Technical Note No 44

Whole building air leakage tests

This Technical note is one of two covering site testing to prove compliance with thermal standards. The other is:

TN45 Thermographic testing - identifying cold bridging and air leakage

This Technical Note considers the issues surrounding whole building air leakage testing and gives guidance on the practical aspects of procuring air leakage tests.

Introduction

Uncontrolled air leakage (into or out of a building) is easily the biggest single factor causing heat losses and high energy consumption in buildings in the UK, TN47.

The Building Regulations recognise this and Part L2 places emphasis on reducing overall envelope air leakage and also proving this has been done on a project-by-project basis.

Independently of the Building Regulations Clients may set air leakage requirements for the whole building envelope to reduce the whole life operating cost of a building.

Whole building air leakage testing may also be undertaken to demonstrate the air leakage rate of a house type although this is not required by the Building Regulations Part L1.

Regulation

The current Building Regulations Approved Documents Part L2 for England and Wales (April 2002) place a greater emphasis on energy conservation. Airtightness is one of a number of factors including solar gain, conduction heat losses through the facade, lighting and ventilation, that need to be taken into account.

The main objective of the airtightness requirement is to aid in the conservation of fuel and power required to heat and cool the building. This leads to other benefits, particularly comfort and economy of operation. An airtight building requires less power to control the quality of the internal environment, thus reducing the annual running costs. Lower rated plant and air handling equipment can be installed; as less demand is put on the system so initial expenditure is reduced. This adds value to the building making it more attractive to the developer and tenant.

Part L1, relating to dwellings, requires the use of robust detailing to show compliance.

Part L2, relating to buildings other than dwellings also requires the use of robust details but further requires that all buildings with a gross floor area of more than 1000 m2 be tested to show that the overall air permeability does not exceed 10 m3/hour/m2. If compliance with the Building Regulations is demonstrated by the 'Carbon emissions calculation method' then the required air leakage value may be lower.

Building Regulations Part L2: Construction part 2.2 refers to airtightness and states, "Air barriers should be installed to minimise air infiltration through the building fabric ... certificates or declarations should be provided .... stating ... that the results of air leakage tests carried out in accordance with CIBSE TM 23 are satisfactory".

The situation regarding testing has been further clarified by a letter from the Office of the Deputy Prime Minister (ODPM) dated 4 April 2003 that states "the Approved Document offers no alternative to pressure testing as a way of showing compliance with the airtightness aspect of Part L2".

The ODPM is clearly frustrated by the attempts of various parties to seek alternatives to testing and the letter further states that "If the present more flexible arrangements continue to falter there is also the possibility of prescribing testing in the legal requirements".

Air leakage rates

Currently buildings are achieving typical air leakage rates in the range 5 to 15 m3/hour/m2 at 50Pa.

Much of the air leakage occurs at interfaces between different zones, or commercial packages, of the building envelope. Interfaces include joints between:

- Windows and walls
- Walls and roofs
- Walls of different construction

Elements of the building envelope such as windows and curtain walling are capable of achieving much lower air leakage rates under standard infiltration tests, 0.28 m3/hour/m2 in the case of good quality curtain walling. Exfiltration rates may be higher but whole building air leakage is still dominated by air leakage at interfaces.

Achieving acceptable airtightness of a building envelope requires good detailing and construction of the interfaces as well as the specification of appropriate components.

Scope of test

Part L2 of the Building Regulations requires all buildings to be airtight.

Airtightness of any building may be demonstrated by whole building air leakage testing to TM23. This is required by Part L2 of the Building Regulations for all buildings with gross floor area of 1000 m2 or more. It may also be a Client requirement on buildings of smaller size.

For buildings with gross floor area less than 1000 m2 it is possible to meet the requirements of the Building Regulations by demonstrating 'That appropriate design details and building techniques have been used, and that the work has been carried out in ways that can be expected to achieve reasonable conformity with the specifications that have been approved for the purposes of compliance with Part L2'.

Test method

The whole building air leakage test is an exfiltration test. Air is pumped into a building at a rate that equals air lost as exfiltration and maintains a constant pressure of 50 Pa. Exfiltration is considered to be as good an indicator of an energy efficient building as infiltration. The exfiltration test allows a smoke test and thermal imaging (see below).

Full test methods are described in:

- TM 23:2000.
- BS EN 13829:2001

What to test

TM23 includes:

- An air leakage index calculated as total air leakage divided by internal surface area of the building envelope excluding any floor in contact with the ground.

- Air permeability calculated as total air leakage divided by the internal surface area of the building envelope, including all floors.

BS13829 defines:

- Air permeability rate calculated as total air leakage (at the reference pressure) per envelope area.
- A specific air leakage rate calculated as the air leakage rate per net floor area.
- Air change rate at the reference pressure calculated as air leakage rate per internal volume.

The air permeability measure of air leakage is recommended by the Building Regulations, Part L2.

Definition of building envelope

The building envelope is the boundary between the internal (conditioned) environment and the external environment.

