The Design and Construction Process Implications of the Airtightness Requirements of the Building Regulations Part L2.

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SUMMARY

The drive to reduce the energy consumption of new buildings has been the prime motivation behind the revised Part L of the UK Building Regulations and the new Approved Document L2. Although some aspects of the requirements build on previous criteria such as increased insulation standards, new requirements including an air tightness standard for buildings present new challenges to the UK construction industry.

Through presenting a case study, this paper looks at the process of achieving air tightness and learning how this new issue affects the construction process, team working, contractual relationships and the implications for the building services.

Riverside House in Newcastle upon Tyne was the first building in the city to be airtightness tested to demonstrate compliance with the requirements of the new AD L2. Although the requirement for a test was introduced late in the design process, the building passed the test with an air permeability of $8.66m^3/h/m^2$ at a differential pressure of 50Pa.

The design and construction team have learnt a number of important lessons from the process, namely:

1. Air tightness must be considered early in the design process and the strategy for achieving it developed at the same time if expensive remedial works is to be avoided.
2. There is never a good time to complete the test, but the earlier the better following weather tightness is achieved avoids costly removal of first and second fix items if remedial sealing works are required.
3. An air tightness champion on site with the role of implementing the airtightness strategy is recommended.
4. CIBSE design advice on infiltration allowances should be brought in line with AD L2.
5. Published advice on robust details should include building services penetrations details.

1. INTRODUCTION

The drive to reduce the energy consumption of new buildings has been the prime motivation behind the revised Part L of the UK Building Regulations. Although some aspects of the requirements build on previous criteria such as increased insulation standards, new requirements including an air tightness standard for buildings present new challenges to the UK construction industry.

The building presented in this case study was the first to be tested under the new requirements in Newcastle upon Tyne and it provided experience of this new requirement for the design team, construction team and local Building Control.

In particular this paper looks at the process and learning how this new issue would affect the construction process, team working, contractual relationships and the implications for the building services.

2. BACKGROUND

The implications of leaky buildings with high levels of infiltration and exfiltration are well known and documented. Uncontrolled air leakage can cause draughts, decrease the effectiveness of ventilation systems, affect controls and optimum start routines, increase the risk of condensation and moisture accumulation, and ultimately increase energy consumption throughout the year. As insulation standards improve, heat loss and gain from air infiltration and exfiltration and the associated energy used to maintain acceptable internal conditions increases.

The significance of energy use and carbon emissions attributed to infiltration for all building types must not be underestimated. For the UK commercial section the rate of growth of energy consumption since the 1970's has been approximately three times greater than in the domestic section[1]. For office buildings in particular the increase in energy consumption is linked to the demand for air conditioning. The Building Research Establishment[2] notes that the exfiltration of warm air can account for as much as 30% of the heat loss through a building's envelope. In short, growing demand for air conditioning compounded with the sensitivity of building air leakage on heating and cooling requirements can lead to significant energy use and associated carbon dioxide emissions.

2.1 Air Leakage and Building Regulations

The Building Regulation's Requirement L2 requires buildings other than dwellings to make reasonable provision for conservation of fuel and power through a number of measures.

Approved Document L2 is intended to provide guidance on ways of achieving compliance with the Building Regulations Requirement L2. It details three methods for demonstrating compliance, an Elemental Method, a Whole Building Method and a Carbon Emissions Calculation method. Each of the methods includes particular requirements for airtightness and the demonstration of the achievement of the airtightness criteria.

One method of demonstrating compliance is for an air leakage test to be carried out in accordance with CIBSE TM 23[2] to show that the air permeability of the building does not exceed $10m^3/h/m^3$ at an applied pressure difference of 50Pa.

2.2 Implication for Achieving Air Tightness

The implications of demonstrating compliance with the requirements of Part L2 of the Building Regulations cut across all members of the design and construction team and all phases of the construction process.

The requirement must be understood, architectural details must be robust, building services plant must be sized appropriately, envelope penetration details must be suitable, interfaces between works packages must be worked through including the contractural implications, and the on-site workmanship must be adequate. Advice on many of these issues is provided in the following documents

TN 8/95 Air Leakage of Office Buildings BSRIA
TN 19/99 Envelope Integrity Demonstration Study BSRIA
TN 19/2001 Air Tightness Testing BSRIA

It was against this background of new regulations, potential contractural conflict and an uncertainty of what would need to be done differently to 'business as usual' to achieve compliance that Riverside House started on site.

