- The building performs better than UK benchmarks for both winter and summer comfort ✓
- The air leakage test was calculated to be 31·9 m^3/h per m^2 of envelope area. ✓
- The building emits 74 kg CO_2/m^2. This is 12% above the typical level for a Type 2 office. ✓

Orchard Learning Resources Centre

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

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 Colleges 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 m^2, of which some 3900 m^2 is for traditional library services and 600 m^2 for non-traditional space such as information technology.

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 Arup[1]. 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 specification[2].

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 engineer was Ove Arup & Partners and the design and build 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 m^2,

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

PROBE 21

To download pdf files of earlier PROBE reports, visit and bookmark the PROBE web site at: www.usablebuildings.co.uk./Probe/ProbeIndex.html

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and plant rooms.

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

Note that the building's use has been well below the design allowances, but will increase considerably when the facility 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. Automatic motorised toplights are on the ground and first floors and clerestory windows are in the roof. The motorised windows are covered by a maintenance contract which includes annual servicing.

There are some manually openable centre-pivoted windows, but most are kept locked for security reasons. The toplights in the offices are maually operable using a window pole.

Background trickle ventilation is via hit and miss type vents located in deep window sills. Those serving the north facing bay windows are set into the floor and are 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/m^2 treated floor area (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 arrangement of switches which could allow the staff to control the public lighting zone by zone. Lighting in the office areas is by conventional wall switches.

The building has around 100 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 their power-save facilities enabled as this has caused confusion in the past as to whether the machines are on or off. Apparently, many pcs are left running all night as the shut down procedure at the end of the day is regarded as taking too long.

Some 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 toplight 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. Morning heating has also caused the building to overheat, invoking 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 some automatic temperature control applies at all times. 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 switch panel in a security room by the main entrance) 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 chargable 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 apparently 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 manual 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 had 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 and beyond.

Light switching could 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. Spot measurement of light levels on the ground floor

Electricity consumption data and CO_2 emissions

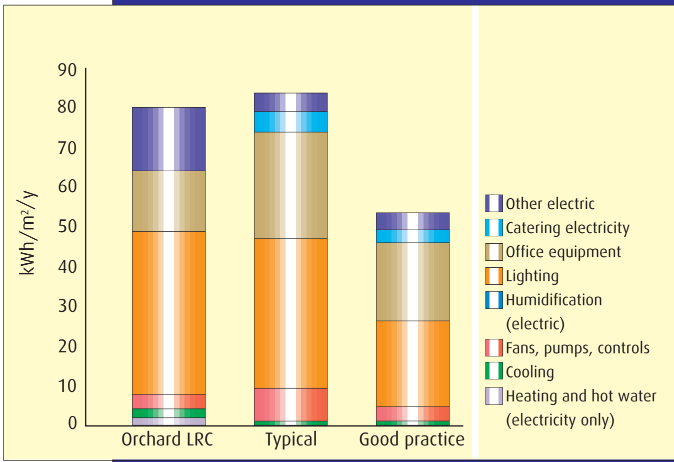


FIGURE 1: End-use electricity breakdown at the Orchard Learning Resources Centre.

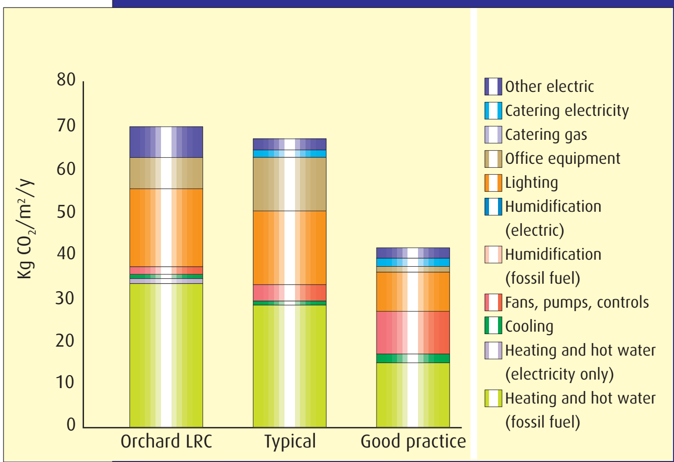


FIGURE 2: Carbon emissions at the Orchard Learning Resources Centre by end use. The conversion factors are 0·46 kg CO_2/kWh for electricity and 0·19 kg CO_2/kWh for natural gas (*Econ 19,* January 2000).

