compressible foam between window and cill piece internally, mastic sealant externally (h)
21. (Deleted)
22. 15mm MDF cill and apron nailed to packer, continuous mastic sealant to both adjoining edges (e) 2 coats paint finish
23. Treated timber packer on dpc (not shown) on inner leaf and batten supporting cill piece and window frame
24. 150mm insitu reinforced concrete slab with float finish
25. Steel beam to structural engineers specification, compressible foam strip to underside affixed during laying of last course of blockwork to fully seal between (also to top of beam if necessary) (i) (check dry pack not required with Engineer)
26. Standing seam roof mechanically fixed to support structure
27. 100mm t&g or shiplap jointed and taped xps batt (c) insulation mechanically fixed
28. Reinforced polyethelene vapour barrier lapped and sealed on supported areas b)
- 28a Vapour barrier (vb) dressed down to beam, and fixed firm to steel by shotfired batten, continuous bed of mastic behind vb, slack left to allow for differential movement (j)
29. 200mm structural metal deck
30. Eaves beam to structural engineers specification, ensure no holes left unsealed, compressible foam strip to underside affixed during laying of last course of blockwork to fully seal between (i)
31. Raking rafter to structural engineers specification
32. PPC metal soffit bolted to outrigger
33. Prefomed gutter and single ply lining mechanically fixed
- 33a. External grade ply or similar to support insulation, fixed to outriggers, Expanding foam to air gap between top of blockwork and ply to reduce air movement into cavity (k)
34. PPC bullnose gutter mechanically fixed to roof structure
35. Cranked galv. mild steel outriggers bolted to eaves beam
36. Continuous mastic sealant (l)

Discussion

Because of the largely wet trades involved, one might imagine a masonry construction like this to be inherently more airtight than the dry fixed timber frame and curtain walling construction types.

However, insofar as concrete inevitably shrinks as it dries, as mortar beds and perpends are often poorly filled, and due to the differential movement between masonry and the steel frame, the myriad pathways that open up can make masonry buildings extremely susceptible to infiltration.

To make things worse, construction such as this does not easily lend itself to a simple, single airtight layer which can be applied separately and therefore the need for vigilance, and some care and attention to a number of small but potentially time consuming sealing jobs is high.

It would be possible to form an airtight layer internally through the use of an applied membrane and the adoption of a service void, much as illustrated in 6.2. This would have the advantage of allowing for changes in the service or fit-out provision without the risk of damage or compromise of the airtight membrane, and for those inclined to this solution, Section 6.2 may be more relevant in parts.

A parge coat and service void could have a similar effect, but the use of plaster internally is a common and effective technique for creating an airtight layer and has been chosen in this instance as it is closer to the original detail.

refer note re. prioritisation on p. 25

HIGH PRIORITY

(d) Wet Plaster Finish, or

Wet plaster coat costs more but provides a better finish overall, as well as significantly improved airtightness across the masonry leaf. Plaster should be extended to all wall areas and not left off in areas which will not be seen, such as suspended ceilings.

(aa) Blockwork Permeability Test

Potentially an alternative to wet plastering, though unlikely to result in such a thorough air barrier overall.

(b) Membranes Lapped & Sealed

2 lines of tape and a positive mechanical fixing by batten ensure laps are sealed for the long term

(e) Mastic to Skirtings, Linings etc.

Critical in this detail since the plaster cannot form a continuous layer at these junctions

(g) Sealed Cavity Closer

Gaps around openings are common so care is needed here to prevent infiltration around the frame and into the cavity

(j) Vapour Barrier Seal at Eaves

Important here since no effective seal is noted on the original which could lead to excessive airflow at this vulnerable point.

MEDIUM PRIORITY

(m) Joinery Draughtstripping

Tubular seals are probably the best option. it is important that they can be easily accessed for maintenance and replacement.

MEDIUM PRIORITY

(f) Concrete Slab Floors

Concrete slabs form an airtight layer but joints with penetrations such as perimeter blockwork, insulation or structural columns must be sealed.

(h) Cill to Window Sealing

Double sealed detail which increases the chance of securing an airtight seal at this often overlooked junction

(i) Compressible Foam between Steel and Blockwork

Potential solution to the inevitable gap which will form here, also sealable with mastic on inside face only.

LOW PRIORITY

(a) Perpend Fully Filled

Not critical if a wet plaster finish is applied internally, but high priority if they are not.

(c) T&G and Taped Insulation

Not technically part of the airtight layer, but gaps here simply increase the likelihood of infiltration and are relatively easily sealed.

(k) Expanding Foam to Gap at Eaves

Not part of the airtight layer but by sealing a large gap in the fabric, this reduces the wind pressure driven airflow within the cavity thus reducing the risk of infiltration indirectly.

Costs

The most significant cost implication is associated with the addition of the wet plaster coat to the inner leaf of blockwork. This results in approximately a 60% increase in cost, although the quality of the blockwork is not as critical. This item is also significant in that it changes the 'look' of the detail but is probably the highest priority.

Otherwise, most of the costs are associated with the additional time, effort and care implicated within the specification and details.

Of these, the most significant is the additional labour and materials required for the joining of the vapour barrier in the roof, and sealing it around the perimeter. This work almost certainly more than doubles the cost of the vapour barrier in the original detail, but again, represents a critical factor in reducing air leakage.

A number of the measures described represent no more than a re-iteration of good practice, such as the sealing of perpend, lapping and sealing of membranes, draughtstripping of windows and so on. These may be assumed to incur no cost implication, but perhaps one of attention to details on site.

The mastic sealant to skirtings, cills and the like would add about 50% to the costs of these items, though these items represent only a small fraction of the overall costs.

Taping of the insulation boards would depend largely on the board type, but might realistically attract only a marginal cost increase, as would the use of compressible foam around the steelwork.

Defects Liability / Insurance Issues

The alternative detail shown has raised no additional concerns from the Insurability Review.

Where the original detail may not meet with current requirements, the alternative detail may also need review. For example, some minor aspects of the details would require to be assessed against individual circumstances (cavity closers, wall tie positions etc.).

6.1 Index

(a) Perpend fully filled

A common problem with blockwork and brickwork buildings is that perpend are not completely filled and this leads to air flow through the wall. To an extent this measure is superceded by both points (aa) and (d), but it is still worth making the point in order to draw attention to this workmanship issue in general.

(aa) Blockwork Maximum Air Permeability by Component Test

An alternative to wet plastering the blockwork on the inner leaf is to require a component test of the blockwork to satisfy a maximum air permeability of, say, $5\text{m}^3/\text{hr}/\text{m}^2$ or less. On larger projects, or where wet plastering is unlikely to be effective or desirable, this is one method of ensuring a reasonable degree of airtightness from the blockwork leaf. These conditions may also be used for the outer leaf but is not as important because it is the inner leaf which is providing the main air barrier.

(b) Membrane Lapped and Sealed

Typically membranes are lapped and stapled or tacked, but in order to create airtight layers, it is important that these laps are rigorously sealed. Best practice in this regard - beyond the correct use of Manufacturers' overlap dimensions, proprietary tapes and other accessories - is to run a layer of double sided tape between the membranes at the overlap and run a tape over the leading edge of the outer sheet. In addition, since many tapes tend not to last too well, it is advisable to ensure that laps are made directly over supported areas (i.e. with studs or dwangs directly behind) and are held down positively with battens fixed through forming a mechanically tight, as well as an adhesive seal.

(c) T&G or Shiplap and Taped Non-Mineral Fibre Insulation

Mineral fibre is permeable to air movement and cannot be counted upon to help in reducing air leakage. Extruded polystyrene and other closed cell plastic insulation materials do not suffer from this and so have the potential to reduce air leakage in and out of the building. However, they are only likely to do so if they are effectively joined at their edges, at corners, openings and around wall ties etc. For this reason, it is likely that t&g or shiplap edge boards (which are available from a number of Manufacturers) will offer better connections, and these can be further augmented by the use of a sealant tape externally.

(d) Wet Plaster Finish Internally

An alternative to arranging component tests for the blockwork, as in aa, above. The original detail notes a simple block finish with 2 coats of paint which in terms of airtightness is an improvement on a uncoated block wall but is not sufficient to consider the blockwork airtight in the least. Wet plastering of the blockwork is more expensive but ensures an airtight masonry leaf. The plaster should extend to all areas of the wall, regardless of whether they will be hidden by suspended ceilings or raised floors. It should extend right to the floor and to undersides of steel beams etc. and where broken by service boxes etc. should be conscientiously filled and sealed.

An alternative which would have a similar effect would be to use a parge coat over the blockwork, before application of a service void and separate finish layer. The simple wet plaster finish is closer to the original.

(e) Mastic Both Edges to Skirtings, Reveal Linings etc.

Where the corner junction behind has been carefully sealed then this measure may not be required, but in the examples shown on this construction, this particular detail is critical since it forms an integral part of the airtight layer, particularly where the plaster (d) has to be discontinuous.

(f) Concrete Slab Floors

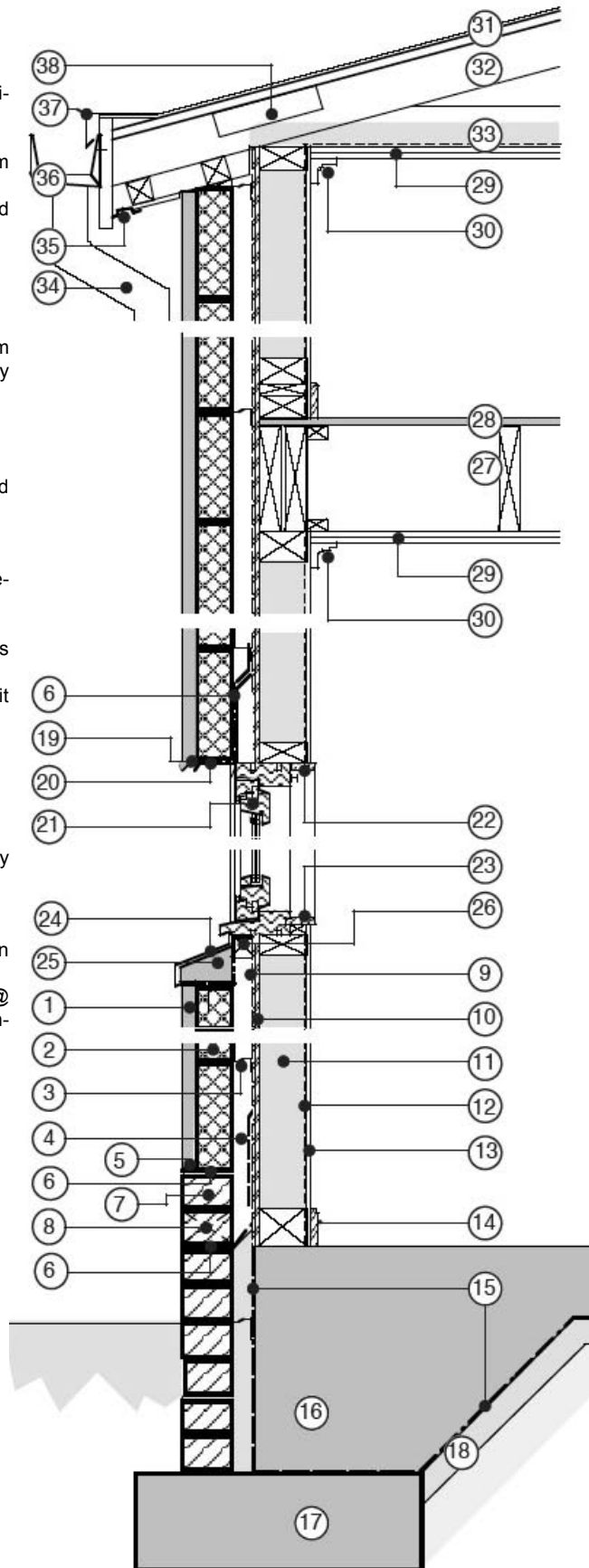
Unchanged from the original detail, this is simply to note that concrete slabs form an airtight barrier and may therefore be considered good practice in this regard. However, no note is made of the need for care to be taken where the slab meets elements of structure which pass through, steel columns, for example. At these junctions, a compressible foam strip may be laid around the steel prior to pouring the concrete if practicable, or a mastic sealant may be used subsequent to the pour to seal the inevitable shrinkage cracks which will form.