In TM23 the area of the building envelope is defined as the area of the internal surface. BS EN 13829 notes that no deduction is made for junctions with internal walls or floor slabs.

For atria:

- If the atrium space is un-conditioned then the atrium should be considered to be an external space and the atrium walls should be tested as part of the building envelope.
- If the atrium space is fully conditioned the atrium roof should be tested as part of the building envelope.
- Even if the atrium roof is fully conditioned individual clients may wish to demonstrate that there is acceptably low air leakage between their compartment and the atrium.

Compartmented buildings

Buildings divided into compartments such as separate apartments or retail units may be tested as separate compartments or as a whole building. When testing individual compartments it is essential that the compartment boundaries can be temporarily sealed one from another.

Testing of very large buildings

When testing very large buildings it may not be possible to achieve the required fan flow rate to balance exfiltration at 50 Pa. TM 23 allows testing at pressures as low as 25 Pa and gives a method of normalizing the measured air leakage to a leakage rate at 50 Pa.

It is also possible to use more than one fan or to test the building zone by zone.

Tall buildings may be zoned vertically for test purposes. When testing a single floor of a high-rise building it is often acceptable to seal the perimeter zone from the core, which is generally easier than sealing the voids in the core horizontally at each floor level.

It may be acceptable to test a single floor or representative floors but air leakage through the roof must also be measured.

Zoning of buildings horizontally is more difficult but may be necessary.

In general any zoning will depend on extensive internal sealing and measured air leakage rates will be higher than those for the building measured as a whole. However, care is necessary to ensure that potential leakage routes, such as a horizontal joint level with a floor slab are not omitted from all zones.

Rather than internally sealing floors to isolate a storey to be tested it may be possible to also pressurise the storeys above and below the one to be tested. This will equalise the pressures on either side of the floors. Note that only air leakage from the middle floor should be measured.

When intending to test by zones it is important to check the acceptability of the method with the Building Control Officer.

Exclusions

Notwithstanding the above definition of air permeability it is sometimes argued that particular components of the building envelope should be excluded from a whole building air leakage test.

Elements should only be excluded if they are shown to have an air leakage rate less than or equal to that assumed in any energy calculations for the building envelope. This will probably have to be agreed by the building services engineer or a facade consultant. (Note that testing a component independently of its surrounding building envelope will neglect any airleakage that may occur at the perimeter of the component).

If it is intended that some elements be excluded from the whole building air leakage test this should be agreed with the Building Control Officer prior to testing.

As a general rule, if components that have high air leakage rates associated with them are used greater air tightness should be achieved in other parts of the building envelope to give the required overall air leakage rate. When using the 'Carbon emissions calculation method' it may be possible to balance high air leakage losses against improved insulation or more efficient heating and cooling plant.

Particular issues relate to the following components and zones:

- Lift shafts/lift doors
- Stairwells/pressurised stairwells
- Roller shutter doors
- Revolving doors
- Air curtain doors

Lift shafts may have doors that connect to the internal space at some floors and to the external environment at other floors.

By their nature lift doors have poor air seals and high rates of air leakage through the building envelope may result. This should be considered at the design stage.

Stairwells/pressurised stairwells link the different floors of the building and may be incorrectly accounted for when testing a building a storey at a time. Depending on how a storey is sealed for testing an external stairwell may be omitted from the air leakage calculation or may be counted twice.

Pressurised stairwells will have additional air leakage resulting from the over pressure in the stairwell.

Roller shutter doors have high air leakage rates because it is impossible to achieve a full air seal between the moving part of the door and the fixed frame. This should be considered at the design stage.

Revolving doors will inevitably allow air leakage in operation but even when in a closed position may not seal as well as a hinged door. The use of a slightly tighter building envelope will counter the greater losses associated with the door.

Air curtain doors are used in retail premises to avoid a perceived barrier on the part of customers. The extent of any such doors is generally small in relation to the whole building envelope and the use of a slightly tighter building envelope will counter the greater losses associated with the door.

Procurement

The stages to procuring whole building air leakage tests start with the design stage. The building has to be designed to comply with the requirements of Part L of the Building Regulations and Client requirements. Assumptions made at the

design stage have to verifiable by test and tested.

The stages to procuring a test are:

1 Design
2 Inspection during construction
3 Appoint tester
4 Book test
5 Prepare building for test
6 Check weather forecast
7 Test
8 Remove all temporary seals

Design

Consider at the design stage: required performance specification, interfaces, material selection, drawings to indicated line of continuous air barrier across envelope.

Construction

On large projects it may be desirable to conduct an indicative air leakage test on a zone of the building envelope at an early stage in construction. In high-rise buildings it may be possible to test the ground floor before completion of the whole building. In smaller buildings it may be possible enclose a zone of the wall and perform a localised test with a small fan. These approaches are particularly recommended where a detail is to be repeated many times and a systematic error may occur.

Indicative tests solely for the Main Contractor's benefit may be carried out by non-UKAS accredited testers.