Overall performance

Electricity

In the year from April 1999 to March 2000, actual total electricity consumption was 356 MWh or 80 kWh/m^2.

Gas

In the year from April 1999 to March 2000, total gas consumption was 797 MWh or 180 kWh/m^2.

Carbon emissions

The building emits 71 kg CO_2/m^2. This is 4% above the level considered typical for a Type 2 office building – the nearest benchmark.

during a bright day showed the potential for daylight switching of the electric lighting for the perimeter fittings at least.

It would also seem that daylight levels on the first and mezzanine levels are more than sufficient to allow the electric lighting to be off for many daytime hours. It is blatently clear that there is no need for strip lighting above the top clerestorey windows during daytime. However, a notice has been stuck to the security room wall, next to the light switches, saying “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 all the lights on every day.

It is worth noting that lighting power densities average about 12 W/m^2, a respectable figure but some 30% above the design figure of 9 W/m^2 given in the original article[2]. 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.

Despite attempts by the design team to instigate such a scheme, nothing seems to have materialised, possibly because library staff are unwilling to take on such responsibilities.

Energy and water consumption

Results from the occupant satisfaction survey

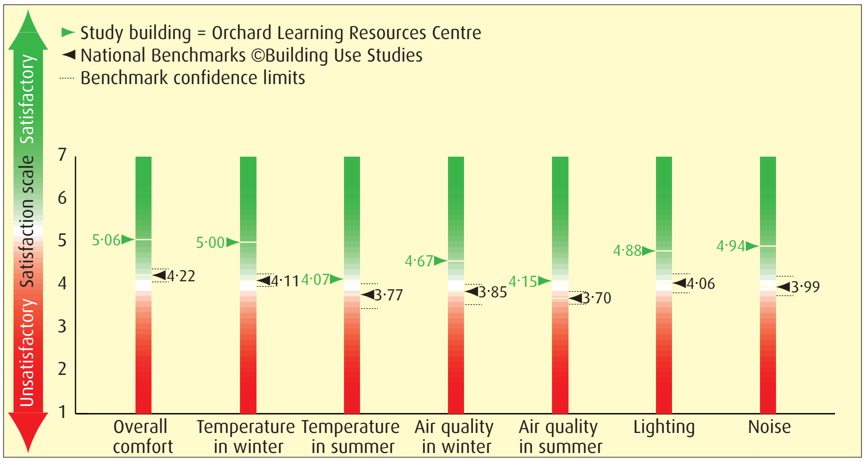


FIGURE 3: Overall satisfaction with comfort conditions at the Orchard Learning Resources Centre. A green arrow signifies a performance at or better than benchmark, a red arrow below benchmark. These scores are relative to the benchmark dataset of 50 buildings. They are therefore not absolute.

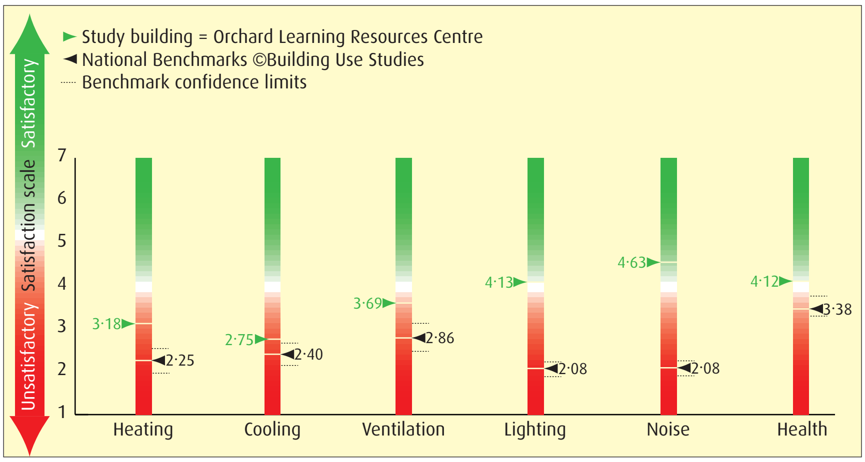


FIGURE 4: Occupants’ perceived control over their environment, plus scores for their perception of the building as a healthy place to be.

