PROBE 13: Charities Aid Foundation

Natural ventilation, adiabatic cooling and passive solar architecture – the makings of an environmentally sound and low energy building. But has the headquarters building for the Charities Aid Foundation lived up to its billing?

BY THE PROBE TEAM

Mixed-mode buildings are very much a nineties phenomenon, a solution to the specific limitations of natural ventilation and air conditioning.

Although married to some unusual services, the headquarters building for the Charities Aid Foundation (CAF) is otherwise typical of the mixed-mode breed. Solar gain is controlled by external shading, openable windows are backed up by displacement ventilation and there is a mild application of electronic controls, notably for the lighting.

For in-depth details of the building, readers must refer to the original article "Working for charity"[1]. Suffice to say that the mainly open-plan office building is home to 200 administrative staff who manage charity funds worth £600 million.

Located at the Kings Hill development on the former West Malling aerodrome, the premises were procured as a pre-let from developer Rouse Kent, a joint venture between Rouse (the US developers) and Kent County Council.

Building design

The 3900 m^2 (3700 m^2 treated), U-shaped three-storey building is brick-clad with a relatively shallow (13·5 m) plan depth in which office space predominates. Entry is via a fully-glazed, double-height reception area, which faces west-north-west.

This leads into a staff room and dining area which opens out into the courtyard on the other side. A domestic kitchen and vending machines provide modest catering facilities.

The building was procured quickly: three months for design and nine months for construction. This – and the CAF's demand for simplicity and frugality – produced a building with a simple plan, no basement, concrete floors and a roof slab with exposed soffits.

CAF currently occupies about 80% of the floorspace. The north wing of the ground floor is on a separate short lease to a company which has some 20 staff in cellular offices, an area which was not surveyed.

An open-plan area at the end of the north wing on the first floor is currently empty and unlet, although it is heated and ventilated and sometimes electrically lit. As neither this area nor the leased zone are sub-metered, their floor areas and energy use are included in the energy consumption figures.

A so-called concurrent mixed-mode operating strategy is used, with full-fresh air mechanical ventilation at some 4 ac/h (3·3 l/s/m^2) via the raised floor, with extract through selected ceiling coffers.

Primary plant consists of a prefabricated boiler plantroom and the two main air handling units (ahus) on the roof. Each ahu includes cross-flow heat exchangers, both to recover heat in winter and for adiabatic cooling in hot weather, when water is sprayed into the exhaust air stream before the heat exchanger.

Fabric heating is by flat panel hot water radiators under the windows, with individual thermostatic radiator valves. In cold weather the ahus can also recirculate air during the preheat period, and if necessary overnight to avoid the fabric becoming chilled.

The windows are to a pattern frequently used in recent naturally-ventilated and mixed-mode offices, being of large openable panes topped with fanlights, both usually in pairs. All are under occupant control.

Horizontal sun louvres are used on the south west and south east facades, but not on the north west elevation. This is partly because buffer zones including reception, toilets, main stairs and air conditioned rooms are concentrated on this side, and windows to other spaces are smaller.

All windows open outwards, but inadequate friction in the mechanisms causes many of the windows to close by gravity or wind pressure shortly after they have been opened. The management team has recently obtained a key to tighten them up.

A small multi-split VRV (variable refrigerant volume) direct expansion cooling system serves four fan coil cooling units: two in the computer room which are available continuously and one each in the boardroom and the training room, which operate on-demand using integral local controls.

Initial occupancy

Design and construction appears to have been relatively painless for the CAF, an advantage of the pre-let route with a committed developer and construction manager, an enthusiastic design team and clear end-user objectives.

Although working well in business terms, there were some initial technical difficulties which were not dealt with as quickly as the occupant would have liked. As other PROBE studies have shown, this is by no means unusual. However, owing to good relationships between all parties, the response does seem to have been better than normal.

The building was initially cold which required attention to bems controls, the heating and ventilation. Draughts also occur, particularly at the continuous vertical strips of the corner windows. The supply air temperature was also raised to 21°C (a common experience with floor supply systems), but during the PROBE visit in November, it was back to 19°C. Room temperature was typically 21°C at 1 m above the floor, and 22°C at 2 m.