Many contractors will be developing robust details that can be used to give confidence that the required air leakage rate is achieved.

Inspection is required during construction to ensure that robust details are constructed as intended and that in the absence of robust details the construction is of a good standard in accordance with the drawings and specification. This should be carried out at regular intervals by a competent person.

Appointment of tester

There are a growing number of testers in response to the greater need for whole building air leakage testing. The tester should preferably be specifically accredited by UKAS for testing to TM23. Alternatively an independent witness may be employed to observe and report on tests performed with measuring equipment that is accurately calibrated and traceable to national standards.

Many new bodies are offering a testing service. It is essential to check that they test correctly to TM23, that the equipment used is accurately calibrated and traceable to national standards, and that the equipment is adequate for the size of building to be tested.

Programming a test

Air leakage tests should be scheduled as early as possible within the construction programme but cannot be undertaken until the building is virtually complete. Early discussion with the tester is important.

The effect of any fit-out will have to be taken into account. For building that depends on a dry-lining system to achieve air tightness this will have to be installed, including all penetrations through it, prior to the test. Where the internal fit-out makes little or no contribution to the airtightness of the building it will be better to test before fit-out so that access to the wall for remedial work is simpler.

It may not be possible to undertake a thermographic survey during some seasons.

During the period of testing (normally a day) most or all other work on the site will be

impossible due to the lack of access to the building.

Preparing building for test

Temporary sealing works may be required if particular components are to be excluded from the test. This is best carried out by the main contractor rather than the tester.

Temporary sealing up can be done by the tester but most are reluctant to do this.

Features that are normally sealed/closed are devices such as:

- Trickle ventilators (closed)
- Purpose made vents intended for ventilation (sealed)
- Letter boxes (closed)

The tester will normally be self-contained but may require access to a power supply and will need space adjacent to a doorway to set up the fan.

Check weather forecast

Tests can only be carried out in suitable weather conditions. It is useful for the tester and main contractor to communicate well in the few days leading up to a test.

Acceptable test conditions are:

- Wind speed must not exceed 3 m/s (TM23) or 6 m/s (BS EN 13829) during test.
- Air temperature difference between inside and outside of building should not exceed 10ºC for air leakage test.
- Thermographic surveys can only be done when temperature difference inside to outside is at least 10ºC.

Reference to short-term localised weather forecasts available from the Meteorological Office is advised. Tests can normally be completed within one day.

Additional testing

Smoke testing may be carried out after the results of the whole building air leakage test are known. A smoke test will show locations where air is leaking from the building as a guide to appropriate remedial action.

Smoke testing can only be undertaken while the building is sealed and pressurised. For this reason it is convenient and economical to carry out the smoke test on the same day as the air leakage test. If a smoke test may be required a tester capable of undertaking this test should be employed and advised that smoke testing equipment should be available at site. It is advisable to warn the fire brigade to avoid false emergency calls from onlookers.

Thermographic testing may be used to identify warm areas of the building envelope associated with escaping warm air.

The effectiveness of thermographic imaging will depend on the temperature difference between the inside and the outside and also the rate of air leakage. Space heating can be used to achieve a temperature difference of 10oC prior to imaging. Thermographic imaging of the building while it is sealed and pressurised will give better quality images.

If a thermographic image may be required a tester capable of undertaking thermal imaging should be employed and advised that thermal imaging equipment should be available at site.

Procedures for thermal testing are described in more detail in TN45.

Removal of temporary seals

On completion of all testing any temporary sealing must be removed. This will normally be the responsibility of the Main Contractor. Any requirement for the tester

to remove temporary sealing should form part of the contract with the tester.

Remedial work

Remedial work to complete or improve air seals in the building envelope will take time. A programme for sealing and retesting should be considered when setting the programme for first testing.

References

TM23:2000, Testing buildings for air leakage, CIBSE, 2000, ISBN 1 903287 10 3

Building Regulations (England and Wales): Part L2, Conservation of fuel and power in buildings other than dwellings (2002 edition), http://www.odpm/gov.uk/

Building Regulations (England and Wales): Part L2, Conservation of fuel and power in buildings other than dwellings (2002 edition), http://www.odpm/gov.uk/

Building Regulations (Scotland): Part J, Conservation of fuel and power, http://www.scotland.gov.uk/build_regs/sect-j.pdf.

Building Regulations (Northern Ireland): Part F, Conservation of fuel and power, http://www.buildingcontrol.org/bcni/legislation/regulations.asp.

TN47 Introduction to building envelope energy transfer, CWCT, 2004.

BS EN 13829:2001. Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method.

Appendix A

Scotland and Northern Ireland

The Building Regulations for Scotland, Part J, only require that 'The infiltration of air into a building through extraneous air paths must be limited as far as is reasonably practical'.

There is no requirement for whole building air leakage testing for any buildings. However, buildings may be tested solely to satisfy the Client.

The Building Regulations for Northern Ireland, Part F, require adequate sealing of interfaces in the building envelope and 'draughtproofing' of windows and doors.

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