TIGHTLY KNIT

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Achieving high standards of air tightness requires thorough planning and close management of the construction process. BSJ reports on the lessons from five recent projects

By Robert Cohen

Improving the airtightness of the UK's buildings is an important part of the government's plans for the building sector to help meet the UK's Kyoto commitments for reduced CO_2 emissions. Furthermore, cold draughts are a notorious cause of occupant discomfort. In even recently completed UK buildings1, such issues are the bane of clients obliged to correct them by remedial action and the main driver for building services engineers' inclinations to oversize boilers and heat distribution systems. Facilities managers may also have to run these systems (and sometimes entire air conditioning systems) overnight to reduce the number of complaints.

Evidence from other countries such as Scandinavia and parts of Canada demonstrates that satisfactorily airtight buildings can quickly become the default once all the players involved in the construction process understand the principles and there is a mandatory need to meet given standards. The UK has yet to go through this culture change, but Part L2 of the April 2002 Building Regulations now require new or substantially refurbished non-domestic buildings to meet minimum airtightness standards. If over 1000 m^2 in gross floor area, they also have to demonstrate compliance, normally by an air leakage test.

This article reports on recent experience of constructing four buildings which have had to meet airtightness specifications and also on a Science Park where, since early 2001, the developer has required its design teams to pay increasing attention to airtightness in order to achieve a smooth transition into the mandatory regime and beyond. The project web site2 contains more information on each building and the airtightness issues encountered.

The project aimed to capture the essence of the knowledge of the vanguard of practical experience of delivering buildings which meet the mandatory airtightness standard and of the related pressure testing. The focus is on the contractual and procedural aspects at each stage of the procurement and construction process, not the technicalities of airtight details and materials, about which much has been written elsewhere3. Precedents have been chosen as the vehicle for knowledge transfer because of their immediacy and interest to designers and clients.

The core material for the project is five new construction projects. With the support of the design team and the client for each project, ESD has examined those aspects at each stage of the process which relate to achieving air leakage standards.

Open University Business School

The Termodeck system of closely controlled ventilation was chosen for the building's office spaces because of its low energy methods of delivering fresh air without compromising the flexibility for a variety of layouts - open plan or cellular.

The Termodeck solution requires minimum standards for the airtightness of the construction so the client needed to ensure the building met its air leakage target of 5·0 m3/h/m2 at 50 Pa. A specific airtightness specification clause was developed which became a contract document. While the cost of the airtightness testing was borne by the client as a provisional sum, the contractor, John Sisk & Sons, maintained responsibility for achieving the required standard in line with the contract specification and drawings.

Achieving an airtightness standard depends on both the design (primarily a responsibility of the design team) and its implementation, ie the construction quality (primarily a responsibility of one or often more contractors). As with many other aspects of building construction, proving liability for failure of a pressure test, rain penetration, etc can be expensive, time consuming and even require a degree of opening-up which may be unthinkable for the client.

Site inspection by designers, project managers and others is the conventional means of double checking that the design is being built correctly, thereby seeking to pre-empt any failure and to sort out emerging problems. Until it becomes second nature for UK contractors to 'build tight', additional quality assurance procedures will be needed to ensure that an airtightness requirement is achieved.

For this project, the architects, Jestico & Whiles and m&e engineers Halcrow agreed with the contractor a protocol covering the design and construction of elements affecting airtightness, to ensure the building passed the pressure test.

Because the key element of an airtight detail is often covered up during the construction sequence, it was agreed to introduce break points in the construction for the clerk of works or services engineer to verify that a detail had been implemented in accordance with the design. A comprehensive 'check sheet for airtight construction' was produced by the contractor.

Pressure testing contractors have probably more empirical experience than anyone else about successful and fallible construction techniques. The testing contractor was therefore invited to visit the site during construction at a stage when it was still not too late to seal potential leakage sources or to adjust design details.

This visit also allowed the testing contractor to specify what preparations the contractor needed to make prior to the test. Limitations on access into the building during the test were also confirmed. Accurate drawings were supplied to the contractor to allow the building's envelope area to be calculated using the correct conventions. The end result was a measured air leakage index averaging 3·2 m3/h/m2 compared with the target of 5·0 m3/h/m2.

Beddington Zero Energy Development (BedZED)

The Beddington Zero Energy Development (BedZED) in Sutton, South London, comprises 82 dwellings. The objective of matching the building's energy demand to available renewable energy sources very quickly led to the conclusion that energy use would need to be reduced significantly by having an enhanced thermal envelope and good airtightness.

The indicative standard required by the Building Regulations Approved Document L1 (2002) requires dwelling air permeability not to exceed 10 m3/h/m2 at 50 Pa (although for dwellings a test is not mandatory). BedZED required a far tighter building envelope - early analysis indicated an air permeability target of 2 ac/h at 50 Pa test pressure.

