

The building performs better than UK benchmarks for both winter and summer comfort



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Orchard Learning Resources Centre

Everyone moans about the impossibly tight budgets that are expected to fund educational buildings. There is strong justification for that. Clients always expect more than the fees are capable of providing, and this leads to invidious trade-offs to keep the project within budget. On the other hand, design professionals seem very adept at delivering simple, robust and consequently elegant designs on a shoestring, so perhaps they do themselves no favours.

The Orchard Learning Resources Centre at Selly Oak College in Birmingham was typical of the breed. Back in 1995, £3.5 million was set aside to buy a library, administrative offices and secure rooms for book storage. And that covered a gross floor area of 4500 m².

It is worth recording that the design process took place in the wake of the PROBE study of the Learning Resources Centre at Anglia Polytechnic University (APU), also designed by Arup¹. The services designer of Orchard LRC, Glen Irwin, wanted to develop the advanced natural ventilation approach pioneered at APU while minimising the revenge effects associated with design & build - like cost cutting measures - and the mercurial nature of lighting and ventilation controls.

Full details of the building's design and construction was reported in the July issue of *Building Services Journal*, and readers should

refer to the original article for the building's full specification².

In brief, the building was originally procured by Selly Oak Colleges but is now managed by the University of Birmingham. The architects were ABK, the consulting was Ove Arup & Partners and the design and building contractor Tilbury Douglas.

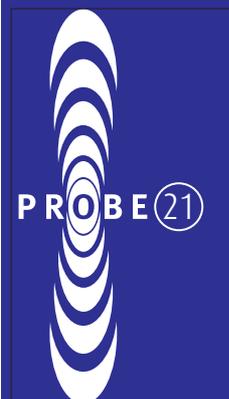
Construction was carried out during 1996 on a quiet parkland college campus site, and the building occupied in the summer of 1997. The gross floor area is 4500 m², of which some 3900 m² is for traditional library services and 600 m² for non-traditional space such as information technology.

Construction was based on three reinforced concrete frame blocks (east, central and west) linked by two wedge-shaped spaces which cause the facade to curve gently on an east-west axis. Fabric U-values were slightly better than prevailing *Building Regulations*.

The main entrance is via a set of motorised doors set into the north elevation. This leads to a main lobby with a glazed roof. The main library spaces are in the central block on the ground floor and all three blocks of the first and mezzanine floors. The east and west blocks of the ground floor contain staff areas, media services, the stack rooms, the secure Mingana manuscript room, information technology rooms

The Orchard Learning Resources Centre at the University of Birmingham attempted to develop the genre for low energy, naturally ventilated academic buildings. How did the design and construction team get on?

BY THE PROBE TEAM



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and plant rooms.

The ground and first floors provide horizontal and vertical circulation, and accommodate two seminar rooms between them. A research reading room is on the ground floor.

Note that the building's use has been well below the design allowances, but this will increase considerably when it starts to service other courses at the University of Birmingham. The library stock will probably increase by 50%, from 155 000 books and pamphlets to 230 000.

Basics of the services design

The building is primarily naturally ventilated via automatic toplights and some manually operable centre-pivoted windows. Most of the latter are kept locked for security reasons.

The clerestory windows in the roof are motorised, while the toplights in the offices are manually operable using a window pole. The motorised windows are covered by a maintenance contract which includes annual servicing.

Background trickle ventilation is via plastics hit and miss type vents located in deep window sills. Those serving the north facing bay windows are set into the floor and designed to be foot operated.

Some spaces like the IT training room and the stack rooms are either mechanically ventilated or air conditioned. The core spaces (photocopying, stores, staff kitchenette, toilets etc) have clock-operated mechanical extract ventilation with make up transfer grilles in doors.

Space heating is provided by perimeter radiators with thermostatic radiator valves, supplied from three 80 kW gas-fired boilers with a flue dilution fan. These give a commendably low capacity of 55 W/m² (tfa). There are two heating zones split between the north and south sides of the building.