- (g) **Insulated and Robust Cavity Closer**
A robust and insulated cavity closer enables the cavity to be effectively closed, the gap to be bridged with insulation without risk of moisture flow between inner and outer and the window to be securely fixed at the head and jambs if required. The gap between window frames and the main wall is a notorious place for infiltration so it is important that this junction is carefully sealed. The flanges of the cavity barrier should be closed against the blockwork faces with a continuous mastic bead between on each flange so that airflow into the cavity from outside or in is prevented.
- (h) **Proprietary Cill with Foam Sealant Internally and Mastic Sealant Externally**
In addition to the mechanical fixing of the window frame through the cill piece, it is important that this fixing is made through a compressible foam strip which is then sealed against air leakage from outside with a mastic type sealant. This gives the Contractors two opportunities to ensure a completely airtight seal at this particularly vulnerable point.
- (i) **Compressible Foam Strip beneath Steel Beam to Blockwork Top**
For reasons of both initial shrinkage and subsequent structural movement, it is to be expected that a direct connection between a steel beam (or column) and a block wall will open up over time to form a potential route for infiltration. One way to try and reduce this inevitable gap is to build the blockwork against a compressible foam strip which immediately expands to fill the gap between and remains flexible thus continuing to fill the gap even after shrinkage and movement. Since compressible foam strips are not intrinsically airtight, mastic sealant should be used in addition to form a neat internal joint which should further seal the connection.
- (j) **Vapour Barrier Detail at Eaves**
Here the vapour barrier is positively sealed to the steel perimeter beam to properly seal the ceiling vapour - and air - barrier along its edge. Assuming that the steel beam is without penetrations (a specification note has been added to ensure that this is checked) then as long as the plaster seal to the underside of the beam is adequate, an airtight layer has been formed which may be discontinuous in materials but continuous in terms of airtightness.
- (k) **Expanding Foam to Large Gap at Eaves**
Whilst not strictly part of the airtight layer, this measure reduces the potential wind pressures on the cavity which in turn reduces the risk of infiltration through the airtight layer itself. Note also the introduction of a ply layer above to support the insulation (nothing is noted as doing so in the original detail) but significantly against which the foam can create a firm seal.
- (l) **Mastic Sealant to Joints**
Additional notes to seal connections between dissimilar materials which are likely to provide routeways for airflow unless conscientiously sealed.
- (l) **Draughtstripping to Windows and Doors**
Most commercially available joinery, metal or plastic windows and doors will be adequately draughtstripped but it is important to explicitly ensure that this is the case, and that seals (preferably tubular rubber / epdm type) are accessible and can be easily replaced should they begin to fail to adequately seal when closed.

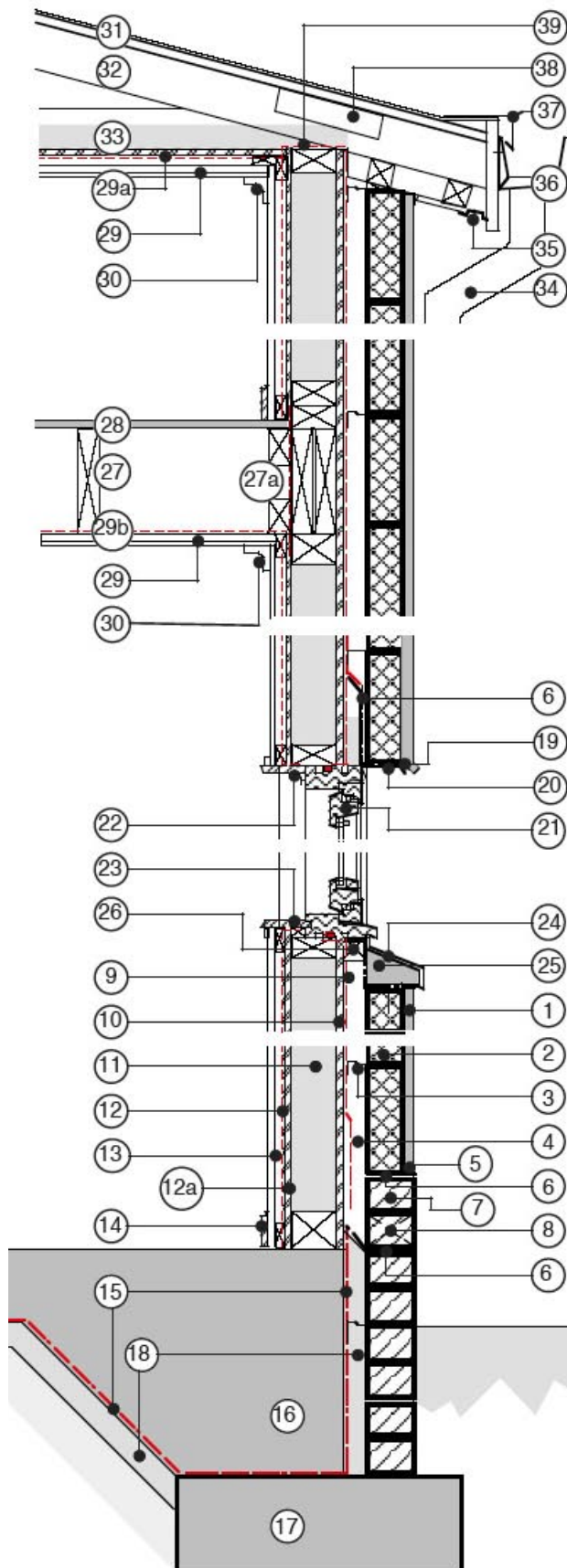
6.2 Timber Frame with Concrete Block Outer Leaf

Original Specification

1. Drydash, cement: lime: sand render to BS 5262.
2. 100mm dense concrete blockwork in 1:1:5 mortar
3. Cavity wall ties mechanically fixed @ 900mm centres horizontally and 450mm vertically - all staggered
4. 50mm ventilated cavity
5. Expamet render stop bead mechanically fixed @ 600mm centres
6. Damp proof course, also as cavity tray with stop ends and weep holes
7. 100mm facing brickwork in 1:1:5 mortar
8. Perpend weep slots @ 900mm centres
9. Breather paper fixed to ply
10. 12.5mm sheathing ply nailed to studs
11. 95mm soft wood studs @ 600mm centres - nail fixed to form frame with 100mm mineral fibre quilt insulation held in cavity by frame construction. Frame design to BS 5268-6-1.
12. Vapour barrier stapled to interior side of studs
13. 12.5mm plasterboard
14. 75 x 15mm MDF skirting board nail fixed to frame
15. Polyethylene damp proof course dressed up edge of slab and tucked behind dpc / breather paper
16. 150mm insitu reinforced concrete slab with float finish
17. Trench foundations
18. 50mm rigid polystyrene eps butt jointed edge insulation beneath slab
19. Render stop nailed to blockwork at 600mm centres
20. Galvanized steel lintol and cavity closer to structural engineers spec
21. Proprietary pine tilt and turn double glazed window unit screwed to frame
22. 15mm MDF nail fixed internal surround
23. 15mm MDF nail fixed cill
24. Aluminium ppc flashing mechanically fixed to frame
25. Precast concrete cill on 1:1:5 mortar
26. SW packer cavity closer
27. Timber joists @ 450mm centres fixed at perimeter support by mechanically fixed steel joist hangers
28. 18mm tongue and groove chipboard screwed to joists
29. 2 layers 12.5mm plasterboard nailed to u/side of joists
30. Extruded polystyrene cornice glue fixed - 1 coat satin emulsion finish
31. Proprietary single ply membrane roofing with profiles @ 600mm centres - membrane mechanically fixed to ply sheathing deck fixed to truss
32. Proprietary timber roof truss with bolted joints
33. 50mm rigid polystyrene eps butt jointed insulation
34. UPVC down pipe
35. Vents within soffit
36. Aluminium ppc gutter mechanically fixed to edge board by brackets
37. Mechanically fixed angle flashing
38. Insulation stop



Alternative Specification



1. Drydash, cement: lime: sand render to BS 5262.
2. 100mm concrete blockwork
3. Cavity wall ties mechanically fixed staggered (a)
4. 50mm ventilated cavity
5. Expamet render stop bead
6. Damp proof course, also as cavity tray over lintol
7. 100mm facing brickwork
8. Perpend weep slots @ 900mm centres
9. Breather paper fixed to ply with corrosion resistant staples (b), lapped and sealed (c), continuous at all laps and junctions (d), taken into opening reveals, sealed at corners and continuous with frame seal (e), refer 21.
10. 12.5mm sheathing ply nailed to studs
11. 95mm sw stud frame, 100mm mineral fibre quilt insulation. Frame design to BS 5268-6-1.
12. Vapour barrier (c) (d) (e) to interior face of OSB (f), lower edge taped to concrete with batten fixed over to seal.
- 12a. 10mm OSB board nailed to inside of studs, vapour check stapled to board (f) with 25x50 untreated sw battens horizontally to form service void (g)
13. 12.5mm plasterboard, use laying tape at junctions with ceiling, floor and openings to form airtight seals (h). Service boxes to fit within void and airtight (i)
14. 75 x 15mm MDF skirting board nail fixed to frame, continuous mastic seal to both connecting faces (j)
15. Polyethylene damp proof course dressed up edge of slab and tucked behind dpc / breather paper. (e)
16. 150mm insitu rc slab with float finish
17. Trench foundations
18. 50mm rigid eps butt jointed insulation beneath slab
19. Render stop nailed to blockwork at 600mm centres
20. Galvanized steel lintol and cavity closer to structural engineers spec. Behind lintol, run taped and sealed membrane into opening behind main membrane which laps dpc as noted over lintol, ref 6. Space behind lintol to be filled with expanding foam before installation of windows, & face sealed with mastic (k)
21. Proprietary pine tilt and turn double glazed window unit screwed to frame through continuous flexible foam on all sides to fully seal connection to frame, allow also for mastic sealant to outer face (l) Opening casements fully draughtstripped with tubular compressible seals, all to be fitted after painting and accessible for replacement (m)
- 22/23 15mm MDF nail fixed internal surround / cill (e), (j).
24. Aluminium ppc flashing mechanically fixed to frame
25. Precast concrete cill on 1:1:5 mortar
26. SW packer cavity closer
27. Timber joists @ 450mm centres fixed at perimeter support by mechanically fixed steel joist hangers (p) (ref. Struct. Eng.)
- 27a. 1000 g polythene strip stapled to inside face of perimeter floor beams, overlapping 100mm, lapped and sealed to vapour check. Ensure any damages to membrane are sealed (q)
28. 18mm tongue and groove chipboard nail fixed to joists
29. 2x 12.5mm plasterboard nailed to battens (h), ensure penetrations (eg ceiling pendants) carefully mastic sealed before concealment (n). Ensure careful sealing of loft hatch. (o)
- 29a 10mm OSB board nailed to underside of trusses (f), vapour check (c) (d) stapled to OSB, lapped and sealed behind battens at junction with wall. Ensure vapour control layer is continuous (lapped and sealed) over partition walls. (r) 25x50mm sw battens forming service void (g)
- 29b 1000 gauge polythene strip stapled to u/side of joists (u)
30. Extruded polystyrene cornice glue fixed (j)
31. Proprietary single ply membrane roofing fixed to ply
32. Proprietary timber roof truss with bolted joints
33. 50mm flexible insulation (s)
34. UPVC down pipe
35. Vents within soffit
36. Aluminium ppc gutter fixed to edge board by brackets
37. Mechanically fixed angle flashing
38. Insulation stop
39. 1000 gauge polythene strip with 100mm overlap each side stapled to top runner of frame and down sides, to be taped and sealed to subsequent membranes both sides. (t)

Discussion

Despite the inherently dry fixed nature of timber frame construction, it offers good opportunities to ensure airtightness because of the existing convention of using vapour control layers internal to the insulation and breather membranes externally.

This gives the Designer two layers with which to work to form a robust airtight envelope overall, and without introducing any significant or new component.

The outer layer of blockwork (or brick, or dry cladding of any type) need not perform any major role in the airtightness strategy.

Although there are a large number of small adjustments to conventional practice outlined, none of these, except perhaps the addition of the service void and backing board involve any major shift in construction process. Experience suggests that such changes are readily made and subsumed within the standard details and specification clauses of the practice.