The fully-glazed reception area was initially uncomfortable, the external manual swing doors and internal motorised sliding doors admitting blasts of air. These were adjusted to improve airtightness and timing, but the lobby is not deep enough to stop both sets of doors being open together.

The heating was able to offset the downdraughts from the glazing, but not draughts and heat loss from the fabric overnight. Initially the receptionists had to use local electric heaters, and electric door curtains were added in summer 1997. These have proved effective, but unexpectedly noisy owing to all the hard surfaces.

The offices at the CAF building feature an exposed concrete ceiling. Good for thermal balance but, without acoustic treatment, poor for noise control.

In the early sketch designs, the reception desk was to have been on the south side of the area and shaded by the offices behind. However, an arrangement with the desk on the north side provided less conflict between access to the tenanted space in the north wing and the CAF's internal movements.

The architect warned that blinds might be necessary, but it was decided to wait and see. In practice, the sun shone onto the desk from about 14.00 h, with severe consequences both for glare and thermal comfort. Motorised internal roller blinds have now been added under manual control from reception.

As with many such areas, there are no openable windows at high (or low) level to let out unwanted heat. Such openings are not easily incorporated in planar glazing, and were not thought to be necessary when the receptionist was on the north-facing side.

The glazed screen between staff/dining area and reception initially had a large gap in the middle, to allow access between it and the reception area. However, given all the reflective surfaces, this did not give sufficient acoustic privacy to either area. This screen has now been extended and double doors added.

CO_2 emissions and energy consumption data

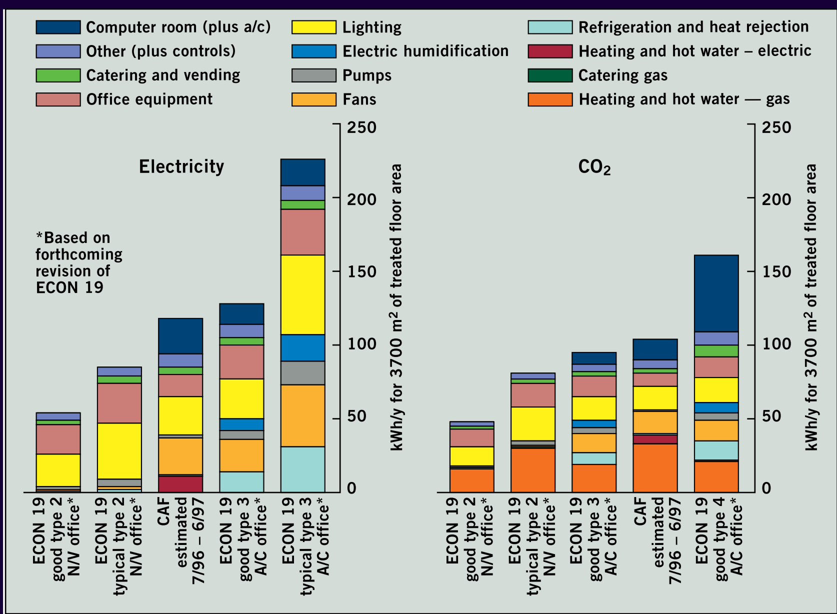

FIGURE 1: End-use energy breakdown at the Charities Aid Foundation building. Note that the conversion factors are: electricity 0·6 kg CO_2/kWh and gas 0·2 kg CO_2/kWh.

Natural lighting

Windows provide well-controlled levels of daylight. As in other buildings with this type of window[2,3], manual blinds to the fanlights above the horizontal louvres on the solar-exposed elevations are often left down, sun or not. This is the most convenient default state.

In response to the CAF's interest in good daylight, the architect also added large central rooflights in the two wings of the top floor. Here, the flat concrete ceiling was retained, but with punched holes instead of coffers.