There are two manually switched air curtains above the main entrance doors, which are generally switched on in cold weather.

Hot water services for the toilet areas and staff kitchenette are provided by local 3 kW electric water heaters, controlled by thermostats, but not time controlled.

Lighting in library areas is based on twin 58 W high frequency fluorescents in wire suspended luminaries, except on the ground floor where luminaries with four 18 W fluorescent lamps are contained in the concrete coffered ceiling.

The lighting is controlled in two simple ways. In the public areas the lighting is controlled by master switches in a small security room off the entrance lobby. The security porter switches all the lights on at the start of the day, irrespective of daylight levels. Lights are then switched off at the end of the day. This regime is followed despite an elaborate switching arrangement which allows the staff to control the public lighting zone by zone. Lighting in the office areas is by conventional wall switches.

The building has 103 desktop pcs, 60 of these located in three clusters of 20 on the ground floor. A further 10 pcs are located in the IT training room.

Most pcs do not have use their power-save facilities enabled as this has caused confusion in the past as to whether the machines are on or off. Many pcs are left running as the boot-up procedure is regarded as taking too long.

The pcs in the IT training room are, curiously, left on in "can be switched off" mode. This mode consumes almost as much energy as a full-on pc.

Operational experience: ventilation

All the various means of achieving natural ventilation – the motorised clerestory windows, toplights, and the trickle ventilators – have suffered some problems.

The pole-operated toplights have a rather awkward mechanism by which the pole operates a rod which engages with locks at each side of the window. Those tried by the PROBE team did not work smoothly. It is difficult to ensure the mechanisms on both sides work simultaneously, and if they don't, the window won't open. Climbing on the window cill is the only practical way to get them open.

The motorised clerestory and topleight windows are controlled by a dedicated Trend control panel, which also controls the heating to a set point of 21°C. There is a simple control

regime for day and nighttime strategies, including a night cooling regime for days when internal temperature rises above 23°C. The windows can be opened to two positions, 15° and 45°, as the internal temperature rises.

There have been instances when the heating system has come on after a period of night cooling. This has caused the building to overheat, and has invoked venting by the afternoon. The problem has been addressed by the addition of a summer/winter switch which disables 'venting' in winter and 'heating' in summer.

Despite early concerns, the window actuators have been generally trouble-free. A couple have been replaced and on the day of the PROBE visit a set of four toplights were stuck open. However, the operating strategy for the motorised windows did not appear to be well understood or even known by the staff. Some thought ventilation only occurred at night, others that the whole system was automatic. The PROBE team could not find instructions in the operating manuals and staff were unaware of any user guides.

The purpose of the manual override (provided by a main switch panel in a security room adjacent to reception) was somewhat defeated by the occupants not being told that they can request more or fewer windows open, and the staff not being given the task of responding to such requests.

When opened, the centre-pivoted windows tend to drop shut immediately due to a lack of friction in the rotary hinge and the absence of any stay mechanism. The problem is (currently) largely academic, as the windows are mostly kept locked for security reasons.

Problems with the trickle ventilators began even before occupation. The metal foot-operated vents were not only installed in the floor but also in the waist-high window cills. These were replaced by plastics cover plates to prevent the serrated metal wheels abrading fingers.

In any case, anecdotal evidence suggests most occupants are unaware of the purpose of the trickle vents and are unlikely to close them in winter if they cause draughts, or to open them in summer to increase the air change rate.

Operational experience: heating and cooling

Management of the heating controls has not been ideal. Currently the responsibilities are split between the external boiler maintenance contractor, who can adjust set points and time settings via a modem link, and site staff who, until the PROBE visit, were unaware that they could make their own adjustments.

Unfortunately, the modem service is rarely used as it is a chargeable item, and the staff have not received training in the use of the controls. Control is largely confined to switching between automatic and manual to cope with bank holidays for example, or to adjust setpoints to respond to complaints of cold.

Some students have complained about being too cold, although this is not corroborated by the occupant survey. Given the building's leakiness, it is not surprising that there are local cold spots (see "The BRE pressure test").