This is equivalent to approximately 0·1 ac/h in normal wind. This is common practice in Scandinavia and there is precedent in the United Kingdom.

The project engineers, Arup provided advice to the client and the team on the need for a strategy for contractual responsibilities, achieving the required details onsite and remedial work. They also advised the likely consequences if the airtightness target was not met, in terms of draughts, temperatures below normal comfort levels and possible use of supplementary electric heating with its implications for CO2 emissions. Arup also gave guidelines for achieving the required air leakage standard such as identifying common infiltration paths and the need for on-site designated responsibility, workshops and supervision.

A testing and remedial regime was also agreed, as follows:
- Test the first unit (the show house) and identify leaks.
- Put leaks right sufficiently to pass a second test.
- Conduct a workshop for all relevant trade contractors, designers and site managers to get this feedback into the construction of all subsequent units.
- Thereafter spot-test to ensure standards are being maintained.

BedZED achieved air permeabilities of between 2 m3/h/m2 and 3 m3/h/m2 at 50 Pa, very good in relation to the current Part L2 standard. However, the more severe target set by the zero-heating objectives proved impossible to achieve everywhere, though it is now seen as appropriate for low energy buildings.

The nature of the construction process today, with its preponderance of work package contractors and consequent remoteness of site supervision and operatives from the design process, inherently means that there are implementation difficulties when innovation or working practice changes are needed. Careful specification and drawing preparation is often insufficient when so many site operatives do not directly use these documents. This is particularly so with airtightness, as the actions of so many parties affect the final outcome.

Responsibility for airtightness involves many parties, including the design detailer, the constructor, and any party responsible for managing and supervising the site works.

Key lessons learned include:
- Avoid testing the prototype too late.
- Allow sufficient time in the programme so that prototype leaks can be fully investigated and the real sources put right.
- Allow sufficient time in the programme for the workshop involving all the relevant parties.
- Make constructors aware that successful airtightness testing is as essential as successful heating system testing, particularly for low energy buildings with their relatively low system capacities.

Building 11, Chiswick Park

Building 11 provided a timely opportunity to ascertain what would need to change to achieve the new air leakage criterion. The Client, Stanhope, commissioned the Building Research Establishment (BRE) to conduct a test.

The result was an air leakage index of 3·7m3/h/m2 at 50 Pa. How was this achieved when there was no specific intent? The main reasons are thought to include the fact that the building form is relatively simple, with no complicated detailing or interfaces in the external envelope. The same cladding system was used throughout and no air leakage was detected through the cladding.

Air leakage was detected, however, between the curtain walling forming the walls of the atrium and the upstand for the atrium roof. This highlights the importance of the det ailing and specification between different elements and packages, together with careful workmanship and inspection.

Also, Building 11 is the fifth building of this type on the site and, for the most part the same erection teams have been involved throughout. The best and most robust details produced by the architect do not necessarily lead to an airtight building. Airtightness is ultimately a function of build quality; and by the time contractors are on to the fifth building of an identical type, they are likely to be a long way up the learning curve.

The third key element in achieving airtightness is that the underfloor ventilation system is reliant on pressurised floor voids. The specification provided a floor void performance criterion and stated that a pressure test for each floor void must be completed and passed. These requirements will inevitably lead to greater attention on site to the sealing of services penetrations.

Medicine, Health Policy & Practice building, University of East Anglia

Here the client was keen to reduce both the capital and running costs of the plant. The whole building (including the core spaces which did not have Termodeck construction), was required to meet an air leakage index of 5 m3/h/m2 at 50 Pa.

The selected contractor, French Kier, was able to demonstrate substantial relevant experience, including their work on Tesco supermarkets which are renowned for achieving low levels of air leakage. French Kier took responsibility for the air test result because they considered the construction method (in situ concrete frame, etc) to be sufficiently well proven by earlier Termodeck projects. Their previous experience told them that the requirement could be met reasonably easily. The procurement method allowed French Kier to check construction details proposed in the first stage of the contract.

The site agent and architect RMJM were responsible for supervision of all work. He made all operatives and foremen aware of the airtightness requirements and the consequent need for following construction details carefully. All potential sub-contractors were informed of the airtightness specification and had to demonstrate their products met any relevant airtightness requirements. The architect took responsibility for design and inspection of interfaces between sub-contract packages.

The test produced an air leakage index of 3·7 m3/h/m2 of envelope area at 50 Pa (air permeability 2·8 m3/h/m2), proving that the measures were successful.