The rooflights were deliberately kept clear in order to improve outside awareness and to admit sunbeams. In practice, solar radiation, direct sunlight on computer screens, and reflected glare from bright areas such as the edges of the holes in the ceiling have been troublesome. Blinds will now be added.

The top floor has an area of planar floor-to-ceiling glazing, above the fully-glazed reception area. Being unopenable and bringing glare and solar radiation from the west, this glazing has made nearby workstations unpopular. Blinds have been fitted and the space is now used as a waiting area for visitors.

Electric lighting and controls

Each 1·5 m by 3 m office bay is lit by a pair of 24 W compact fluorescent lamps in a square louvred fitting. This is surrounded by a perforated metal disc which helps to diffuse the upward component into the coffer, and to hide the ventilation outlets.

Although compact fluorescent lamps are not quite as efficient as the linear variety, using high-frequency control gear and opting for illuminance levels of 350-400 lux has led to an effective and attractive scheme. The installed power density is a creditable 12 W/m², with an efficiency of some 3 W/m²/100 lux.

The lighting is grouped in zones averaging some 30 m², each with 6-8 fittings. These are wired via flexible links to marshalling boxes and controlled by occupants' telephones.

To switch lights, occupants dial a control box and key in a PIN, an operation which they regard as more complicated than necessary. Occupants would have liked finer zoning, but the installed system had little spare capacity and at £400 for each new control box – including wiring alterations – changes are now regarded as too expensive.

The telephone switching has caused difficulties for the cleaners, who do not know all the numbers. Hence all lighting (except that in reception) is now programmed to switch on automatically from 17.00 h to 20.00 h.

While kitchens and meeting rooms have PIR sensors, occupants seem to think that ordinary light switches would have been just as effective. Absence sensing – where occupants can switch lights as they wish, but they go off after the room has been empty for a while – might have combined the benefits of both manual and automatic controls.

Nearly everyone has a pc and works at the screen over 5·5 h each day on average. With an average of three or four pcs per laser printer, equipment heat gains in the open offices average 10 W/m², with some local clusters rising to 16 W/m² (design: 15 W/m²). Switching-off discipline is good, and few pieces of office equipment are left on overnight.

Operational issues

Working hours are typically between 08.00 h and 18.00 h Monday-Friday, with many people working more-or-less nine-to-five – more routine than in many offices. Cleaning is between 17.00 h and 19.30 h, when any office equipment left on is switched off.

At 20.00 h the lighting control system switches-off any lights which still remain on (though they can always be switched on again on a local basis). Only reception and outdoor lighting and office equipment in the computer room stay on overnight.

In-house facilities management staff look after CAF staff and operations. Other aspects of building management, systems operation and maintenance are more similar to a multi-tenanted rented building than to a single tenancy or a pre-let. All building-related work is handled by the developer, which maintains a 24 h helpdesk. The CAF is happy with the level of service, its cost-effectiveness and its response to urgent problems.

Energy management is not a high priority, though the maintenance contractors review meter readings on their computer. Fortunately, the CAF's regular pattern of occupancy means that time programs for hvac and lighting control do not need constant adjustment, and so the widespread problem of leaving plant on to suit possible late and weekend working does not occur. This helps to keep energy use down.

There are also local switches on each floor intended to provide local on-demand extension time override for the heating. However, these switches are well-concealed inside locked service riser cupboards (to which tenants do not have routine access) and, to date, have seldom been used.

Energy analysis

For various reasons it was not possible to get as much access to the plant and do as thorough an analysis of operation, fuel consumption and energy end-use breakdown as usual. As there have been no gas bills from occupation until February 1997 (and many estimated ones after that), a detailed degree-day analysis was also not possible.

Furthermore, the control system does not include a central supervisory computer for routine interrogation and trend logging. However, using various sources of information, a reasonable breakdown of annual consumption has been obtained.

Electricity is on a day/night maximum demand tariff, with an available capacity of 450 kVA – over three times the maximum demand recorded to date. Some of this spare capacity was required (and is paid for) by the developer to secure flexibility for other possible uses, tenancies and extensions.