The foyer is always cold in winter, probably because both sets of double doors can be open at the same time. This problem may well worsen as the use of the building increases.

The seminar room on the first floor has a notice advising users to request electric heaters if the room is too cold. It is ironic that staff are keen to respond to this shortcoming in the environmental conditions but have not implemented similar arrangements for the lighting or motorised window overrides.

Some problems have also been experienced with the building's dedicated mechanical and air conditioning systems.

The close control unit for the large stack room is understood to have suffered continual false alarms. These have been dealt with by external maintenance contractors.

The close control system for the Mingana manuscript room also needed resetting to control relative humidity and the staff have to ensure that the air intake and extract paths are kept clear.

Operational experience: lighting

Library staff do not seem to have been given responsibility for adjusting the amount of electric lighting. As a consequence all public area lighting has defaulted to on for all occupied hours.

Spot measurement of light levels (electric plus daylight) during a bright day showed light levels at the perimeter of between 1200 and 3400 lux. Even 10 m from the facade the penetration fell to only 250 lux. This indicates the potential for daylight switching of the electric lighting, with staff having access to the master light switches, for the perimeter fittings at least.

Light switching could also be better matched to occupancy if library staff could switch most lights off when they left, rather than waiting for the lock-down procedure by security staff.

It is also clear that during daytime there is no need for the strip lighting above the top clerestorey windows to be on. However, a notice has been stuck to the wall next to the switch saying

CO₂ emissions and electricity consumption data

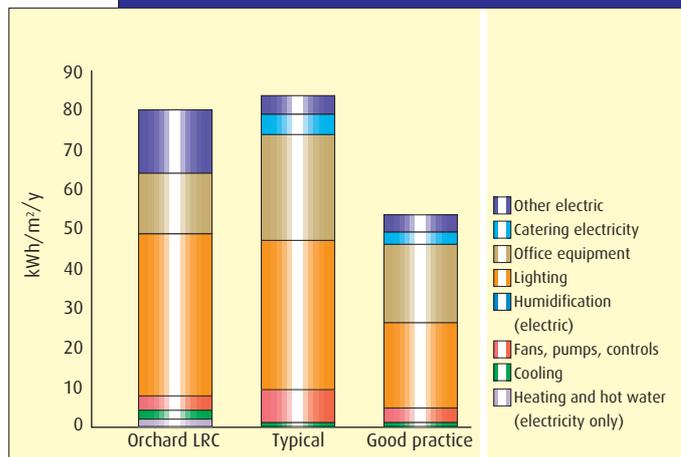


FIGURE 1: End-use electricity breakdown at the Orchard Learning Resources Centre.

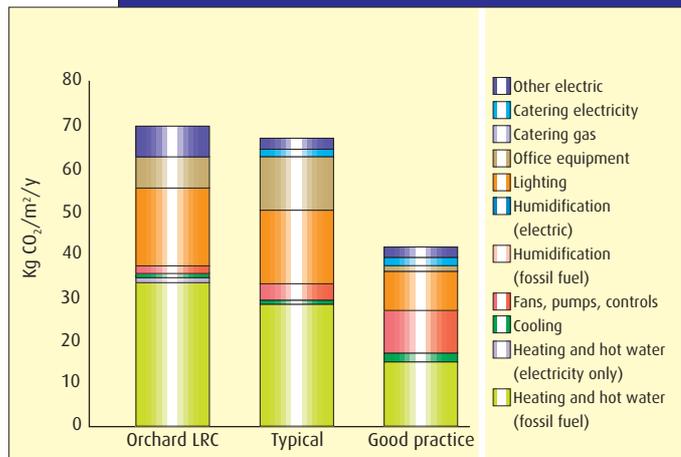


FIGURE 2: Carbon emissions at the Orchard Learning Resources Centre by end use. The conversion factors are 0.46 kg CO₂/kWh for electricity and 0.19 kg CO₂/kWh for natural gas (Econ 19, January 2000).