More tricky is the need to convey the need for greater effort, co-ordination, care and vigilance to Contractors for whom there is little to be gained from the good practice noted, and quite a lot to be lost in terms of potentially time consuming additional tasks. In the short term it is important to emphasise the additional co-ordination and tasks to Contractors at the time of tendering so that these are not overlooked and the extra effort can be adequately assessed.

refer note re. prioritisation on p. 25

HIGH PRIORITY

(d) Continuity of Layer / Co-ordination of Trades

General measure to ensure tradesmen are aware of the need for airtightness, that all involved are conscientious and rigorous, and that someone is responsible for co-ordination between trades

(g) Service Void

Use of a service void means most if not all penetrations through the vapour control and airtight layer can be avoided.

(p) Joist Hangers

Use of Joist hangers avoids the common problems of air infiltration where joists are built into the inner leaf

(q) Membrane to Floor Perimeter Beams

Slightly awkward solution for solving the problems of discontinuity at this area which is nearly impossible to solve otherwise.

(m) Flexible Foam around Joinery

Gaps around openings are common and neat, effective solutions can be difficult, careful use of flexible foam enables effective and durable seals to be formed.

(r) Continuous Layer Over Partitions

High priority because of the high potential exfiltration rates and condensation risks at this point

(f) Backing Boards

Use of backing boards makes installation of the membrane easy and thus less prone to poor workmanship and subsequent failure.

MEDIUM PRIORITY

(c) Membranes Lapped & Sealed

2 lines of tape and a positive mechanical fixing by batten ensure laps are sealed for the long term

MEDIUM PRIORITY

(m) Joinery Draughtstripping

Tubular seals are probably the best option. It is important that they can be easily accessed for maintenance and replacement.

(e) Continuity at Openings

Continuity between the framing sealant (m) and the membrane can be tricky and care is needed to ensure a good, durable seal.

(o) Seal Loft Hatches

Unsealed loft hatches may contribute to air leakage, so worth some care.

(n) Plasterboard Penetrations

If the airtight layers are sound then this should not matter, but still worth attention.

(s) Flexible Not Rigid Insulation

Flexible Insulation provides a better fill between studs, rafters etc.

LOW PRIORITY

(g) Continuity Behind Lintols

An extra strip of membrane to form a continuous layer when the main one is lapped over the cavity barrier, also fill behind lintol.

(j) Mastic to Skirtings, Linings, Cornices

Not necessary if the airtight layer is sound

(u) Air Barrier to Ceiling

High Priority in separating floors

(h) Laying Tape to Plasterboard Junctions

(a) Wall Tie Fixings

(t) Top Runner Strip Seal

(i) Airtight Service Boxes

(b) Corrosion Resistant Fixings

Costs

Not surprisingly, the addition of the service voids adds considerably to the costs of both the walls and ceilings. Of course, such costs say nothing of the increased ease of services installation, nor of the long term benefits of a much greater access for upgrading and alterations.

Nonetheless, the addition of the OSB and battens forming the service void in the walls adds approximately 35% to the cost of the external wall. Mechanically fixing the vapour barrier to the floor and taping would add approximately 4% to the overall wall cost in addition.

Adding the service void to the ceiling would represent an approximate 130% increase in cost over just the 2 layers of plasterboard. But again, services installation would be easier.

The additional work associated with the breather membrane would incur a similar additional cost, but may not be a priority if the internal vapour barrier is well installed.

The mastic sealing of the skirting boards would increase the cost of their installation by about 50%, although these represent only small costs overall, the use of polythene strips at the floor and eaves, and the use of foam around the windows would attract only a marginal cost increase.

The use of flexible insulation need not attract any increase in cost if a common, economical type was chosen.

Defects Liability / Insurance Issues

The alternative detail shown has raised no additional concerns from the Insurability Review.

Where the original detail may not meet with current requirements, the alternative detail may also need review. For example, some minor aspects of the details would require to be assessed against individual circumstances (cavity closers, roof ventilation etc.)

6.2 Index

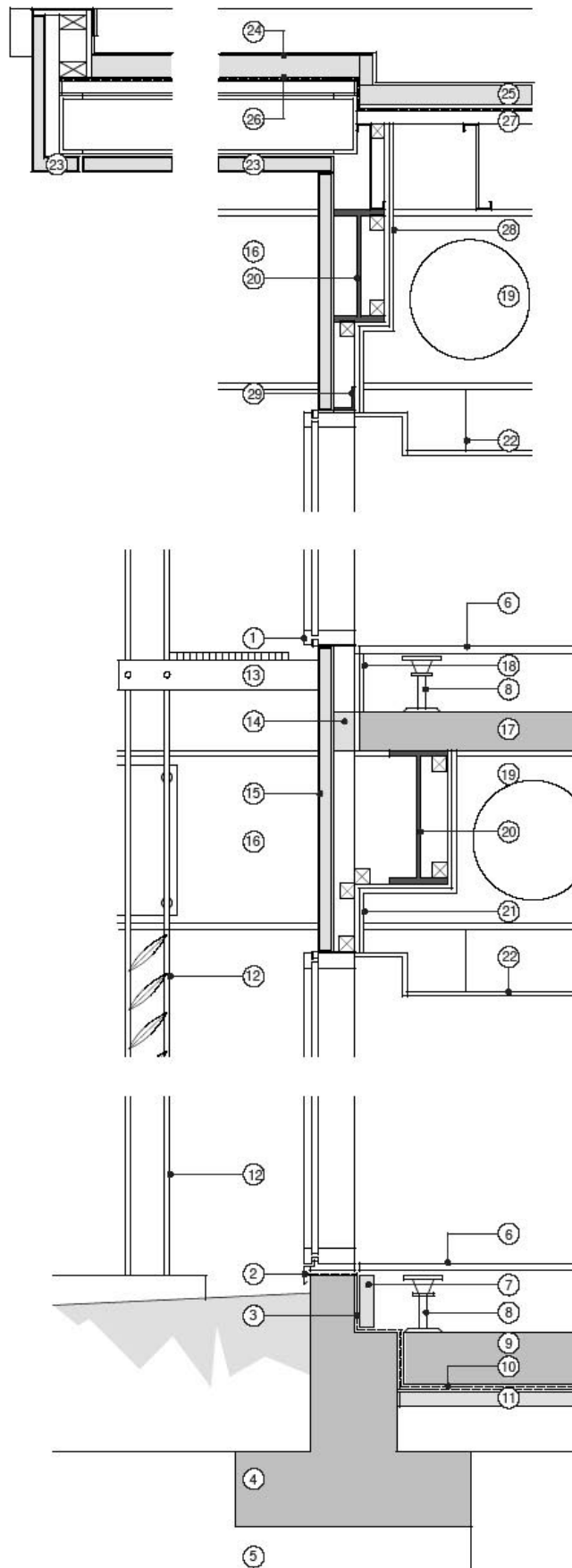
- (a) **Wall Tie Fixings to Timber Frame** (Specification Item 3)
The breather membrane is not the main air barrier, but it is nonetheless a useful ally in reducing air leakage through the construction generally. Ensure that wall tie fixings do not lead to damage to the membrane, ideally, by taping over the area of membrane at which the tie is fixed.
- (b) **Use of Corrosion Resistant Staples or Fixings** (Specification Item 9)
Non-corrosion resistant fixings to external breather membrane can corrode to a point where they fail, allowing the membrane to come loose, often creating a small hole in the membrane and reducing the effectiveness of the membrane as an airtight layer. Copper is non-corrosive but can affect polyethylene, whereas stainless steel has no effect on polyethylene and so should be preferred.
- (c) **Membranes to be Lapped and Sealed** (Specification Item 9, 12, 29a)
Typically both internal and external membranes are lapped and stapled or tacked, but in order to create airtight layers, it is important that these laps are rigorously sealed. Best practice in this regard - beyond the correct use of Manufacturers' overlap dimensions, proprietary tapes and other accessories - is to run a layer of double sided tape between the membranes at the overlap and run a tape over the leading edge of the outer sheet. In addition, since many tapes tend not to last too well, it is advisable to ensure that laps are made directly over supported areas (i.e. with studs or dwangs directly behind) and are held down positively with battens fixed through forming a mechanically tight, as well as an adhesive seal. This requires consideration of lap positions early on if extra framing or subsequent battening is needed.
- (d) **Ensure Continuity of Membrane / Co-ordination of Trades** (Specification Item 9, 12, 29a)
Whilst this is easy to achieve across large, flat areas, it is more difficult at the many awkward angles, junctions, corners and so on on a typical site. There is no specific guidance except to ensure that those responsible for installation of the membrane are rigorous and conscientious in their attention to all of the inevitable nooks and crannies, and that the person responsible for co-ordination is equally attentive, particularly when the junctions are between separate forms of joint and separate trades.
- (e) **Ensure Membrane is taken into Opening Reveals, Taped and Sealed and Made Continuous with Opening Seals** (Specification Item 9, 12, 15, 22, 23)
it is typical at openings in timber frame buildings to allow the membrane to run across the opening initially, then form a star cut into the opening, folding over the sections of membrane and trimming as necessary. In these cases, there are inevitable gaps in the airtight layer at the corners of the opening, and it is important to ensure that these are made good before subsequent installation of joinery etc.
- (f) **Fix Airtight Membranes to Firm Backing Boards** (Specification Item 12, 12a, 29a)
In conventional timber frame construction, vapour barriers are fixed across studwork, usually after the installation of insulation and prior to the fixing of the internal lining. Equally external breather membranes are sometimes installed across gaps between rafters or studs. In both cases membranes are susceptible to pressures from both sides, leading to the membrane breaking free of its fixing and creating holes in the airtight layer. Ideally, membranes should be fixed against a firm backing board by way of protection against damage of this nature.
- (g) **Service Void** (Specification Item 12a, 29a)
The principal advantage of a service void is related to functionality and maintenance over time, but a secondary advantage which relates directly to airtightness is that since all services may be incorporated within, that is, on the inside of the vapour control layer, there is no need to penetrate the layer at each and every service installation, thus significantly cutting down on the myriad potential gaps that are typically formed and either left, or made good which is time consuming and costly.
- (h) **Laying Tape at Plasterboard Junctions** (Specification Item 13, 29)
Using laying tape at junctions makes the formation of an airtight junction both conscious and relatively easy, even allowing for subsequent shrinkage and cracking of the skim layer.
- (i) **Airtight Service Boxes** (Specification Item 13)
Developed in Canada where airtight construction is more advanced, these service boxes are fitted with gaskets and a flange surround allowing for an airtight seal at all openings in the lining.
Contact: NuTek® / Thomas & Betts