3. RIVERSIDE HOUSE

Riverside House is a speculative office development on the Newburn Riverside Industry Park in Newcastle upon Tyne. The park is on the site of a former power station and graphite works and is a brownfield reclamation project by the regional development agency One North East.

Riverside House is situated on an area of the site owned and being developed by UK Land Estates Limited (UKLE). It has a gross floor area of approximately 5900m² over three floors and has been recommended for a BREEAM rating of Excellent. At time of writing, the client is awaiting the issue of the final confirmatory certificate from the BRE.

Riverside House is UKLE's second office building on the Park and develops further the concept of the smaller and more simply serviced first building.

Following advice from his letting agents the client opted for comfort cooling and mechanical ventilation for fresh air. The environmental strategy included four pipe fan coils for heating and comfort cooling and mechanical fresh air ventilation with heat recovery. Boiler and water services plant are housed in a roof level plantroom there are two external air-handling units and an air-cooled chiller. Rainwater is collected from the roof, stored in an underground tank and then treated with ultra-violet light before being used in all WC's and for irrigation of external landscape areas.

The main client and design team members were:

Client:	UK Land Estates Limited – A Bartle
Architect:	FaulknerBrowns Architects – P Holgate & B Bowley
Structural Engineer:	Arup – G Mungall
Building Services Engineer:	Arup – A S Mace
Main Contractor:	Tolent Construction Limited – S Waite

4. AIRTIGHTNESS FOR RIVERSIDE HOUSE

The project had started on site before the position on airtightness and the requirement for an air leakage test to CIBSE TM23 were clarified and agreed with Newcastle City Council's Building Control Department.

The building had achieved planning permission before the recent amendments to Part L of the Building Regulations and the design had progressed on this basis. As the project entered the construction stage the design team, main contractor and Building Control were interpreting the new regulations and the implications for Riverside House.

Early indications suggested air leakage testing could be expensive and difficult to program. The preferred method of demonstrating compliance was to show robust details and Tolent had some experience of this approach being acceptable to other building inspectorates.

After a short period of negotiation with Newcastle City Council, Building Control clarified the Building Regulation requirement directly with the Office of the Deputy Prime Minister and confirmed that an air leakage test would be required to demonstrate compliance with Part L2.

With the requirement set, the Design Team held a workshop with Tolent on site to agree a strategy for detailing, construction and testing. Tolent took the sensible step of undertaking an air leakage pre-test when the building was substantially airtight, although it was known that there was still an amount of sealing to complete. Air Tightness Services from Leeds completed this pre-test in October 2002 and it demonstrated an air permeability of 14.6m³/h/m² at 50Pa. Testing with smoke pencils clearly indicated the leakage paths to Tolent and this information was fed through to the site team for remedial action where required.

Figure 1. Air Leakage Testing at Riverside House, January 2003.

The final test witnessed by Building Control was carried out in January 2003 (see Figure 1) and the building passed the Approval Document L2 criterion with an air permeability of 8.66m³/h/m² at 50 Pa.

4.1 Design and Construction Team Commentary

4.1.1 Building Services Engineer: Arup - Andy Mace

Andy recalled that the requirement for an air leakage test hit the team as a new challenge fairly late in the day, as the project had achieved planning permission before the new Building Regulations L2 came into effect.

With some experience of low energy projects that inherently required very good air leakage standards such as the BedZED project in London, Andy knew that the team had to act fast if expensive remedial work was to be avoided.

He convened a workshop on site with the design team and Tolent where everyone brought whatever experience they had to the table in a proactive manner. One of the main issues was for the team to understand what it needed to do differently to ‘business as usual’ to meet the criterion. With no individual experience of buildings that had been tested previously it was difficult for Tolent to accurately assess the cost and program risks involved.

Andy tabled the graph from the PROBE studies in the CIBSE Journal (see Figure 2), which is based on BRE and BSRIA data and demonstrates that an 'average' UK building industry approach would be risky.