Overall performance

Electricity

In the year from April 1999 to March 2000, actual total electricity consumption was 356 MWh or 80 kWh/m².

Gas

In the year from April 1999 to March 2000, total gas consumption was 767 MWh or 180 kWh/m².

Carbon emissions

The building emits 74 kg CO₂/m². This is 12% above the level considered typical for a Type 2 office building – the nearest benchmark.

"Please can you remember to turn all the lights on in the morning, even on the mezzanine". This suggests that at some stage an attempt was made to avoid switching the mezzanine lights on every day.

It is worth noting that that lighting power densities average about 12 W/m², some 30% above the design figure of 9 W/m² given in the original article². It is curious that a design build contract has ended up with more lighting than specified. It is understandable, but regrettable from an energy efficiency standpoint, that the client appears to have accepted extra lighting as a potential advantage rather than a liability.

Operation and maintenance

The building is in the process of being incorporated into the University of Birmingham's planned preventative maintenance system, but currently maintenance is on a breakdown-only basis. There is no explicit energy management.

The PROBE team did not come across any "detailed user guide", mentioned in the original

article, to be handed out to students and permanent staff to explain the building's operation and the correct use of windows and trickle vents. The guide was reportedly to be given out to users to prompt them to ask the help desk to consult their own user guide before asking the caretaker to adjust the relevant controls.

Such a scheme, or anything like it, does not seem to have materialised, possibly because library staff are unwilling to take on such responsibilities.

Energy and water consumption

The Orchard Learning Resources Centre is a predominantly naturally ventilated, open plan building. On that basis it is relevant to consider the *Econ 19* Type 2 energy consumption figures for benchmarking, even though the building is a University library rather than an office. Compared with an office, the occupant and office equipment densities are far lower, but the hours of use are arguably longer.

Gas is only used for space heating. An analy-

sis of gas bills shows that in the year from April 1999 to March 2000 total gas consumption was 767 MWh or 180 kWh/m². Normalised for standard weather conditions of 2462 degree days, the gas consumption for space heating increases to 205 kWh/m² (tfa) This is 36% above the Type 2 'typical' value of 151 kWh/m² and over two and a half times the good practice benchmark of 79 kWh/m².

An analysis of electricity bills shows that in the year from April 1999 to March 2000, actual total electricity consumption was 356 MWh or 80 kWh/m² (tfa). Total unadjusted electricity consumption is about 50% above the Type 2 good practice benchmark of 54 kWh/m² and 6% below the typical figure of 85 kWh/m².

The Office Assessment Method analysis considers performance against benchmarks. It excludes the floor areas and energy consumptions of the Mingana manuscript room and the book stack rooms to recognise that the type 2 benchmark building does not allow for such loads. The result of this analysis puts the adjusted electricity consumption at 69 kWh/m² tfa, which is about 28% above Type 2 good practice and 18% below typical (figure 1).

It seems appropriate to take into account that the energy consumption by office equipment at 11 kWh/m² is substantially below the type 2 office good practice and typical figures of 20 and 27 kWh/m². For benchmarking the Orchard Learning Resource Centre, those for office equipment load should be adjusted downwards to the building's actual figure of 11 kWh/m². This would make the adjusted electricity use (excluding the Mingana room) exactly the same as the adjusted type 2 typical value of 69 kWh/m²/y.

The PROBE team noted that the building has been paying for a supply capacity of 250 kVA despite an all time maximum demand of 94 kVA. This is costing the college an extra £2300/y

Total annual CO₂ emissions (after adjustment for weather) are 74 kg CO₂/m²/y, 12% above the typical level (figure 2). In comparison with the Anglia Polytechnic University learning resources centre, examined by the PROBE team in 1996³, the Orchard Learning Resources Centre uses twice the amount of gas, 50% more electricity and emits 82% more CO₂.

Total water consumption is some 545 m³/y, which equates to an annual usage of about 28 m³ per staff member. The PROBE team is not aware of water consumption benchmarks for learning resource centres, but Office Tool Kit benchmarks⁴ are 10 m³/person for an efficient office and 25 m³ for an inefficient one.