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[3]. 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 analysis of gas bills shows that in the year from April 1999 to March 2000 total gas consumption was 797 MWh or 180 kWh/m^2. Normalised for standard weather conditions of 2462 degree days, the gas consumption for space heating increases to 205 kWh/m^2 (tfa) This is 36% above the Type 2 ‘typical’ value of 151 kWh/m^2 and over two and a half times the good practice benchmark of 79 kWh/m^2.

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/m^2 (tfa). Total unadjusted electricity consumption is about 50% above the Type 2 good practice benchmark of 54 kWh/m^2 and 6% below the typical figure of 85 kWh/m^2.

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/m^2 tfa, which is about 28% above Type 2 good practice and 18% below typical (figure 1).

It also seems appropriate to take into account that the energy consumption by office equipment at 16 kWh/m^2 is significantly below the type 2 office good practice and typical figures of 20 and 27 kWh/m^2. Therefore, for benchmarking the Orchard Learning Resource Centre, the office equipment load for the type 2 office might be adjusted down to the building’s actual figure of 16 kWh/m^2. This would make the adjusted electricity use (excluding the Mingana room) 6% below the adjusted type 2 typical value of 74 kWh/m^2/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 CO_2 emissions (after adjustment for weather) are 71 kg CO_2/m^2/y, 4% above the typical level (figure 2). In comparison with the Anglia Polytechnic University learning resources centre, examined by the PROBE team in 1996[1], the Orchard Learning Resources Centre uses twice the amount of gas, 50% more electricity and emits 82% more CO_2.

Total water consumption is some 545 m^3/y, which equates to an annual usage of about 28 m^3 per staff member. However, the toilets are also used by the students.

The PROBE team is not aware of water consumption benchmarks for learning resource centres. Office Tool Kit benchmarks[4] 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.

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 than 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 (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 even 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

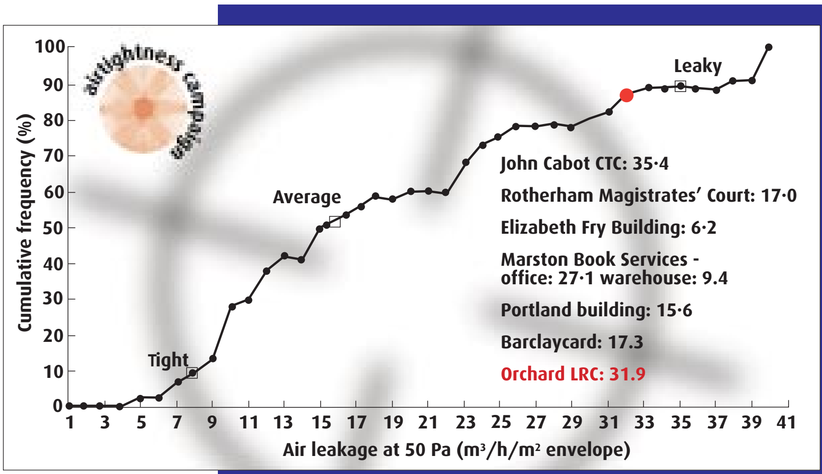


FIGURE 5: The air leakage data for the Orchard Learning Resources Centre, plotted on the BRE/BSRIA database. The cumulative distribution represents a sample of three building types: those designed to be airtight, buildings designed without airtightness as a design criteria, and some older buildings.