- (j) **Mastic Both Edges to Skirtings, Reveal Linings, Cornices etc.** (Spec. Item 14, 22, 23, 30)
Where the corner junction behind has been carefully sealed then this measure may not be required. In addition to the nail or screw fixing, a mastic seal both edges aids efforts to guard against infiltration, but it makes removal and alterations more difficult.
- (k) **Ensure Continuity of Membrane behind and around Lintols** (Specification Item 20)
It is likely that to achieve this requires two separate measures. First the breather membrane needs to be continuous and extend into the opening, thus a second strip should be affixed to the wall and lapped and sealed to the main membrane which must lap over the lintol or cavity barrier etc. Second, it is likely that gaps could form between the top, outer edge of the joinery and the lower, inner edge of the lintol, leading to a cavity behind the lintol. This cavity should be filled with expanding foam or mineral wool and if possible the gap filled, probably with a mastic sealant.
- (l) **Flexible Foam Sealant around Joinery Insertions** (Specification Item 21)
Gaps around openings are one of the most common of infiltration paths. They range from 0 to 20mm, which is too large to be filled by mastic. Compressible flexible foams are ideal for this application. Ensure that the airtight membrane meets the seal on both sides to maintain the airtight layer overall. Contact for example: Alfas Industries, 0191 419 0505 www.compriband.co.uk
- (m) **Draughtstripping of Openings in Joinery** (Specification Item 21)
Draughtstripping of joinery comes in many forms. It appears that synthetic rubber or elastomeric tubular seals work well, creating good seals with minimal compression, depending on the size of the gap. It is important that seals are unaffected by paintwork and subsequent decoration, or are easily accessible and removable. This is important so that seals can be replaced as they start to fail to maintain the airtight layer.
- (n) **Seal all Penetrations in Plasterboard / Internal Lining** (Specification Item 29)
Even with the use of airtight outlet boxes there will be inevitable penetrations such as ceiling pendants, pull cords, recessed fittings etc. which must be made good manually, typically with mastic.
- (o) **Seal Loft Hatches** (Specification Item 29)
Generally, this involves a continuous bead of mastic to the underside flange, and, depending on the design, the use of compressed and flexible foam, or mineral fibre etc. above.
- (p) **Use of Joist Hangars as Opposed to Built-in Joists** (Specification Item 27)
The original specification here is already good practice, that is, the use of joist hangars which sidestep the problems of joist movement and shrinkage allowing infiltration and airflow within the floor voids.
- (q) **Membrane Strip to Inner Face of Floor perimeter Beams** (Specification Item 27a)
100 gauge polythene or similar fixed to the inner face of the perimeter beams early on in the framing process can lapped and sealed to the internal vapour control layer typically installed a good deal later, so that a continuous internal vapour control and airtight layer may be effectively created.
- (r) **Continuity of Membrane to Ceiling over Partition Walls** (Specification Item 29a)
Ideally this would comprise a continuous membrane affixed before the partitions are installed. However it is more likely that partitions are installed before, therefore such a layer would require strips to be fixed to the partition top runners to be later lapped and sealed to the ceiling vapour control layer.
- (s) **Flexible, Rather than Rigid Insulation** (Specification Item 33)
Rigid insulation between joists, studs or trusses generally has to be cut to fit and this is never 100% accurate, leading to myriad gaps and routes for airflow. Flexible insulation avoids this problem.
- (t) **Top Runner Strip Seal** (Specification Item 39)
The use of this strip, lapped and sealed with subsequent membranes both sides prevents infiltration into the wall itself from the ventilated eaves area, thus ensuring continuity of the airtight layer.
- (t) **Air Barrier to Ceilings** (Specification Item 29b)
In ceilings within dwellings of the same occupancy, this is unlikely to be useful, but in separating floors, it is extremely important that an air barrier is included in the floor and ceiling make-up. Noted here by way of a reminder.

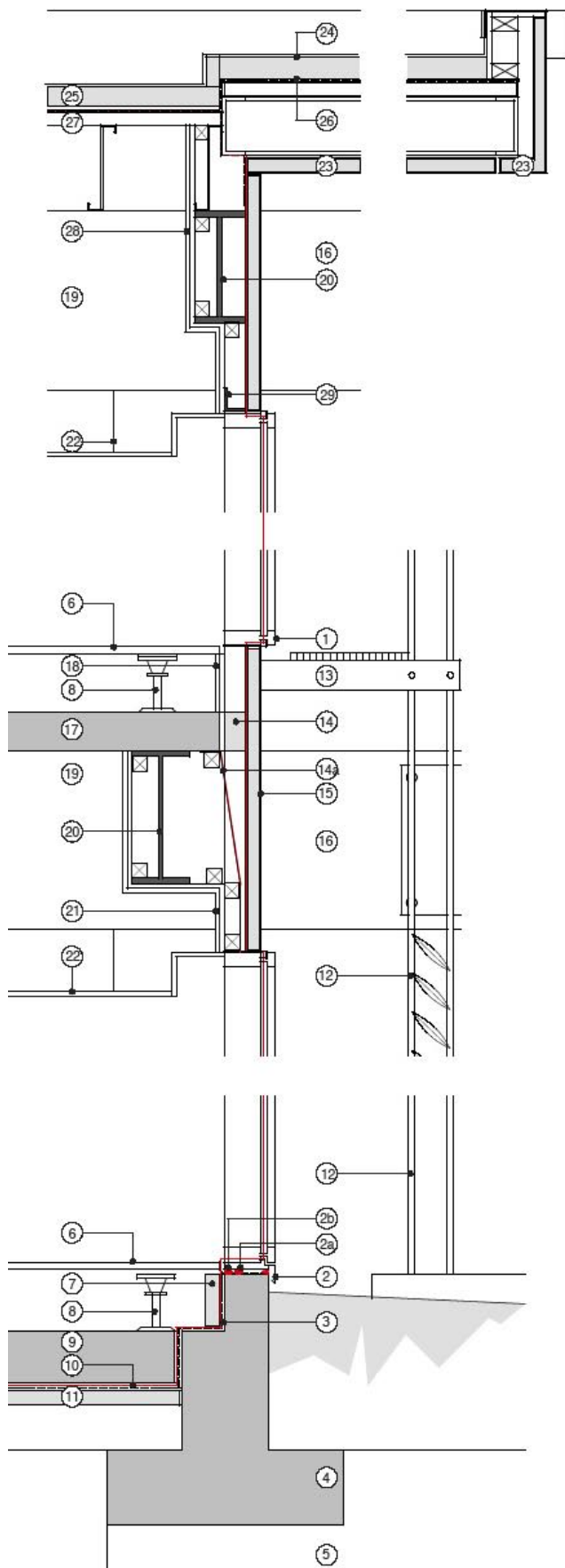
6.3 Steel Frame + Glazed Facade

Original Specification

1. 175mm deep overall ppc aluminium curtain walling system spanning from ground floor slab to secondary steel at roof level, tied back to steel structure at intermediate floors levels
2. Mechanically fixed flashing and infill between curtain walling and upstand
3. PVC damp proof course
4. Concrete strip foundation spanning between pad foundations with 295mm wide upstand, reduced to 150mm to suit curtain walling
5. Pad foundation to external column running to roof level to support steel
6. 225mm deep overall proprietary access floor system
7. 50mm rigid polystyrene eps butt jointed insulation glued to DPC
8. Raised access floor pedestals mechanically fixed to concrete slab @ 600mm centres
9. 175mm insitu rc slab with float finish
10. Polyethylene damp proof membrane dressed up and lapped with DPC
11. 50mm rigid polystyrene eps butt jointed insulation
12. Aluminium louvre blade sun shading on tensioned steel rods spanning from roof steel to ground level
13. Steel maintenance walkway, with mansafe anchor points, on cantilever steel arm, fixed to secondary steel and tension steel rod
14. 1 hour stopping at floor slab edge
15. Insulated aluminium ppc panel glazed into curtain walling horizontally and vertically @ 1500mm centres
16. Projecting beam with bolted fin plate connection to external chs column beam end profile to match column
17. 125mm insitu concrete floor slab with float finish
18. 2 x 15mm wallboard infill below raised access floor
19. Cellular beam
20. Steel I section beam
21. 2 layers 15mm wallboard infill between curtain walling and floor slab
22. Proprietary suspended ceiling system fixed as per manufacturers recommendations
23. Insulated aluminium ppc ladding panels fixed to secondary steel framing to soffit
24. Single ply roof membrane mechanically fixed
25. 80mm butt jointed mineral fibre slab insulation mechanically fixed
26. Reinforced polyethelene vapour barrier laid loose with lap joints
27. Profiled metal deck with Z purlins mechanically fixed @ 600mm centres
28. 2 layers 15mm wall board infill between curtain walling and roof deck
29. Insulated aluminium ppc flashing, glazed into curtain walling horizontally, with cassette panel joints vertically @ 1500mm centres



Alternative Specification



- 1 175mm deep overall ppc aluminium curtain walling system, spanning from ground floor slab to secondary steel at roof level, tied back to steel structure at intermediate floors levels. Fixed glazing to have a maximum air permeability of 1.5 m³/hour/m² at a minimum pressure of 600 pascals, and opening glazing to have a maximum air permeability of 2.0 m³/hour/ linear metre at a minimum pressure of 600 pascals, complying with CWCT 'Standard and Guide to Good Practice for Curtain Walling': 1996, or BS EN 12152:2002 - 'Curtain Walling - Air Permeability - Performance Requirements and Classification' (a)
- 2 Mechanically fixed flashing and infill between curtain walling and upstand, all fixings to be bedded in mastic, with further mastic perimeter seal (b)
- 2a EPDM seal, or proprietary curtain walling system sealing foil installed in accordance with manufacturers instructions (c)
- 2b Foam filler to internal joint (d)
- 3 Damp proof course, lapped and sealed (e)
- 4 Concrete strip foundation spanning between pad found's with upstand to suit curtain walling
- 5 Pad foundation to external column running to roof level
- 6 225mm deep overall proprietary access floor system
- 7 50mm rigid eps t&g jointed and taped insulation (f)
- 8 Raised access floor pedestals mechanically fixed to slab
- 9 175mm insitu reinforced concrete slab with float finish
- 10 Polyethylene damp proof membrane dressed up and lapped with DPC
- 11 50mm rigid eps t&g jointed and taped insulation (f)
- 12 Aluminium louvre blade sun shading on tensioned steel rods spanning from roof steel to fixing point at ground level
- 13 Steel maintenance walkway, with mansafe anchor points, on cantilever steel arm, fixed to secondary steel and tension steel rod
- 14 1 hour stopping at floor slab edge
- 14a Airtight membrane between separating floors fixed to underside of insitu concrete floor slab and curtain walling transom with timber batten on continuous mastic seal, fixing through mastic seal. Membrane to have some slack to allow for movement. (g)
- 15 Insulated aluminium ppc panel glazed into curtain walling horizontally and vertically @ 1500mm centres
- 16 Projecting beam with bolted fin plate connection to external chs column
- 17 125mm insitu concrete floor slab with float finish
- 18 2 layers 15mm wallboard infill below raised access floor
- 19 Cellular Beam, with side and web plates welded locally at curtain walling to enable simple airtight sealing at this point (h)
- 20 Steel I section beam
- 21 2 layers 15mm wallboard infill between curtain walling and floor slab
- 22 Proprietary suspended ceiling system fixed as per manufacturers recommendations
- 23 Insulated aluminium ppc ladding panels fixed to secondary steel framing to soffit
- 24 Single ply roof membrane mechanically fixed
- 25 80mm t&g jointed mineral fibre slab insulation mechanically fixed
- 26 Reinforced polyethelene vapour barrier lapped and sealed, (e) extended behind steel frame soffit and fixed to curtain walling system over continuous mastic seal, fixing through mastic seal.
- 27 Profiled metal deck with Z purlins mechanically fixed @ 600mm centres
- 28 2 layers 15mm wall board infill between curtain walling and roof deck
- 29 Insulated aluminium ppc flashing, glazed into curtain walling horizontally, with cassette panel joints vertically @ 1500mm centres

Discussion

It is important to be confident that the curtain walling manufacturer, supplier and installers all share an explicit commitment to producing an airtight wall overall, as it will be very difficult for the Main Contractor to ensure a continuous airtight fabric if this element is not firmly 'tied down' before the start on site.

The focus of concern then falls to all the various corners and perimeters where the system meets other construction elements and here both Designer and Contractor need to have carefully considered in detail each occurrence and made adequate provision, to avoid large amounts of ad hoc remedial work.

The roof membrane must be carefully sealed and the perimeter condition considered so that a continuous and positive connection can be made.

refer note re. prioritisation on p. 25

HIGH PRIORITY

(a) Curtain Walling Performance Spec.

Since this represents the largest area exposed to wind it is important that the performance specification is adequate and that the components are conscientiously installed

(b) Mastic Perimeter Seals

With the main curtain walling components installed and airtight, the next most significant air leakage route is likely to be the perimeter seals. Both mastic and membrane seals are valuable in this regard.

(c) Membrane Perimeter Seals

With the main curtain walling components installed and airtight, the next most significant air leakage route is likely to be the perimeter seals. Both mastic and membrane seals are valuable in this regard.

(e) Roof Membrane Sealing

Any leakage in the roof membrane or at the roof / wall junction could be serious in terms of both energy waste and risk of moisture related damage to the roof build-up, so this detail is important.

MEDIUM PRIORITY

(h) Plates Added to Beam

Because of the difficulty in forming an adequate seal to protruding beams, this is likely to be a major source of air leakage in the long term so designed, rather than ad hoc site measures to reduce infiltration are important.

(f) T&G and Taped Insulation

Potentially a minor issue, but given higher priority because it is relatively easy to solve and reduce airtightness and thermal insulation related risks.

LOW PRIORITY

(g) Membrane Seal between Floors

The existing detail should provide a reasonable degree of airtightness, but this measure will make the task conscious and effect a greater degree of separation.

(d) Foam Filler

Should not be required if the measures in (b) and (c) are completed, but an additional measure that also has value in providing a backing to a continuous mastic seal internally.

Costs

It is difficult to ascertain any meaningful cost implications with this detail because of the variety of curtain walling systems available.