The occupant survey

A survey of building occupants was carried out on 11 May. Currently 19 full time staff work in the building, of which 85% have regular working hours, and 15% flexitime. Forty percent work in open plan areas. Most staff have worked in the building for more than a year and churn rates can be said to be low relative to benchmarks.

Results from the occupant satisfaction survey

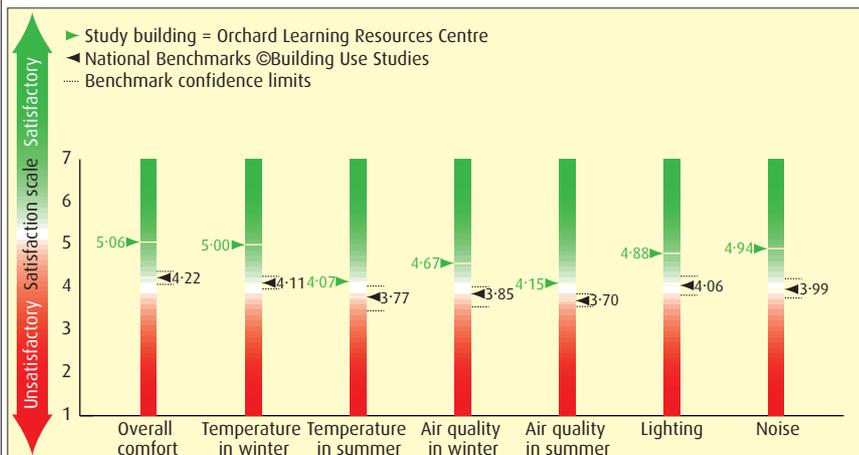


FIGURE 3: Overall satisfaction with comfort conditions at the Orchard Learning Resources Centre. A green arrow signifies a performance at or better than benchmark, a red arrow below benchmark. These scores are relative to the benchmark dataset of 50 buildings. They are therefore not absolute.

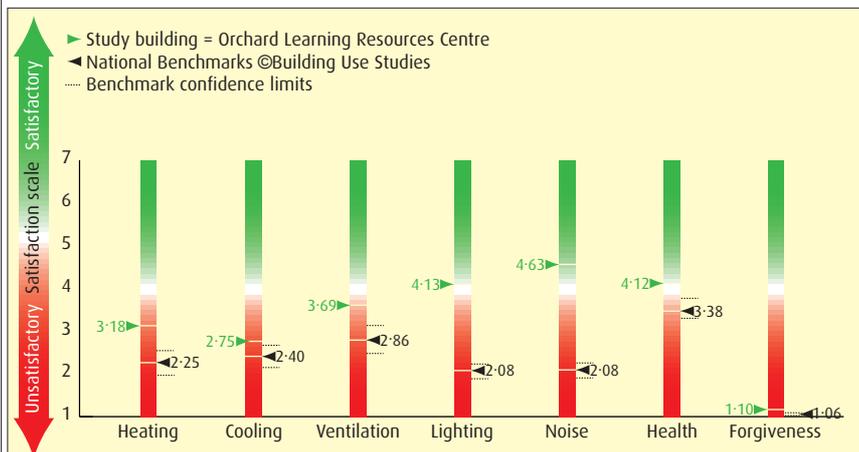


FIGURE 4: Occupants' perceived control over their environment, plus scores for their perception of the building as a healthy place, and their level of 'forgiveness' stemming from architectural delight.

All staff were asked to fill in the standard BUS/PROBE questionnaire. All 18 responded, but only 17 were available for analysis (a 94% response rate). The building was only lightly occupied on the day of the survey, but a sample of 41 students was obtained, using a cut-down version of the questionnaire designed to be filled in quickly.

As the building is not yet being used to full capacity, occupant densities (especially of students) are low. This will probably tend to create more favourable scores from both staff and students. Admittedly the study sample is small, so possibly subject to greater random variation than normal, and more likely that not to push up the comfort and satisfaction scores.