Annual electricity consumption between July 1996-June 1997 was 117 kWh/m² of treated floor area, very close to the design estimate of 120 kWh/m². Figure 1 shows a detailed breakdown and compares it with a range of relevant benchmarks from the forthcoming edition of *ECON Guide* 19[4].

ECON 19 is currently under revision, and the new benchmarks will take into account reductions in energy consumption by heating and electrical end uses, and improvements in insulation, plant and control efficiency. *ECON 19* will also contain a wider gap in energy consumption between typical and good practice examples to take account of the added benefits of good design and management.

As a mixed-mode design, the CAF building's electricity consumption would be expected to lie somewhere between naturally-ventilated open-plan (Type 2) and standard air conditioned open-plan offices (Type 3). It does, and in the 'good practice' bracket too.

This level of electricity use is not only reasonable in relation to the benchmarks, but very good in comparison with the four financial services offices studied earlier in PROBE, which had energy profiles more similar to *ECON 19's* typical Type 4 air conditioned head office category, even though two of them were not much more densely and intensively-occupied than the CAF building.

Water consumption averages some 1400 m³ per year, or about 7000 litres/person/y (28 litres per working day) – a considerably better return than the BRE's good level of 10 000 litres/person/y for existing offices.

Results from the occupant satisfaction survey

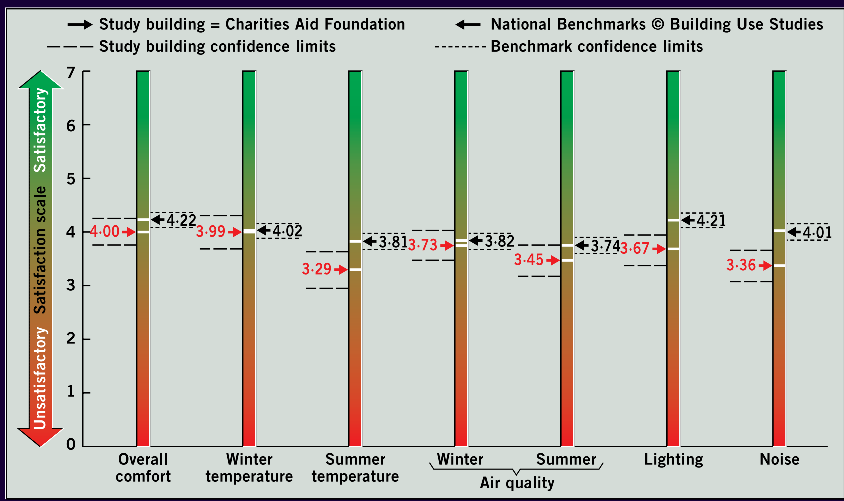

FIGURE 2: Overall satisfaction with comfort conditions at the CAF. Green scores are good, red are poor.

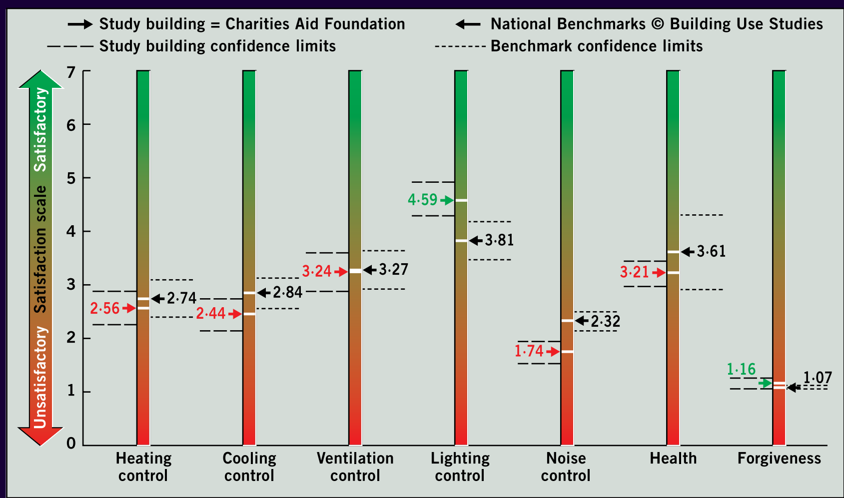

FIGURE 3: Occupant satisfaction with the CAF building's health, management and control strategies.