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 (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

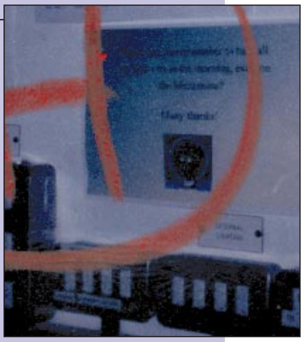
1. Gas consumption is important Just because electricity usually generates more CO_2 than gas does not mean that gas can be completely ignored. At the Orchard Learning Resources Centre, the high gas consumption is emitting more carbon than the electricity. The cause is poor heating control, the lack 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, helped, no doubt, by its relatively quiet site and low utilisation to date. Given the leaky fabric and the building management shortcomings, the design team clearly 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 $m^3/m^2/h$) 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. To date the outcome has been an extreme default to on. This is less a failure of design and more a reflection of the general lack of occupant interest in saving energy (the 10 m distance from reception desk to security room is proving too great). The alternative – technically elegant controls – may have sex appeal, but they often demonstrate fragility.



☐ 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.

In summary, the Orchard Learning Resources Centre provides a comfortable and attractive working environment, proving that advanced natural ventilation can be a viable strategy for delivering occupant satisfaction. Its energy consumption will be a particular disappointment for the design team who tried hard to achieve a low energy building within the constraints of a design and build contract and the difficulties of cajoling a client to operate their building efficiently.

Hopefully the PROBE study will stimulate the new owners to manage the building to its true low energy potential.

[1]PROBE 8: Anglia Polytechnic University LRC, *Building Services Journal* 12/96.
[2]Bunn R, "Book Review", *Building Services Journal* 7/97.
[3]*Energy Consumption Guide 19: Energy Use in Offices*, DETR, January 2000.
[4]Office Tool Kit, BRE, 1995.

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 Gordon Harris, director of the Orchard Learning Resources Centre.

PROBE is a collaborative research project conducted by *Building Services Journal*, co-funded under the Department of the Environment, Transport and the Regions' Partners in Innovation (PII) initiative, and managed by Energy for Sustainable Development.

The designer's response

Please see additional page for the design response. This was missing from this scan of the draft article, so the published version has been attached as a separate page.

key design lessons

1. Gas consumption is important Just because electricity usually generates more CO_2 than gas does not mean that gas can be ignored. Here, the high gas consumption churns out more CO_2 than that from electricity use. The cause is poor heating control, the lack of condensing boilers, the leaky envelope (and lack of control over ventilation devices) and low internal heat gains.

2. Advanced natural ventilation The occupant survey result is the best yet for an advanced naturally ventilated building, helped, no doubt, by its relatively quiet site and low utilisation to date. Given the leaky fabric and the building management shortcomings, the design team clearly got many things right: the shading, the glazing, the thermal mass and the night ventilation.

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The designer's response to the feedback survey

It is pleasing that the occupant survey revealed a good overall level of comfort perception. If the occupants are happy, then the building is usually perceived as a success, *writes Glen Irwin of Ove Arup & Partners.*

Clearly, there are problems associated with the understanding, operation and perhaps maintenance of the control elements, which result in some dissatisfaction with controllability.

It is important to look at the Orchard Learning Resources Centre as a value for money solution. For example, while condensing boilers would have saved energy, the budget of £110/m² meant they could not be specified. Design and build inherently focuses the mind of the designer on money from a very early stage, and the priorities are usually the user facilities.

Despite that, we were able to design a low energy building. Although the results of the energy study are disappointing, we believe the building has the potential to achieve a rating between the Typical and the Good Practice benchmarks. This will take further commitment from all quarters: the contractor, designers, the building users, and the facilities team.

For example, while the lighting controls are simple and appropriate, energy savings will only come from the adoption of a more flexible regime. Computer power-down settings are also making a significant impact on electricity usage. Auto power down settings should be set by the IT staff. Users will need to be briefed, and notices are required on all computers.

The maintenance contract for the window actuators to be reviewed as clearly it is not proving effective. A lot of effort also went into briefing the user on the window control regime at the completion stage. That information needs to be re-issued and the design principles display boards, also provided at completion, need to be reinstated.

The simple network display panel for the heating controls does not appear to be as easy to re-program. It may be worth considering provision of a supervising pc to ease setting and adjustment of occupied periods and setpoints.

Readers should not draw the conclusion that these types of building cannot be procured effectively using design and build. They can – within budget, on time and offering good value for money – which is very important on education projects. But if low energy designs are going to make an impact, then they need to be more broadly applicable.

It is also vital that the training and education of the users provided at handover is reinforced continually through the life of the building.