For comfort, the building is significantly better than the UK benchmarks for both winter and summer. These benchmarks are based on the 50 most recent buildings studied by Building Use Studies, so they represent average (not necessarily good) UK conditions.

On temperature and air quality, the building is perceived to be neither too hot nor too cold, although there were localised complaints. In winter it is considered stable, still, dry, fresh and odourless. Winter air quality is also perceived to be satisfactory. For summer, the building is comfortable overall, but too hot, stable, still, dry and stuffy. Again, air quality is satisfactory.

Overall, these results are what might be expected from a naturally ventilated building (figure 3).

The scores for lighting were good, with natural light levels perceived to be just about right. In fact, this is one of the few buildings where the occupants did not ask for more natural light.

There is evidence of sporadic glare. Interestingly, given the high lighting loads discussed earlier, occupants say there is too much electric light.

Every one of the scores for perceived control and quickness of response is significantly better than the dataset benchmarks. The score for occupants' view of the building as a healthy environment are also high (figure 4).

Overall, the findings are almost all positive, with good rating scores and praiseworthy comments. The responses given by students tend to be more positive than those from staff, which is not unusual.

Niggles include:

- poor acoustics, especially where noise from staff offices conflicts with library quiet areas.
- problems with the siting of the book issue desk, its lighting, the location of the lifts and draughts
- localised hot and cold spots
- problems with automated window control
- workstation ergonomics
- lack of toilet facilities.

When the building is working to its design capacity, the PROBE team expect the ratings to drop, but not in a way which would cause serious concern.

¹PROBE 8: Anglia Polytechnic University LRC, *Building Services*

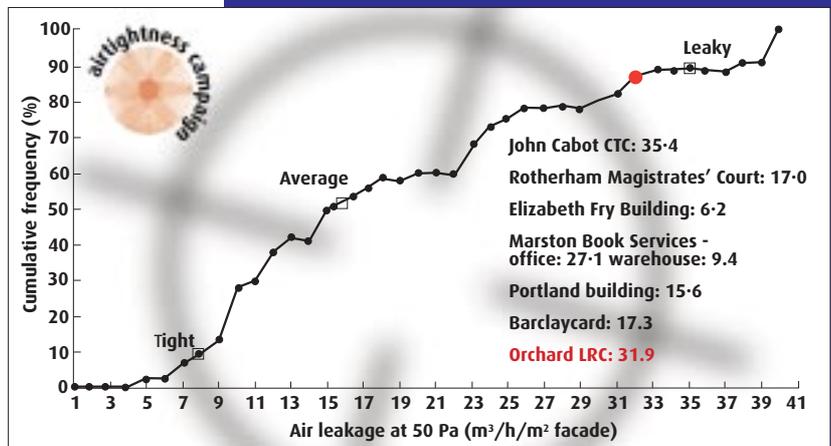


FIGURE 5: The air leakage data for the Orchard Learning Resources Centre, plotted on the BRE/BSRIA database. The cumulative distribution represents a sample of three building types: those designed to be airtight, buildings designed without airtightness as a design criteria, and some older buildings.

The BRE pressure test

The BRE carried out a pressure test of the Orchard Learning Resources Centre using the Large Fan Pressurisation System, BREFAN.

Before the test was carried out, the mechanical ventilation systems were turned off and apertures sealed with polythene sheet or masking tape. All windows, trickle ventilators and external doors were checked that they were closed.

The resulting air leakage test (at a reference pressure of 50 Pa) was calculated to be 31.9 m³/h per m² of envelope area. As a tight non-domestic building would have an air leakage index of less than 7.5 m³/h per m² of envelope area, and a leaky one 34 m³/h per m² of envelope area, then the Orchard Learning Resources Centre can be considered to be close to the leaky benchmark on the BRE/BSRIA database.

A brief air leakage audit using hand-held smoke tubes identified the leakage paths in the envelope. Significant air leakage occurred at the coffered ceiling/external wall junction. The top and bottom of the columns also leaked.