The measures outlined are fairly standard in most installations and should in all cases represent no more than a re-iteration of good or best practice. However, they could attract an additional cost where one particular system did not address airtightness in one way or another.

Measures such as the additional efforts associated with air barriers at the separating floor, eaves and floor / wall junction might attract additional costs over that aspect of the original detail by approximately 30% largely because of the additional labour and attention required.

Defects Liability / Insurance Issues

The alternative detail shown has raised no additional concerns from the Insurability Review.

Where the original detail may not meet with current requirements, the alternative detail may also need review. For example, some aspects of the details would require to be assessed against individual circumstances, such as the protrusion of structural members through the cladding (leading to airtightness concerns as well as the need for corrosion resistance), and the acceptability of the cladding in terms of wind loads, maintenance loads and weathertightness.

6.3 Index

(a) Airtight Performance Specification for Curtain Walling

The de facto standard for curtain walling air permeability that most curtain walling manufacturers comply with is the CWCT (Centre for window and cladding technology) 'Standard and Guide to Good Practice for Curtain Walling'. This specifies a maximum air permeability of 1.5 m³ / hour/m² @600pascals for an area of fixed glazing, and 2m³/hr/linear metre of joint for opening panels. This is the same as the British Standard BS EN 12152:2002, category A4. However, the BS has a further category, AE that achieves 1.5m³ /hour /m² at a pressure differential of more than 600pascals. Specification of this 'exceptional category may be possible but it may mean a reduction in choice as this is a more stringent level of testing. The rule is: If wind load up to 2400kn then curtain walling to be tested to 600 pascals. If wind load greater than 2400kn then test to wind load/4, e.g if 4000kn, test curtain wall to 1000 pascals.

Maximising airtightness can be done by having vulcanised welded joints to gaskets within the curtain wall frame, instead of usual mitred ones. This should ensure that the unit its self is airtight, although it is an expensive option.

(b) Mastic Bedded Fixings

Where membranes and components are connected, it is often possible for thin - and often more or less invisible gaps to be left between the joint. A continuous mastic seal used along the line of any such mechanical fixing ensures that any minor cracks like this are completely sealed.

(c) Additional Membrane Seal at Junction

Some Manufacturers (eg Schuco) supply as part of their system an EPDM perimeter gasket seal that should be tied into vertical DPM. Angle at jambs and loose dpm to wrap ensure good seal with EPDM. This is a particularly good way to ensure airtightness at these critical junctions because it requires a conscious task (sealing the membrane) to ensure all 'loose ends' are firmly fixed, as opposed to leaving the airtightness to be achieved through the use of applied sealants.

(d) Foam Filler to Internal Joint

Assuming that the seal mentioned above is installed correctly this should not be required, but such a seal acts as an additional check against air leakage and could be used as a backing strip against which to seal a continuous mastic seal internally.

(e) Membranes to be Lapped and Sealed

Best practice in this regard - beyond the correct use of Manufacturers' overlap dimensions, proprietary tapes and other accessories - is to run a layer of double sided tape between the membranes at the overlap and run a tape over the leading edge of the outer sheet. In addition, since many tapes tend not to last too well, it is advisable to ensure that laps are made directly over supported areas (i.e. with solid materials directly behind) and are held down positively with battens fixed through, or some other 'positive' connection forming a mechanically tight, as well as an adhesive seal. This may require consideration of lap positions early on.

(f) T&G Jointed and Taped Rigid Insulation

Butt jointed insulation, even if installed firmly may be subject to movement during the course of construction and over time, and is unlikely to offer a continuous insulation layer in the long term. Using t&g slabs overcomes some of this problem and taping the slabs ensures that air leakage paths cannot form between the minute, but inevitable cracks between the units.

(g) Additional Airtight Membrane

It is likely that the fireproof stopping noted in Spec note 14 will not be able to create an adequately airtight seal and so this measure ensures the task is performed consciously. Using a simple polythene membrane and forming positive connections to the underside of the slab and the top of the curtain walling ensures an airtight seal between floors and at the vulnerable connection of curtain walling to spandrel panels

(h) **Localised Welding of Plates of Beam**

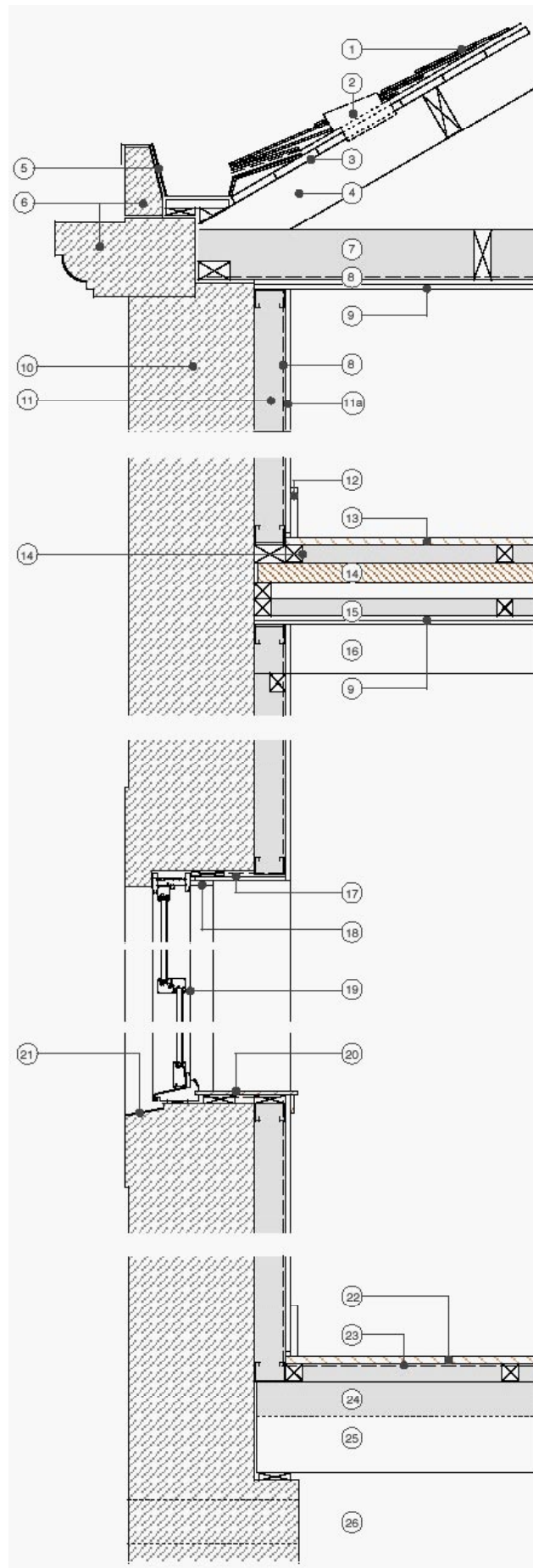
It is practically very difficult to form an airtight seal perpendicular to an 'I' beam or similar, expanding foam tends to be used because no 'built' connection appears workable, nor cost effective. Such ad hoc seals are unlikely to last in the long term.

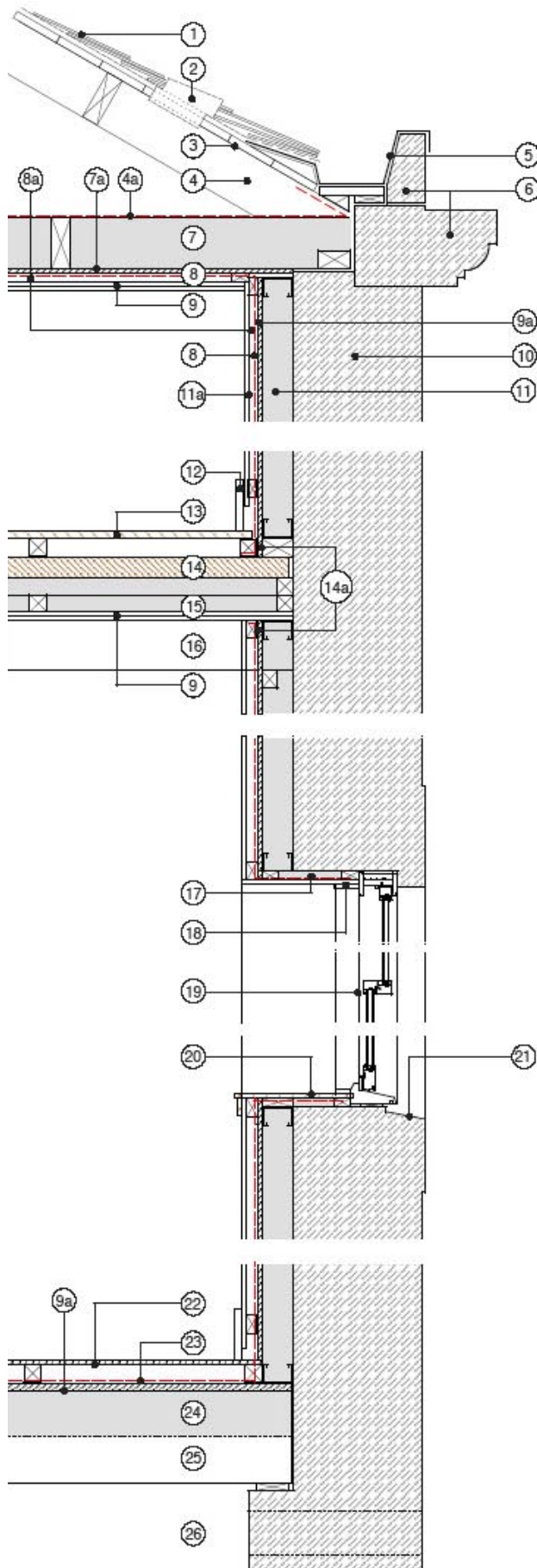
Ideally plates should be welded to the beam such that there is no air route along the length of the beam (a plate welded perpendicular to the web and extending between the two flanges) and such that airtight seals are easily formed around the beam as it passes the airtight layer. Side plates fixed between flanges form a sort of localised rectangular section which is more easily sealed. This makes the task more readily achieved on site, and more durable in the long term.

6.4 Refurbishment of Masonry Building

Original Specification

1. Existing slates taken up and replaced, nailed through breather membrane with stainless steel nails.
2. New slate vent and flashing to ventilate attic space.
3. Existing 100x20mm softwood sarking on
4. Existing 165x75mm softwood rafters.
5. New lead sheet gutter laid on marine ply sole and dressed under breather membrane
6. Ashlar facing stone naturally bedded.
7. 150mm Rockwool insulation within existing 150mm ceiling joists.
8. Vapour Control layer
9. 2 layers of 12.5mm t&f plasterboard nailed to underside of existing ceiling joists (lath and plaster removed) 2 coat satin emulsion finish
10. Existing Stone External Wall.
11. 100mm rockwool between 95mm proprietary metal studs fixed to existing external wall
- 11a 1 layer of 12.5mm t+f plasterboard screwed to metal studs thru' vapour control layer (existing lath and plaster removed)
12. MDF skirting glued to plasterboard, 3 coat gloss finish
13. Raised 22mm type III chipboard floor screwed to cushioned timber battens 50x50mm at 400 centres, 50mm mineral wool infill.
14. Existing 60mm thick floor boards.
15. 50mm mineral wool insulation within 50x50 softwood battens nailed to joists, with dwangs, to form ceiling between joists
16. Existing softwood joists, lower section exposed, 2 coat varnish. Check Fire Protection.
17. Plasterboard returned to form soffit, vapour control layer continuous over treated softwood or ply packers
18. MDF Soffit lining tacked and glued to window frame and plasterboard, silicon sealed with 3 coat gloss finish.
19. Double glazed replacement timber sash and case window. Silicon sealant all around externally.
20. MDF Cill into frame groove and over vapour control layer and packers, silicon sealed and with 3 coat gloss finish.
21. Existing shaped stone cill.
22. Raised 22mm type III chipboard floor screwed to cushioned timber battens 50x50mm at 400 centres, 50mm mineral wool infill, resting on existing floor joists. (existing floor boards removed)
23. Vapour barrier
24. 100mm Rockwool insulation within existing joists, supported by netlon.
25. Existing softwood joists, resting on packers.
26. Existing ventilated solum.