End-use breakdown: electricity

The CAF building consumes 11 kWh/m²/y of treated floor area for heating and hot water. This includes electric domestic hot water throughout the building, plus supplementary electric heating in the reception.

The figure is likely to rise by 2 or 3 kWh/m² in 1998 owing to the addition of electric door curtains.

Refrigeration comes in at 1 kWh/m², including local on-demand cooling for the boardroom and training room. While the use of indirect evaporative cooling eliminates chiller consumption for office cooling, the occupant survey suggests that, in 1997, it was not very effective. This may need some investigation.

The CAF building's computer room is relatively small – both absolutely and in relation to the size of the building. Its air conditioning requirement is consequently modest, consisting of comfort-cooling units with efficient compressors under variable speed inverter control. These account for an estimated 30% of the room's total annual consumption, measured at 24 kWh/m².

From the commissioning figures the specific fan power of the office ventilation system is 3 W/litre/s for the supply and extract fans (or 10 W/m² of mechanically ventilated floor area). The 25 kWh/m² fan energy is higher than the *ECON 19* benchmark of 2 W/litre/s for a good system and a current target of 1·5 W/litres/s or less for an energy-efficient installation.

The CAF figures give an installed power of some 10 W/m² of mechanically-ventilated office area. Owing to moderate running hours, estimated at just under 3000 h/y, annual consumption is similar to the *ECON 19* good level for Type 3 air conditioned offices (typical levels are considerably higher) and below the design estimate of 30 kWh/m². However, occupants perceive the effectiveness of the mechanical ventilation and cooling to be less than an air conditioned building.

At 2 kWh/m², energy consumption for pumping is fairly typical for a heated-only building where electric hws and ahu heat recovery allows boiler plant to be switched off in summer. Energy use by the adiabatic cooling pump and a sump pump is estimated to be small.

At 26 kWh/m², lighting energy consumption is at the good practice levels suggested in the new *ECON 19*. This is considerably less than those in the 1991 edition due to a low installed power density (12 W/m²) and lux levels between 350-400 lux.

The routine occupancy of the building has avoided lights being left on unnecessarily, as often occurs when operating hours are extended, though the 100% lighting throughout the building during cleaning hours is wasteful.

On a bright day, more lights were on than the staff considered necessary, owing to the coarse zoning and the relative difficulty of using the telephone switching system. However, even on dull days, people did not switch the lights on in some areas.

On asking why, a common reply was that the ceiling lights caused headaches. One reason for this seemed to be that the louvres had different cut-off angles in different directions, causing distracting reflections in some computer screens. Interestingly, some local problems have been resolved by rotating fittings through ninety degrees.

At 17 kWh/m², office equipment consumption is below the typical level for a naturally-ventilated office, despite the high use of pcs. This is because the building is not quite up to capacity, and is also due to the fact that relatively energy efficient pcs and screens (95 W together) have been used.

The computer room also houses server equipment which would otherwise be spread about the offices.

Gas consumption levels

Annual gas consumption for the two years since occupancy averages 151 kWh/m², or 165 kWh/m² with simple correction to the standard 2462 degree days. Although less than typical for an air conditioned office, this is well above the *ECON 19* good level for both naturally-ventilated and air conditioned offices and the design estimate of 100 kWh/m².

The figure raises the energy-related carbon dioxide emissions a little above a good practice air conditioned office. However, at today's low gas prices of about 0·9 p/kWh, the extra gas consumption only costs some £1700/y.

In the absence of monthly meter readings, it has not been possible to investigate gas consumption in detail, but the available information suggests high consumption in winter rather than wastage in mild weather. Possible reasons for this include a high air infiltration rate, but for various reasons a full pressure test of this essentially speculative building was not possible.