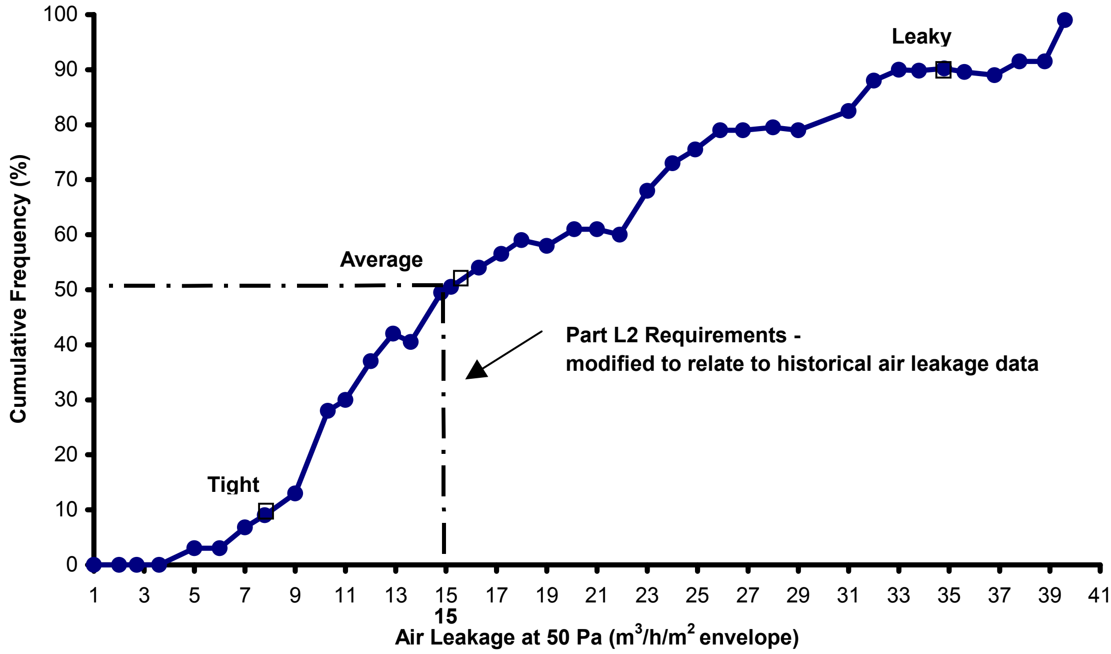

Figure 2. Air Leakage Data from the BRE/BSRIA Database (CIBSE Journal)

The strategy for achieving and adequately airtight envelope was discussed, together with contractural implications and issues of workmanship.

At this point the Building Services Engineer stepped back, as airtightness of the envelope is the responsibility of the Architect. Nevertheless, as Arup's role in terms of the Building Services was to produce a performance specification for detailed design by Sub-Contractors, there were still a number of issues that could potentially affect the air leakage of the building, including:

- Sealing of building services penetrations through the building envelope, including ground floor;
- Detailing of builderswork requirements that would traditionally be weathertight but not necessarily airtight; and
- The sensitivity of air potentially leaking to outside via services risers. Would this be a significant proportion of the overall leakage? If so, then sealing of penetrations will become critical.

4.1.2 Architect: FaulknerBrowns - Peter Holgate

Peter recalls that as it become clear that Riverside House would be subject to the requirements of the new Part L2 of the Building Regulations, his initial concern was with meeting the solar overheating criteria. Once this had been resolved the team moved to the issue of air leakage.

A strategy for the compliance and testing was adopted in agreement with Newcastle City Council Building Control. In essence, detailing was pursued to achieve a continuous airtight barrier, akin to the principle of continuity of insulation. This line of continuity was sited at the inner face of the external wall and roof construction. The problems of achieving airtightness in the masonry cavity wall precipitated this strategy, whilst detailing of weep holes, builder's work openings, louvres, vents, porosity of masonry, and the cavity itself informed the choice.

Consequently, the dry lining of the inner leaf was extended up to the soffit and down to the structural floor, with the junctions being suitably sealed for airtightness. Where structural movement was expected, such as where the inner leaf adjoined structural steelwork, butyl tapes and sealants were adopted. Porous block work was sealed with suitable paints.