Alternative Specification

1. Existing slates taken up and replaced, stainless steel nails.
2. New slate vent and flashing to ventilate attic space.
3. Existing 100x20mm softwood sarking on
4. Existing 165x75mm softwood rafters.
- 4a. Breather membrane (a) lapped and sealed (b) over joists, taken up against underside of sarking and sealed
5. New lead sheet gutter laid on marine ply sole and dressed under breather membrane
6. Ashlar facing stone naturally bedded.
7. 150mm Rockwool within existing 150mm ceiling joists.
- 7a. Existing lath and plaster retained
8. Vapour Control layer lapped and sealed (b) over existing ceiling finish (c)
- 8a. 25mm service void formed by 25x50 sw battens @ 600 centres also over vapour control layer laps (d)
9. 2 layers of 12.5mm t&f plasterboard nailed to underside of battens, 2 coat satin emulsion finish
- 9a. 10mm OSB board to inner face of joists / studs to form firm substrate to vapour barrier (e)
10. Existing Stone External Wall.
11. 100mm rockwool between 95mm proprietary metal studs fixed to extg external wall (extg lath and plaster removed)
- 11a 12.5mm t+f plasterboard fixed to battens and studs behind
12. MDF skirting screwed through plasterboard to batten, mas-tic seal to both adjoining edges (f), 3 coat gloss finish
13. Raised 22mm type III chipboard floor screwed to cushioned timber battens 50x50mm at 400 centres
14. Existing 60mm thick floor boards.
- 14a Detail above and below Floor. Vapour control layer taken down to existing floor boards / taken up to double plasterboard, and sealed through continuous mastic bead behind batten as shown (g)
15. 100mm mineral wool insulation within and above 50x50 softwood battens nailed to joists, with dwangs, to form ceiling between joists, all penetrations in plasterboard (eg pendant lamps) to be sealed with fireproof sealant (h)
16. Existing sw joists, lower section exposed, 2 coat varnish. Check Fire Protection.
17. Plasterboard returned to form soffit, vapour control layer continuous (i) over treated softwood or ply packers and insulation, batten against window frame to be bedded in mastic or compressible foam against frame and existing masonry, as required to form airtight seal against both (j)
18. MDF Soffit lining tacked through plasterboard to batten with mastic seal to both adjoining faces (f), 3 coat gloss finish.
19. Double glazed replacement timber sash and case window, continuous compressible foam on all edges between frame and existing masonry to form airtight seal on all sides (k), fully draughtstripped (l). Silicon sealant externally (m).
20. MDF Cill into frame groove and over vapour control layer, insulation and packers, vapour control layer continuous (i) over treated softwood or ply packers and insulation, batten against window frame to be bedded in mastic or compressible foam against frame and existing masonry, as required to form airtight seal against both (j), 3 coat gloss finish.
21. Existing shaped stone cill.
22. Raised 22mm type III chipboard floor screwed to cushioned timber battens 50x50mm at 400 centres, forming service void (d) resting on vapour barrier on the OSB. (existing floor boards removed to insert insulation)
23. Vapour barrier lapped and sealed (b) and laid over OSB (e), lapped with wall vapour control layer and sealed behind perimeter batten over continuous bead of mastic (g)
24. 150mm Rockwool within extg joists, supported by breather membrane (n).
25. Existing softwood joists, resting on packers.
26. Existing ventilated solum.

Discussion

If the existing masonry fabric of a refurbished building is in good condition, it is potentially simple to render it relatively airtight if the details proposed - particularly the use of service voids - are followed. All the work can be carried out internally and is simple to install and check

In addition there is no cavity in this form of construction and this means there are fewer opportunities for undetected airways.

It goes without saying that any cracks or damage to the existing fabric should be made good before installation of the internal frame.

If there is enough space, it might be best to retain all existing lath and plaster on ceilings and walls, ensure that it is effectively sealed, and work inwards from there. Experience suggests that lath and plaster itself is fairly airtight and removing it merely creates more waste. One potential disadvantage is that in keeping the existing plaster, it may not be possible to access the gaps behind which may run into floor voids and partitions creating air leakage paths throughout the building.

A number of reviewers of this Guide commented that it is more common to maintain a cavity between the existing wall and any new-build internal leaf. The alternative proposed keeps to the same format as the original, but the advantages of the use of a cavity are well understood.

refer note re. prioritisation on p. 25

HIGH PRIORITY

(b) Membranes Lapped & Sealed

With only one membrane to ensure airtightness it is crucial that laps and junctions are conscientiously sealed.

(d) Service Void

Use of a service void means most if not all penetrations through the vapour control and airtight layer can be avoided.

(j) Joinery Edge Sealing Batten

If the membrane generally is well sealed, the only other major area for infiltration is the openings and the gap between the frame and masonry. If the windows can be effectively sealed by (k) then this measure is not necessary.

(l) Joinery Draughtstripping

A particular issue with sash and case windows. It is important that seals can be easily accessed for maintenance and replacement.

MEDIUM PRIORITY

(k) Flexible Foam around Joinery

Gaps around openings are common and neat, effective solutions can be difficult, careful use of flexible foam enables effective and durable seals to be formed. If this can be effectively achieved with the sash and case window then (j) is not necessary.

(i) Continuity at Openings

Continuity between the framing sealant (m) and the membrane can be tricky and care is needed to ensure a good, durable seal.

(e) Backing Boards

Use of backing boards makes installation of the membrane easy and thus less prone to poor workmanship and subsequent failure.

MEDIUM PRIORITY

(g) Batten Seal at Corners

A version of (b) but worth particular mention as these junctions are particularly important to seal well.

(c) Keep Existing Lath and Plaster

Really a version of (e) except in this case we suggest retaining the existing firm base of lath and plaster against which to affix the vapour control layer.

(h) Plasterboard Penetrations

If the airtight layers are sound then this should not matter, but still worth attention.

(a) Membrane Over Roof Insulation

Protects installed insulation from disruption and provides a secondary layer at this important area.

LOW PRIORITY

(m) Silicone to Joinery Externally

Should be standard practice, but forms useful role in airtightness as well as weatherproofing.

(j) Mastic to Skirtings, Linings, Cornices

Not necessary if the airtight layer is sound but worth attention in these examples.

Costs

The retention of the ceiling lath and plaster saves approximately 24% of the costs of that element, while the addition of the service void and vapour check represents a 18% cost increase, thus, without the addition of the breather membrane over the ceiling joists (a medium priority measure) there is a cost saving to complement the increase in ease and cost of services installation.

The breather membrane represents a 13% increase in cost and therefore tips the balance of the ceiling cost overall.

The addition of the OSB backing board and service void to the walls constitutes around a 46% increase in cost of the wall, the majority of which (33%) is made up by the OSB, so perhaps a cheaper, yet firm backing board might alleviate the cost burden.

The addition of the OSB layer to form a service void beneath the floor boards would add approximately one third to the cost of the original detail.

Double mastic sealing of the skirting boards adds approximately 50% to their installation cost, although their overall costs are small in the overall picture.

The sealing of the vapour control layer above and below the intermediate floor should not attract any additional cost if assumed to be part of a standard, if careful installation.

Measures to help seal around the window would add marginally to a standard installation cost.

Defects Liability / Insurance Issues

The alternative detail shown has raised no additional concerns from the Insurability Review.

Where the original detail may not meet with current requirements, the alternative detail may also need review. For example, some aspects of the details would require to be assessed against individual circumstances. In particular, it is unusual to place the internal wall insulation directly against the existing masonry wall and in most cases a space of at least 25mm is left between. We have maintained parity between the details but would draw the reader's attention to this particular aspect.

6.4 Index

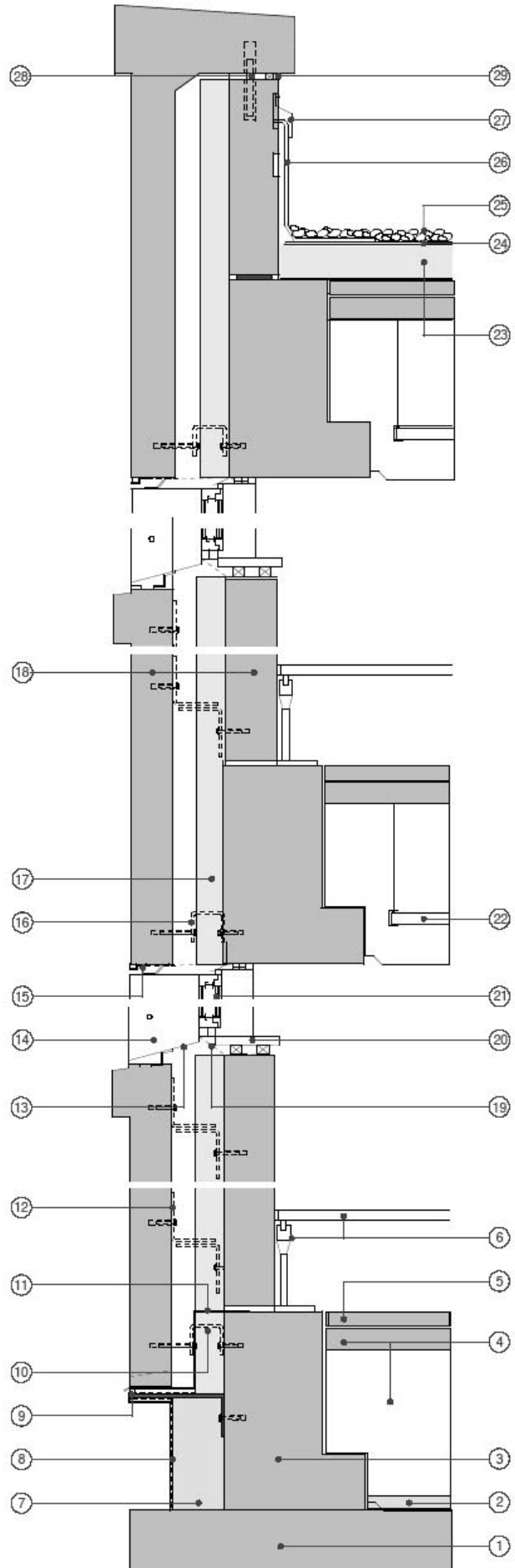
- (a) **Breather Membrane over Insulation** (Specification Item 4a)
In well ventilated loft areas, loose insulation may become dislodged by air movement. This precautionary measure ensures that the initial fully fitting installation of batts against joists etc is maintained over time, reduces dirt and debris entering and provides an additional airtight layer (which is useful since the loft is ventilated) whilst allowing for vapour egress into the ventilated space.
- (b) **Membranes to be Lapped and Sealed** (Specification Item 4a, 8, 23)
In order to create airtight layers, it is important that laps are rigorously sealed. Best practice in this regard - beyond the correct use of Manufacturers' overlap dimensions, proprietary tapes and other accessories - is to run a layer of double sided tape between the membranes at the overlap and run a tape over the leading edge of the outer sheet. In addition, since many tapes tend not to last too well, it is advisable to ensure that laps are made directly over supported areas (i.e. with studs or dwangs directly behind) and are held down positively with battens fixed through forming a mechanically tight, as well as an adhesive seal. This requires consideration of lap positions early on if extra framing or subsequent battening is needed.
- (c) **Vapour Control Layer over Existing Lath and Plaster** (Specification Item 8)
Rather than remove the existing lath and plaster ceiling, this detail saves a little money, time and resources by reusing the existing ceiling as a backing to the installation of the vapour control layer (refer also (e)) Plaster need not be repaired if damage is localised and does not threaten the integrity of the vapour control layer.
- (d) **Service Void** (Specification Item 8a, 22)
The principal advantage of a service void is related to functionality and maintenance of services over time, but a secondary advantage which relates directly to airtightness is that since all services may be incorporated within, that is, on the inside of the vapour control layer, there is no need to penetrate the layer at each and every service installation, thus significantly cutting down on the myriad potential gaps that are typically formed and either left, or made good which is time consuming and costly.
- (e) **Fix Airtight Membranes to Firm Backing Boards** (Specification Item 9a)
In many situations membranes required for vapour control and airtightness are installed unsupported and are thus susceptible to pressures from both sides, leading to the membrane breaking free of its fixing and creating holes in the airtight layer. Ideally, membranes should be fixed against a firm backing board by way of protection against damage of this nature.
- (f) **Mastic Both Edges to Skirtings, Reveal Linings etc.** (Specification Item 12, 18)
Where the corner junction behind has been carefully sealed then this measure may not be required, In the examples shown on this construction, this particular detail is not critical but is nonetheless valuable in helping to ensure a good seal at all points.
- (g) **Airtight Layer Taken Behind Batten at Corners** (Specification Item 14, 23)
As noted in (b) above, the best airtight seal is a positive and mechanical one such as shown here whereby at corners and edges, a membrane is not only lapped and taped against the adjoining surface, but held firm by a batten fixed through. This overcomes any potential adhesive failures or tears in staples or tacks etc.
In the ceiling junction where the plasterboard layer must be continuous for reasons of fire spread prevention, it is also advisable to install laying tape at the junction between the plasterboard and the wall to ensure an airtight seal here also.
- (h) **Seal all Penetrations in Plasterboard / Internal Lining** (Specification Item 15)
Even with the use of airtight outlet boxes there will be inevitable penetrations such as ceiling pendants, pull cords, recessed fittings etc. which must be made good manually, typically with mastic, and in this case, with a suitably fireproof mastic to maintain the fire barrier.