Nevertheless, spot tests with a smoke pencil revealed leakage around the edges of the windows, particularly for the planar glazing in reception and on the second floor. Comments on the top floor also suggest that there may be infiltration around the rooflights, but the PROBE Team could not obtain safe access to confirm this.

Other smoke tests revealed that some of the convective plumes from the radiators rose straight to the extract points, while some supply air may be leaking into the roofspace via the floor voids and riser ducts.

Control problems may also be responsible for high gas consumption. Pre-commissioning of the plant and the absence of a central supervisory computer means that there might be undetected problems under certain conditions, common when systems are monitored.

The occupant survey

Building Use Studies carried out a survey of the internal environment and related variables on 100% of CAF staff, obtaining a 95% response. On average, the staff judged winter temperature and overall air quality to be similar to the benchmarks derived from the fifty most recent surveys carried out by the BUS. The building rated slightly on the cool, dry and draughty side, but – oddly – significantly more stuffy (though not smelly).

Summertime temperatures overall were perceived to be much hotter, less comfortable and more variable than the benchmarks (figure 2). Analysis shows thermal comfort on the first floor to be similar to the building mean, the ground floor is cooler and more comfortable and the second floor is hotter owing to the additional planar glazing and rooflights.

Natural light levels are regarded as somewhat low (as is the benchmark), and there is little difference between floors. Artificial light levels are seen as a little too high (but again similar to the benchmark) and prone to glare.

The management is experimenting with reducing the lamps from 24 W to 18 W. Overall, occupants regard the lighting as less satisfactory than the benchmark.

DESIGNERS' FEEDBACK

As the designer for the CAF project we set out to make a building that would be inexpensive to construct, economical to run and have high levels of comfort with plenty of daylight and good outlook, *write Richard Partington and Jim Grace.*

Considerable thought was applied to the design of the exposed concrete soffit which integrates lighting, air extract and structure, and helps to stabilise the internal temperature.

Although there is no direct feedback from the PROBE analysis on the thermal benefits of this device, it remains one of the most successful and most commented-upon features of the building.

As far as the CAF building is concerned, air leakage (which may contribute to high fuel costs for heating) was not anticipated.

Preventing water ingress at the window/wall interface is the normal priority for designers and builders, but a watertight detail is not necessarily an airtight detail.

The question of air leakage is certainly being considered in current projects and its importance, now that external walls are so well insulated, must also be communicated to the builder. For the most part, leakage seems to occur at the overlap between trades.

The issues raised by the end-users' survey are particularly interesting, and perhaps not surprising if one considers the contrast with their previous accommodation – a large converted town house.

For many of the building occupants, the move to computerisation and an open-plan office will have been a new experience.

The observation that electric light levels are felt to be too high, even at 400 lux, confirms our predictions, and questions industry-established standards. Unfortunately, letting agents still take 500 lux as the norm.

The glare problems highlight the difficulties of designing for good daylight where there is also extensive computer use.

This is one area, along with improved services monitoring, where sensible fine tuning can be applied at reasonable cost.

Richard Partington is an architect with Nicholas Hare Architects. Jim Grace is a services designer with Atelier 10.

On the first and second floors, glare from natural light is much higher than the benchmark. Ground floor occupants report less glare (presumably owing to the barrier of a mail room on the south side), but paradoxically are also less happy with the lighting overall. This may be a function of task: the marketing department prefers to work with the general lighting off, using task lighting as necessary – those who do not want to work with the lighting off have to fit in with the rest.

Noise is the bugbear of the open-plan office. In the UK one finds almost universally low levels of occupant satisfaction. The CAF scores on the ground and second floors are similar to the national benchmark, but the first floor is significantly worse, presumably because it has a much larger open-plan area and a greater diversity of activities. One person compared the office to working in a swimming pool.

Although overall comfort is slightly below the benchmark, within statistical significance the CAF's score is no different from the typical (median) level on the BUS database. This is better than would be inferred by the individual scores, indicating a high forgiveness and a feel-good factor arising from the design and management of the building. People with window seats were more comfortable than those without – a common feature[3].