Continuous site supervision checked that membranes were suitably lapped and that all services penetrations were sealed. Sub-contractors works and details were coordinated to ensure that interfaces were airtight as well as watertight, and care was taken to ensure that seals were not totally dependant on sealant and mastics that could eventually fail.

In hindsight it is regretted that the Mechanical and Electrical Sub-contractors were not more fully involved in the early discussions with regards to the air tightness details. Nevertheless, the design team and Tolent worked together to ensure key details and penetrations would not be susceptible to air leakage. The site supervision and monitoring of Sub-contractors works was considered essential to delivering the air tightness standard.

In general, the issue of air tightness had been helped by a very pro-active team, particularly Arup and Tolent and this, combined with the Design and Build procurement route and both Arup and FaulknerBrowns being novated to Tolent, led to a successful conclusion.

4.1.3 Main Contractor: Tolent Construction Limited- S Waite

An open forum was held early in the project to define the requirements and responsibilities for the air tightness demands. It was thought at the meeting that an airtightness 'champion' was needed and S Waite took up this role.

The champion needed to monitor and react to site issues and Scott considered the champion role to have been essential in satisfying the required air tightness criterion.

Robust details were considered as an option particularly due to the early £30,000 estimate for the test. A pre-test was arranged by Tolent for two reasons:

1. They had no previous experience of air testing; and

2. To confirm that there were no fundamental problems with the build quality.

Scott noted that he would not use a pre-test on future projects, as he is now confident in Tolent's ability to meet the current standards.

The additional costs to the project (excluding the actual test) were £12,000, less than 2% of the contract value. The design team were very pro-active and the type of contract (Design and Build) with Arup and FaulknerBrown novated to Tolent, greatly supported the sharing of the issue. He thought that a more traditional contract would make the responsibility for air tightness detailing 'muddy' –particularly in the worst case scenario of a of the building failing the test, when issues of buildabilty would arise. Tolent did detail the sealing of services penetrations but still consider this to be the responsibility of the Architect or Mechanical and Electrical Engineering Consultant.

4.1.4 Detailed Mechanical Services Designers: J Humphries & Partners – V Rumis

The air tightness requirement was considered to be the responsibility of the Builder and the Architect. The Builder and Architect specified the building services penetration details.

The only area where the requirement had a potentially significant role for the design was in the air change rate used for heating and cooling load calculations. Arup specified this in their Performance Specification at 0.5 air changes per hour. This figure was not amended in light of the air tightness requirement.

4.1.5 Newcastle City Council Building Control: P Nicholl

A preliminary consultation was held with FaulknerBrowns about meeting the requirements of the new Part L2 of the Building Regulations. This was the first project in which they had to apply the new requirements. There was some uncertainty about whether 'robust' drawn details for the project would be sufficient to gain approval and if an air tightness test was required.

At this stage the design team informed Building Control that £30,000 might be the order of cost for the test and that Tolent would meet this cost.

Building Control contacted the Office of the Deputy Prime Minister and it was confirmed that air tightness testing was required. Robust details are published for housing, but for commercial office buildings they were not available. A site inspector visited the site on the day of the final test and the test certificate was submitted to Building Control. They were aware of the pre-test but this was a matter for the construction team and did not involve Building Control, who see their role as confirming the test is required and checking that a suitable organisation, with a track record, carries out the test.

It is noted that at that stage, no list of approved testing organisations was in existence. Since that time BSRIA have set up an association (ATTMA) of testing organisations at the request of the ODPM. The ODPM has now written to building control bodies to inform them that ATTMA members as well as the two existing accredited organisations should be used to carry out tests. ATTMA currently has 4 members.