Granta Park, Cambridge

Granta Park Ltd (GPL) is a joint venture between developers MEPC and TWI, the world centre for welding and joining technology, whose site it adjoins. It is developing a site of laboratories and offices for high technology companies, using the following techniques to minimise construction times for these fast-moving companies:

- framed construction;
- lightweight cladding and roofing;
- construction management to allow site works to start before the design has been finalised.

As is normal for speculative and pre-let buildings, the developer hands over the building to the customer in a shell-and-core state. The fitout is then completed - which may include all the building services in the highly-serviced laboratories. Fitouts are usually designed and managed by the shell-and-core team, but not always.

In early 2000, GPL identified the importance of airtightness in the following words: 'Good practice requires:

- Knowing where airtightness is needed. Draw a red line on plans and sections to find the most appropriate location and identify the details needing attention.
- Detailing and specification to make airtightness achievable at interfaces between components and work packages.
- Careful site instructions and quality control.
- Possibly pressure testing upon completion.'

From early 2001 GPL, also anticipating the likely requirements of the new Building Regulations Approved Document Part L2, advised its design teams to pay much more attention to airtightness.

An evolutionary approach was applied to five buildings, starting in 2000 with the design and specification of a two-storey speculative office (Building 1), which included:

- A concrete framed structure with insitu concrete floors.
- A single work package for the cladding, including the window system.
- Selection of sub-systems which already met appropriate airtightness specifications.
- Care in detailing the connections at the heads, cills and edges of the cladding.

The energy consultant recommended an air pressure test, but when cladding costs came in high the budget ceased to be available. Airtightness became more of a priority for GPL when

Building 2 (a laboratory block, an office block and a link building) was in its sketch design stage.

The design was reviewed and improved details developed, particularly at the foundations, the eaves, and junctions between the three types of cladding used. All the principles developed for Building 1 were adopted, including putting all the cladding and windows into a single work package.

The experience on Buildings 1 and 2 convinced the designers and the construction managers that airtightness was a strategic, not a detailed issue, to be clearly addressed at outline proposals stage. It required:

- Care in simplifying the geometry of the connections, ideally to straight lines, flat planes, or planes with a single, straight fold.
- Engineered junctions which either came together automatically in an air seal (as with some cladding systems), or allowed the entire airtightness connection to be a second fix.
- Where not 100% robust for the lifetime of the building, the airtightness connections needed to be capable of easy inspection, repair or replacement.
- The airtightness strategy, detailing and quality control needed diligent progression through the processes of design, specification, construction and sign-off.

Building 3 - a large laboratory building - was to a similar programme to Building 2, but a turnkey operation, with less direct involvement by the developer and their onsite project managers. This team took the idea of single point responsibility still further, with the entire envelope (cladding, windows and roof) forming a single work package to an overall airtightness specification.

The envelope contractors followed all the rules established above, selecting only components and systems which met stringent airtightness standards. They also developed robust details for sealing the cladding to the frame at foundation and plant room floor level. Buildings 2 and 3 were planned to have full air pressure tests, but in the event this would have extended the construction programme, owing to phased handovers from shell-and-core to occupant fit-out and the impossibility at any stage of getting a sealed envelope to test. (Note that extra time may need to be programmed for tests now they are required under Part L2). Instead, pressure tests of sample areas were undertaken.

Building 4 was an extension, connected by a link to a laboratory building of similar appearance. It started on site in early 2002 and took account of lessons from Buildings 1 to 3. Air sealing was designed on a similar basis to Building 2, but more rationalised. A whole building pressure test was undertaken for Building 4 at shell-and-core stage, with all duct ends closed off in the occupied spaces.

This gave an air infiltration index of 5·6 m3/h/m2 at 50 Pa. The equivalent air permeability was 3·9 m3/h/m2, commendably well below the Part L2 requirement of 10 m3/h/m2; and impressive given the number of services penetrations for fume cupboards etc and the use of external ducting.

The design of Building 5 (another laboratory/office building) has built on the experience of all its predecessors (and particularly Building 2, by the same architects) to further rationalise the strategy and construction details. In particular, strategic design has reduced the interfaces where possible to engineered linear or planar connections. A pressure test will be statutory.

Conclusions

All these projects have demonstrated that airtightness needs to be managed, from the initial strategy, through the setting up of work packages, the management of the technical and contractual interfaces, briefing of all involved on site, and maintaining rigorous levels of inspection and quality control with tests where necessary.This article was prepared by Dr Robert Cohen of Energy for Sustainable Development. Contributions from Dr Bill Bordass, William Bordass Associates; Jude Harris, Jestico & Whiles; Andy Mace, Arup. Thanks to clients, designers and contractors involved with each building. This project was part-funded by the DTi under their Partners in Innovation programme.

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