- (i) **Ensure Membrane is taken into Opening Reveals, Taped and Sealed and Made Continuous with Opening Seals** (Specification Item 17, 20)
it is typical at openings to allow the membrane to run across the opening initially, then form a star cut into the opening, folding over the sections of membrane and trimming as necessary. In these cases, there are inevitable gaps in the airtight layer at the corners of the opening, and it is important to ensure that these are made good before subsequent installation of joinery etc.
- (j) **Sealing Batten** (Specification Item 17, 20)
This detail may be considered as an alternative, or ideally as an additional measure with (k). Since it is possible that replacement sash and case windows cannot be easily sealed around their perimeter (they are often 'open' around the outer edge) it may be necessary to use this detail which creates the airtight seal on the inside of the frame rather than 'in line' with the frame as noted below.
- (k) **Flexible Foam Sealant around Joinery Insertions** (Specification Item 19)
Gaps around openings are one of the most common of infiltration paths. They range from 0 to 20mm, which is too large to be filled by mastic. Compressible flexible foams are ideal for this application. Ensure that the airtight membrane meets the seal on both sides to maintain the airtight layer overall. Contact for example: Alfás Industries, 0191 419 0505 www.compriband.co.uk
- (l) **Draughtstripping of Openings in Joinery** (Specification Item 19)
Draughtstripping of joinery comes in many forms. It appears that synthetic rubber or elastomeric tubular seals work well, creating good seals with minimal compression. It is important that seals are unaffected by paintwork and subsequent decoration, or are easily accessible and removable. This is important so that seals can be replaced as they start to fail to maintain the airtight layer. Brush seals are likely to be used in sash and case windows.
- (m) **Silicone Sealant to External Window Surround** (Specification Item 19)
Some form of neat and potentially paintable edge seal will be required externally.
- (n) **Breather Membrane Instead of Netlon** (Specification Item 24)
Notwithstanding the air barrier placed above, mineral wool is permeable to air movement and so replacing the netlon with a vapour permeable but airtight breather membrane reduces air movement in the insulation, improving insulation levels and reducing the risk of air leakage generally.

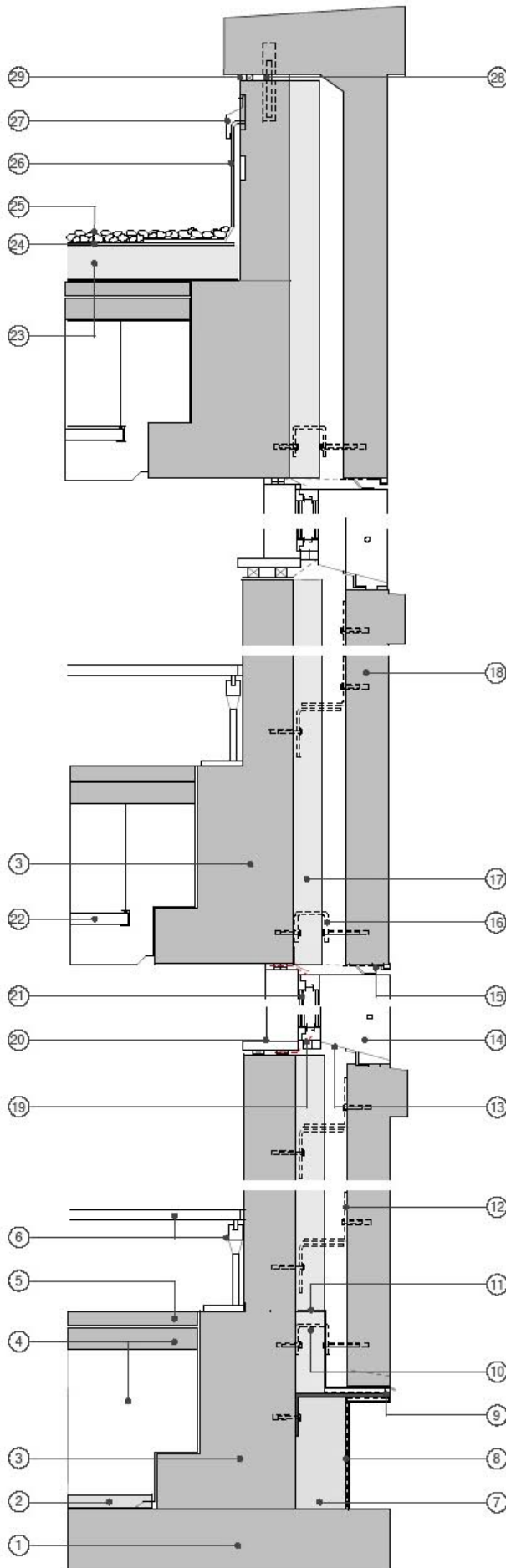
6.5 Concrete Frame and Panel

Original Specification

1. Pad foundation
2. 50mm rigid polystyrene eps butt jointed insulation
3. 690 x 350mm pre-cast concrete beam
4. Pre-cast concrete double T-unit spanning between beams
5. 50mm bonded screed
6. 300mm deep access floor system
7. 175mm expanded polystyrene insulation
8. Mesh and waterproof cement render
9. Bond breaker and sealant
10. Stainless steel shelf angle attached using wedge anchor insert with 10mm gusset centrally welded
11. Continuous aluminium flashing
12. 140 x 180 x 10mm stainless steel angle
13. PPC aluminium sill with silicone sealant
14. PPC aluminium window trim sealed with silicone
15. Weephole in recessed joint
16. 135 x 115 x 215mm stainless steel channel
17. 100mm expanded polystyrene insulation
18. 150mm sandstone coloured pre-cast panel
19. EDPM membrane locked into window
20. Treated timber window sill
21. Thermally broken triple-glazed window
22. Ceramic tile as suspended ceiling system
23. 20mm asphalt roofing
24. Non-compressible extruded polystyrene insulation
25. Stone chippings as ballast
26. Asphalt up-stand on high-bond primer
27. Aluminium flashing mechanically fixed into rebate in panel
28. Dowel fixing
29. Silicone seal



Alternative Specification



1. Pad foundation
2. 50mm rigid polystyrene epps butt jointed insulation
3. pre-cast concrete beam and integral internal panel (a) Ensure all penetrations are carefully sealed with double silicone beads (b)
4. Pre-cast concrete double T-unit spanning between beams
5. 50mm bonded screed with edge strip and silicon sealant to finish (c)
6. 300mm deep access floor system
7. 175mm expanded polystyrene insulation
8. Mesh and waterproof cement render
9. Bond breaker and sealant
10. Stainless steel shelf angle attached using wedge anchor insert with gusset centrally welded
11. Continuous aluminium flashing
12. Stainless steel angle
13. PPC aluminium sill with silicone sealant (d)
14. PPC aluminium window trim sealed with silicone (d)
15. Weephole in recessed joint
16. 135 x 115 x 215mm stainless steel channel
17. 100mm expanded polystyrene insulation
18. 150mm sandstone coloured pre-cast panel, joints to be double silicon sealed to create airtight facade (e) Ensure all penetrations are carefully sealed with double silicone beads (b)
19. EDPM membrane locked into window on all sides and held firmly against panel over mastic bead by packers, under cill, and reveal boards on other three sides (f)
20. Timber window sill
21. Thermally broken triple-glazed window with accessible draughtstripping as required (g)
22. Metal tile as suspended ceiling system
23. Non-compressible extruded polystyrene insulation laid on taped and sealed vapour / air barrier (h)
24. 20mm asphalt roofing
25. Stone chippings as ballast
26. Asphalt up-stand on high-bond primer
27. Aluminium flashing mechanically fixed into rebate in panel
28. Dowel fixing
29. Silicone seal

Discussion

Concrete panel construction represents a potentially good airtight form of construction. This is because the panels themselves are essentially airtight and being large, have fewer gaps which must be sealed. Being fairly predictable in terms of thermal and structural movement they are easy to seal well, and the only areas of concern then are the service penetrations and junctions with openings. With care and attention in these areas, a very good overall airtight external envelope is easily within reach.

Having said that, in some early examples of this building type, the sealants between panels have failed, highlighting the vulnerability of the system to such failure and the importance of correct specification and application.

A number of systems are available but the principles outlined for the improvement of the system chosen are widely applicable.

Where two leafs of concrete panel are used, it is unlikely that the outer layer will be used as a rain-screen layer, but this is sometimes done, and in these cases the airtightness of the internal layer of panels becomes critical, and may be augmented by the application of a vapour control and airtight membrane on the inner face of the insulation, applied to the panels before the insulation is installed. Guidance on the application of this membrane, and on potentially more airtight forms of insulation may be found in 6.1 and 6.2.

In Sweden, concrete panels are sometimes sealed to each other using polyurethane foam which is claimed to increase the airtightness levels, but there does not appear to be any evidence of this form of sealant in the UK.

refer note re. prioritisation on p. 25

HIGH PRIORITY

(a) Integral Beam and Internal Panel

Important because this reduces the number of joints and simplifies construction.

(b) Sealing of all Penetrations

Care and attention to detail at all services and other penetrations is vital, most pressure tested panel buildings suffer leaks at these locations.

(d) Sealing around Windows

The other major source of leaks in concrete panel buildings apart from (b) above, care and attention to detail along all joints needed.

(c) Screed Edge Strip and Seal

Ensures that air does not leak between floors around the perimeter and at other floor penetrations and breaks in the screed.

MEDIUM PRIORITY

(g) Accessible Draughtstripping

It is important that the draughtstripping is accessible since it is likely that it will not last as long as the windows themselves and require replacement.

(f) Membrane around Windows

Required for vapour and air leakage control, this also required attention and inspection and can be seen as complementary to the mastic / silicon sealants noted in (b)

(e) Double Silicon Seal to External Panels

Double silicon sealant lines in the external panels is normally standard practice, and is typically good enough to ensure that the outer panels provide an effective airtight seal throughout.

LOW PRIORITY

(h) Membrane Under Roof Insulation

May not be required if the screed below is fully sealed against vapour and air flow, but given the typical number of penetrations in a commercial roof screed, the addition of a dedicated membrane may be considered advisable.

Costs

The alternative specification highlights best practice installation and should not incur any additional costs. The design of the panel construction system itself would dictate any cost difference.

Defects Liability / Insurance Issues

The alternative detail shown has raised no additional concerns from the Insurability Review.

Where the original detail may not meet with current requirements, the alternative detail may also need review. For example, some aspects of the details would require to be assessed against individual circumstances. Several aspects of the window installation, flashings and weatherproofing would require further development in particular.