5. DISCUSSION

5.1 Airtightness Requirement

The Approved Document L2 will lead to greater energy efficiency in buildings now that a criterion has been set for air leakage from buildings. In future revisions to the Building Regulations it is expected that the criterion will become more onerous. It is interesting to note that it is the regulatory process that is most effective. Other drivers for energy efficiency such as professional codes of conduct[3], energy taxes[4] and building branding[5] have not had such widespread impact. The effectiveness of the regulatory approach has been demonstrated by researchers in Denmark[6] who note:

"The analyses indicate that building regulations have been very important policy measures in the pursuit of improving energy efficiency in new buildings in Denmark. Also estimation results indicate that policy measures affecting the price of oil or district heating, i.e. taxes have very limited effects on the consumption of energy in apartment blocks in the short run "

The Approved Document L2 criterion was been met without any substantial problems for the design and construction teams on Riverside House. A proactive approach and the sharing of experience amongst the team most definitely benefited the project and the 2% addition to construction cost did not affect the project's viability. The fact that it was a Design and Build contract and the design and construction teams quickly broke down barriers and worked well together can only have helped to remove a contractual response to the aightightness issue.

There was an amount of uncertainty in the early stages of construction and the 'robust details route' for demonstrating compliance would have been preferred given the lack of general team experience on the implications of an air test. It could be argued, however, that robust details would not have led necessarily to a suitably airtight building and the failed pre-test reinforces this view.

The final test produced a building air permeability of $8.66m^3/h/m^2$ at 50Pa. Although this passes the Approved Document L2 (AD L2) criterion of $10m^3/h/m^2$ at 50Pa, there is still some way to go for future projects to meet the CIBSE air permeability recommendations[2] for offices with balanced mechanical ventilation systems of $3.5m^3/h/m^2$ and $2.0m^3/h/m^2$ at 50Pa for Good Practice and Best Practice respectively.

5.2 Building Services Design

There are a number of implications for the design of building services systems that come from improved building airtightness standards.

In terms of infiltration allowances used in the design of systems, current CIBSE guidance[7] provides and empirically derived value of 1.0 air change per hour (ACH) for offices. The Arup Performance Specification for Riverside House stated a design value of 0.5 ACH. An air leakage criterion of $10m^3/h/m^2$ at 50Pa equates to an average air infiltration rate of about 0.2 ACH for average wind speeds for typical office buildings[2]. This suggests that new buildings will probably have air change rates below 0.5. Although calculation of the air change rate from the air permeability figure is not possible, relationships in the CIBSE[2] guide indicate an air change rate in the order of ¼ for riverside house.

In short, these figures demonstrate that:

1. There is a mismatch between current CIBSE design guidance and the requirements of the AD L2; and
2. The building services plant at Riverside is potentially oversized.

CIBSE guide TM 29[8] provides guidance on the design strategies for well-insulated airtight structures and it suggests that for the UK climate this may mean that heating is not required or only needed during the pre-heat period.

The guide goes on to illustrate design solutions using changeover heating/cooling systems. This system would use the same emitter for heating and cooling – pre-heating in the morning and then changing over to a cooling function during occupation. This type of solution would be novel and certainly have not been used in Riverside House. The cost savings of changeover systems make them attractive, but experience in use is limited.

Monitoring of Riverside house is being considered and it would be interesting to see the heating load profiles and whether a change over system would be a feasible solution. The additional building construction costs on future projects could be recouped to some extent if confidence in the effects of the realised smaller air change rate was used to re-assess design sizing and the strategy of the mechanical systems.

Other implications are associated with the detailing of builders work. There is existing guidance on air leakage standards for builders work shafts[9] but penetration details for pipes and ducts that pass through the air tight barrier will need additional thought as the air leakage through what are historically only waterproof details becomes more significant.

6. CONCLUSIONS

Riverside House in Newcastle upon Tyne was the first building in the city to be airtightness tested to demonstrate compliance with the requirements of the new AD L2. Although the requirement for a test was introduced late in the design process, the building passed the test with an air permeability of $8.66m^3/h/m^2$ at a differential pressure of 50Pa.

The design and construction team have learnt a number of important lessons from the process, namely:

- Air tightness must be considered early in the design process and the strategy for achieving it developed at the same time if expensive remedial works is to be avoided.
- There is never a good time to complete the test, but the earlier the better following weather tightness is achieved avoids costly removal of first and second fix items if remedial sealing works are required.
- An air tightness champion on site with the role of implementing the airtightness strategy is recommended.
- CIBSE design advice on infiltration allowances should be brought in line with AD L2.
- Published advice on robust details should include building services penetrations details.

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