Much of the roof/wall interface could not be checked, but the areas that were tested proved to be leaky, especially at one point where a roof beam penetrated the external wall.

The building's windows had a variety of leakage points, such as around their frames, pivots and under the window cills. Air leakage was detected underneath the skirting boards on the first floor and down through the gaps around the heating pipes.

The centre-pivoted clerestory windows were found to be very leaky. This was because the automatic controllers did not close them up tightly against the draughtproofing.

External doors were quite leaky especially the rear double loading-bay doors, where daylight could be seen around its perimeter.

Even closed trickle ventilators were a source of air leakage, and a few of them even had to be forced shut before the test.

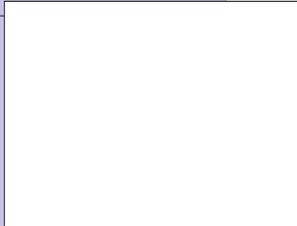


The BREFAN Large Fan Pressurisation System during the BRE pressure test at the Orchard Learning Resources Centre.

Brian Webb is a senior scientist and heads the airtightness Technical Consultancy at the BRE. This pressure test was funded by the DETR as part of the BRE/BSRIA/Building Services Journal initiative on improving building airtightness.

key design lessons

1. Gas consumption is important Just because electricity generates more CO₂ than gas does not mean that gas can be completely ignored. At the Orchard Learning Resources Centre, the high gas consumption is emitting more carbon than the electricity. The cause is poor heating control, the lack of condensing boilers, the high air leakage rate, and low internal heat gains.



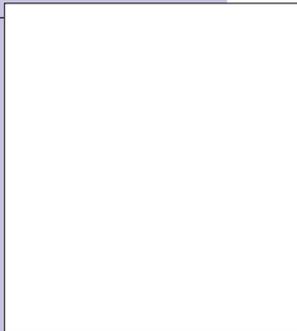
2. Advanced natural ventilation The occupant survey result is the best yet for an advanced naturally ventilated building, by virtue of its relatively quiet site and low utilisation to date. Given the leaky fabric and the building management shortcomings, the design team must have got many things right: the shading, the glazing, the thermal mass and the night ventilation.



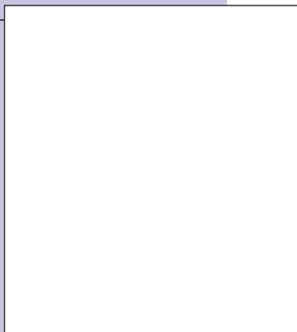
3. Ventilation components and controls The components seem to be reasonably robust but the pressure test revealed that they do not shut tightly. The legislative proposals on pressure testing should result in a general improvement in suppliers products. Until then, designers need to select components with great care and pay attention to products' performance guarantees.



4. Air leakage The poor results from the pressure test (of 31.5 m³/m²/h) demonstrates that merely registering concern with a contractor is not enough. The only surefire way to achieve an airtightness standard is to include in the main contract a requirement to demonstrate compliance by means of a pressure test. That said, the design team needs to provide air tight construction details for the contractor to follow, and to provide effective site supervision until the principles become second nature for builders.



5. Lighting control The design team tried hard to create an efficient light switching system without going to the cost and complexity of automatic daylight or occupant sensing. The outcome was an extreme default to on. This is less a failure of design and more a reflection of the general lack of public interest in saving energy (the 10 m distance from reception desk to security room proved too great). The alternative – technically elegant controls – may have sex appeal, but they often demonstrate fragility.



Journal 12/96.

¹*Energy Consumption Guide 19: Energy Use in Offices*, DETR, January 2000.

²Bunn R, "Book Review", *Building Services Journal* 7/97.

³Office Tool Kit, xxxxxxxxxx BRECSU?

The PROBE team for the investigation of the Orchard Learning Resources Centre comprised Dr Robert Cohen of Energy for Sustainable Development (ESD), John Field of Target Energy Services and Adrian Leaman from Building Use Studies. Thanks are extended to the Gordon Harris, director of the Orchard Learning Resources Centre.

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The designer's response