6.5 Index

- (a) **Integral Beam and Internal Wall Panel** (Specification Item 3)
There was some concern from the industry as to the buildability of the original detail and among suggestions was that the internal panel and beam be constructed together. This would have practical advantages and would increase the airtightness of the design considerably, as it results in fewer joints. The panels themselves may be considered to be completely airtight so it is only the joints, any openings, and any penetrations through the panels which are of concern.
- (b) **Service and Other Penetrations to be Sealed** (Specification Item 3, 18)
All involved in Concrete Panel construction noted that whilst the panels themselves are normally entirely airtight, it is the various inevitable grilles, ducts, extract louvres, flues and other service penetrations which give rise to infiltration and exfiltration. All stressed the need for careful and conscientious workmanship at these points, together with vigilance and good co-ordination between trades to ensure that seals are properly applied.
- (c) **Edge Strip and Seal to Screed** (Specification Item 5)
Due to shrinkage and movement, cracks inevitably form between the poured insitu screed and surrounding and supporting pre-cast elements. Along the perimeter this could potentially lead to air leakage between floors and so it is advisable to allow for the crack, install a flexible perimeter strip and after curing of the screed, to apply a flexible sealant to ensure complete airtightness at this point.
- (d) **Silicone Sealant to Window and Cill** (Specification Item 13, 14)
Already specified in the original detail, this is highlighted simply to emphasise the need for care and attention at these points to ensure a complete and durable seal around the windows and doors. It is more about workmanship and inspection, than about design or specification.
- (e) **Double Silicone Seals to External Panels** (Specification Item 18)
Double silicone sealing of external panels tends to be standard practice, but is worth stating in case it is missed. Such a seal, sometimes with a drain between, will ensure an airtight seal across the outer face of the construction.
- (f) **Membrane around Window** (Specification Item 19)
This membrane, already noted in the original detail serves both as a vapour barrier and as an airtight membrane at this vulnerable point in the construction. As in 9d) above, this is highlighted merely to bring the attention of the Design team and Contractor to this area to ensure good workmanship and careful inspection.
- (g) **Draughtstripping to Window** (Specification Item 21)
A high performance window such as the triple glazed item specified is likely to have a well engineered draughtstripping system installed as standard. If not then this is critical, but significantly the issue is more to ensure that the draughtstripping may be made accessible and easily replaced should it begin to fail, since its likely service life is shorter than the main frame and glazing to which it is attached.
- (h) **Lapped and Sealed Membrane under Insulation** (Specification Item 23)
Even allowing for the perimeter seal as noted in (c), it may be worth consideration of a vapour and airtight membrane below the insulation. This serves to ensure that vapour is not carried into the insulation and then presents the risk of interstitial condensation. Following on from this, it is important that laps are rigorously sealed. Best practice in this regard - beyond the correct use of Manufacturers' overlap dimensions, proprietary tapes and other accessories - is to run a layer of double sided tape between the membranes at the overlap and run a tape over the leading edge of the outer sheet.

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Acronyms

ATTMA	Air Tightness Testing and Measurement Association
BPEO	Best Practical Environmental Option
BRE	Building Research Establishment
BS EN	British Standard European Norm
CIBSE	Chartered Institute of Building Service Engineers
CIRIA	Construction Industry Research and Information Association
EC	European Community
EU	European Union
NBS	National Building Specification
NGO	Non-governmental Organisation
RIAS	Royal Incorporation of Architects in Scotland
RIBA	Royal Institute of British Architects
SEDA	Scottish Ecological Design Association
SEPA	Scottish Environmental Protection Agency
UKAS	United Kingdom Accreditation Service

References

Web based Information

General Information (much also to be found on Company websites noted below)

Air Infiltration and Ventilation Centre

32 2 655 77 11 (Holland) (Operating Agent is INIVE, contact Dr. Peter Wouters, there is no participating agent in the UK)

<http://www.aivc.org/> or <http://www.inive.org>

CIBSE (Chartered Institution of Building Services Engineers)

0208 675 5211 (London)

<http://www.cibse.org/>

BSRIA Ltd.

01344 465 600 (Berkshire)

<http://www.bsria.co.uk/>

Research Council Canada: Institute for Research in Construction

<http://irc.nrc-cnrc.gc.ca/irccontents.html>

UK Companies Specialising in Airtightness Testing etc.

Stroma Technology Ltd.

01924 870 677 (West Yorkshire)

<http://www.stroma-ats.co.uk>

Building Envelope Technologies

(00353) 055 28869 (Co. Wexord, Eire)

<http://www.betechnologies.ie/page6.html>

BSRIA Ltd.

01344 465 600 (Berkshire)

<http://www.bsria.co.uk/content/?content=air+tightness>

HRS Services Ltd.

0114 272 3004 (Sheffield)
<http://www.air-tightness.co.uk/>

Chiltern Dynamics

01494 569 830 (Buckinghamshire)
http://www.chilterndynamics.co.uk/airtightness_framer.htm

BRE

01923 664 500 (Watford)
<http://www.bre.co.uk/service.jsp?id=134> or
<http://projects.bre.co.uk/envdiv/airtight/index.htm>

Wintech Test Engineering

01952 586 580 (Shropshire)
<http://www.wintechairpressuretesting.co.uk/>

Steel Construction Institute (Testing of Construction Types rather than whole Buildings)

<http://www.steel-sci.org/consultancy/Thermal/default.html>

Published Information

Standards and Regulations

British Standards Institution

BS EN 13829: 2001 Thermal performance of buildings: Determination of buildings - fan pressurization method

BS 4255: Rubber used in preformed gaskets for weather exclusion from buildings Part 1: 1986 Specification for non-cellular gaskets .

BS 4873: 1986 Specification for aluminium alloy windows

BS 5368: Methods 01 testing windows Part 1: 1976 (EN 42) Air permeability test

BS 5925: 1991 Code of practice for ventilation principles and designing for natural ventilation

BS 6375: Performance of windows: Part 1: 1989 Classification for weathertightness (including guidance on selection and specification)

BS 6510: 1984 Specification for steel windows, sills, window boards and doors

BS 7386: 1997 Specification for draughtstrips for the draught control of existing doors and windows in housing (including test methods)

BS 7412: 1991 Specification for plastics windows made from PVCu extruded hollow profiles

BS 8200: 1985 Code of practice for design of non-loadbearing external vertical enclosures of buildings

International Organisation for Standardisation (ISO)

ISO 6589: 1981 Nr permeability of joints, watertightness

ISO 6613: 1980 Nr permeability of tests on windows and doors

ISO 9972: 1996 Thermal Insulation – Determination of building airtightness – fan pressurization method

Building Regulations

Conservation of Fuel and Power

England and Wales. Approved Document L2. 2002 edition.

Northern Ireland. Part FF of the Building Regulations (Northern Ireland). 1990.

Scotland. Part J of the Technical Standards for Compliance with the Building Standards. 1990.

Ventilation

England and Wales. Approved Document F.1995 edition.

Northern Ireland. Part K of the Building Regulations (Northern Ireland). 1990.

Scotland. Part K of the Technical Standards for Compliance with the Building Standards. 1990.

Offices, Shops and Railway Premises Act 1963.

By Specific Organisations

Chartered Institute of Building Services Engineers (CIBSE)

Testing buildings for air leakage. CIBSE Technical Memorandum TM23, London, 2000.

Building energy code. Part 2 (a) Calculation of energy demands and targets for newly built, heated and naturally ventilated buildings

BRE

BRE Reports

BR 154 Improving the Habitability of large panel system dwellings. 1989

BR 162 Background Ventilation of Dwellings: A Review, 1989

BR 262 Thermal Insulation: Avoiding Risks. 2002

BR 359 Airtightness in UK Dwellings: BRE's test results and their significance. 1998

BR 448 Airtightness in Commercial and Public Buildings 2002

BRE Digests

306 Domestic Draughtproofing: Ventilation Considerations

350 Climate and site development

Part 1: general climate of the UK

Part 2: influence of microclimate

Part 3: improving microclimate through design

398 Continuous mechanical ventilation in dwellings: Design Installation and Operation

399 Natural ventilation in non Domestic buildings

BRE Good Building Guide

32 Ventilating thatched roofs

BRE Good Repair guide

21 Improving ventilation in housing

BRE Information Papers

14/79 Resistance to Air Flow through External Walls

6/89 Use of BREFAN to Measure the Airtightness of Non-domestic Buildings

5/95 Testing the performance of terminals for ventilation systems, chimneys and flues

6/95 Flow resistance and wind performance of some common ventilation terminals

13/95 The passive gas tracer method for monitoring ventilation rates in buildings

4/98 Night ventilation for cooling office buildings

12/98 Trickle ventilators in offices

4/99 Ventilators: ventilation and acoustic effectiveness

5/99 Humidistat-controlled extract fans

1/00 Airtightness in UK Dwellings

12/00 Positive input ventilation in dwellings

9/04 Maintaining good air quality in your home

Energy Efficiency Office

A list of publications related to energy conservation and management in commercial and public buildings is available from BRECSU at BRE.

Metal Cladding and Roofing Manufacturers Association.

Guidance for the design of metal cladding and roofing to comply with AD L2. Tech. Note 14, 2002 Edition.

AIVC (Air Infiltration and Ventilation Centre)

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Glossary

This glossary has been developed to be as consistent as possible with those defined in Technical Note AIVC 36 Air Infiltration and Ventilation Glossary

Air barrier

An air barrier comprises materials and/or components, which are air impervious or virtually so, separating conditioned spaces (heated), from unconditioned spaces (unheated).

Air change rate

The rate at which outside air enters a space divided by the volume of that space. This is expressed as ach (air changes per hour).

Air curtain

A stream of high velocity, temperature-controlled air which is directed across an opening. It enables control of conditions in a space, which has an open entrance.

Air exfiltration

The uncontrolled outward leakage of indoor air through cracks, discontinuities and other unintentional openings in the building envelope.

Air infiltration

The uncontrolled inward leakage of outdoor air through cracks, discontinuities and other unintentional openings in the building envelope.

Air leakage audit

The inspection of materials and components, between conditioned and unconditioned spaces to try to establish where major discontinuities in an air barrier system might exist.

Air leakage index

The leakage of air ($m^3.h^{-1}$) in or out of a building space, per unit area (m^2) of envelope (excluding ground floor area, except for non-ground supported lower floors) at a reference pressure of 50 Pa between inside and outside the building.

Air permeability

The leakage of air ($m^3.h^{-1}$) in or out of a building space, per unit area (m^2) of envelope (including ground floor area) at a reference pressure of 50 Pa between inside and outside the building.

Air leakage rate

The leakage of air ($m^3.h^{-1}$) in or out of a building space, per unit volume (m^3) at a reference pressure of 50 Pa between inside and outside the building.

Air leakage path

A route by which air enters or leaves a building or flows through a component.

Airtightness

A term describing the leakiness of a building. The smaller the leakage for a given pressure difference across a building, the tighter the building envelope.

Airtightness layer

A layer built in to the external envelope to minimise air infiltration/exfiltration. It may consist of a wide range of materials (for example, sealants, gaskets, glazing or membranes) and should be continuous to be effective.

Breather membrane

A water-resistant sheet which allows transmission of water vapour, but which provides resistance to air-flow.

Conditioned zone

The occupied zone in a building requiring heating or cooling and normally bounded by an airtightness layer.

Draught

Excessive air movement within the conditioned zone, which may cause discomfort.

Draughtproofing

Filling gaps between opening parts of components and their frames.

Envelope area

The boundary or barrier (m²) separating the interior volume of the building from the outside environment. This includes the area of the external walls, roof and depending upon the air leakage parameter specified the area of the ground supported floor.

Fan pressurisation test

A method of testing air leakage of a building. It allows airflow and pressure difference across the envelope to be measured and an estimate of leakage to be obtained.

Infiltration rate

The rate at which outside air infiltrates a building or a room under natural meteorological conditions (normally expressed in air changes per hour or litres per second)

Infrared camera

A camera sensitive to the infrared part of the spectrum, which can be used to 'see' locally cooled areas on the internal surfaces or heated areas on internal and external surfaces of the envelope of a building.

Minimum ventilation requirement

The minimum quantity of outdoor or conditioned air which must enter a building to maintain an acceptable indoor air environment for occupants.

Natural ventilation

The movement (caused by wind and outside temperature) of outdoor air into a room or space through intentionally provided openings, such as windows and doors and non-powered ventilators.

Smoke test

A building (or parts of it) is filled with smoke using smoke machines and then pressurised to force the smoke through gaps in the building envelope.

Smoke tube/pencil

A hand held device which produces smoke in small quantities for more specific identification of leakage paths within a building under pressurisation or depressurisation, or under natural infiltration.

Stack effect

Air movement through a building caused by differences in the density of air due to temperature differences between the air inside and outside of the building.

Thermography

The use of cameras sensitive to infrared radiation to identify thermal weak spots in the envelope of the building and to help identify air leakage paths through gaps and cracks in the building.

Vapour control layer

A layer impervious to water vapour and usually enclosing an occupied space.

Ventilation

Supplying or removing air, by natural or mechanical means, to or from a space.