Quickness of system and management response to problems is an important ingredient of occupant satisfaction (figure 3). Apart from noise (which is worse), the CAF building is better than the benchmarks for responsiveness, and significantly so for lighting. The fact that people feel that they can do something, even if it has limited effect on comfort, will have contributed to the high forgiveness score.

The PROBE 13 Team comprised Bill Bordass, Adrian Leaman and Mark Standeven.

References

[1]Bunn R, 'Working for charity', *Building Services Journal*, 3/96.

[2]BRECSU/Energy Efficiency Office, *Best Practice Programme Case Study No 13: NFU Mutual & Avon Group hq*, 6/91.

[3]DETR, 'Naturally comfortable offices: a refurbishment project', *Good Practice Case Study No 308,* 3/97.

[4]DETR, *Energy Consumption Guide 19: Energy efficiency in offices*, 1998 (To be published).

Further reading

Bordass W, Bromley A K R and Leaman A, 'Comfort, control and energy efficiency in offices', BRE *Information Paper 3/95*.

BRECSU/Energy Efficiency Office, *General Information Leaflet No 11: Energy efficiency in offices: review of twelve office case studies*, 1/94.

The PROBE Team would like to thank the following for their help during the PROBE investigation: Andrew Cooke, Jean Allan, Ann Simmonds and the staff of the CAF, John Foot of Rouse Kent, Barry Waters of Kvaerner Rashleigh Weatherfoil, Nick Hare and Richard Partington of Nicholas Hare Associates and Jim Grace of Atelier Ten.

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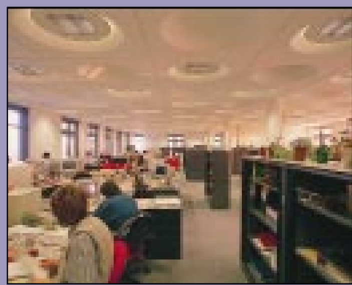
Key design lessons

Mixed-mode fulfils the promise of using less energy than full air conditioning, although CO_2 emissions are higher than good practice levels. The straightforward concurrent operating strategy has been particularly easy to operate with the CAF building's routine occupancy patterns. With attention to controls it may be possible to reduce wintertime gas consumption and summertime temperatures. In future schemes, there would be scope for more refinement in air change rates, system efficiency and control.

ABOVE: Despite the lack of a pressure test, evidence of uncontrolled infiltration was easy to find using a smoke pencil, specifically around the edges of the planar windows, LEFT.

Window design often needs to be improved in naturally-ventilated and mixed-mode buildings. As in many buildings, the handles for upper windows were too high for most people to reach, and even less accessible when opened out. While the lower windows have been used more than CAF had anticipated, they also lack insufficient fine control, cause low-level draughts and tend to close by gravity or wind pressure.



The project architect for the CAF building provided a high quality exposed ceiling-scape into which the services engineer integrated the lighting, but...

Lighting energy consumption is good, but occupant satisfaction with daylight and artificial light is disappointing, perhaps exacerbated by the intensive vdu use. Lighting control was felt to be a good idea, but not sufficiently fine-grained, user-friendly or easy to change. The occupants would have preferred a simpler-to-use system with smaller zones, preferably down to the level of the single occupant. Absence sensing – whereby occupants can switch lights as they wish, but the lights go off after the room has been empty for a while – might combine the benefits of both manual and automatic controls.

...the penalty has been glare problems on computer screens, and additional noise pollution from the untreated soffit.

Noise is the bugbear of the open-plan office. While the occupancy survey scores for the ground and second floors at the CAF are similar to the national benchmark, the first floor is significantly worse. People mentioned hearing remote conversations, banging doors, rain on the plastic rooflights and an inability to identify whether a ringing telephone was for someone in their workgroup or from some distance away. Like many passive solar buildings, the exposed concrete ceiling has no acoustic treatment.

Sun glare into the reception area required a retrofitted sunblind.