Cable & Wireless College PROBE 5

Mark Standeven and Robert Cohen report on how the Cable & Wireless College, the fifth building in our post-occupancy review series, has performed since completion. To understand the building's detailed design readers should refer to the original article "Cable talk", which appeared in the November 1993 issue of *Building Services Journal.*

When it was completed at the end of 1993, the Cable & Wireless College represented the very latest approach to natural ventilation for low rise buildings. Widely acclaimed, it won the Royal Fine Arts Commission and - *Sunday Times* Building of the Year Award for 1994.

Situated on the outskirts of Coventry at Westwood Heath, the college incorporates high quality teaching and residential accommodation for long and short-term courses and business support in technology, management and sales and account management for the Cable & Wireless (C&W) Group.

There are two lecture theatres, 20 classrooms and 22 technical training rooms for teaching, in addition to a well stocked library. Accommodation for residential courses is provided by 168 study bedrooms, divided between nine houses. C&W also provided a central restaurant facility, while recreational activities are catered for by a high quality leisure centre incorporating a 25 m indoor swimming pool, large sports hall, squash court, aerobics gym, sauna and café-bar.

The college is made up of three building blocks. The single storey teaching blocks lie to the south of the site, with the three storey residential/administration block to the north and the sports and leisure centre to the east. Gross floor area is 12019 m^2, with the treated floor area covering 11 400 m^2.

The client's brief was for a low tech but distinctive building. To satisfy this, the designers opted to minimise mechanical ventilation and cooling, a decision which led ultimately to the distinctive wave-form roof, a design strongly influenced by the requirements of buoyancy-driven natural ventilation. This ingenious building form solves the problem of how to naturally ventilate what is effectively a 45 in-deep space.

On completion C&W London handed over the building to its operating division, the training college. From C&W's point of view this proceeded very smoothly with no major problems, and it is very pleased with the building. C&W attribute its high overall satisfaction to the close working relationship and continued involvement with the design team[1].

However, although C&W's Clerk of Works was able to maintain high standards of build quality through persistent checking, in April 1996 the Clerk of Works was still completing the snagging reports.

Services issues

For a full services description readers should refer to the original *Building Services Journal* article “Cable talk”[2]. The building is predominantly naturally ventilated for predicted internal gains of up to 50 W/m^2. Heating in the residential and teaching blocks is provided by 1thw perimeter convector heaters served by modular boilers housed in a central plantroom.

In classrooms and technical teaching rooms which have predicted heat gains above 50 W/m^2 there are recirculating downflow fan coil units served with chilled water from a 47 kW packaged chiller. Air supply is via displacement terminals set in the floor.

It is not clear how simultaneous heating and cooling is avoided in those classrooms served by 1thw radiators and fan coil units. The chiller plant is controlled separately from the heating plant, but is timed to operate between 05.30 h and midnight to maintain a flow set-point.

Control of the services in the teaching and residential blocks is largely left to individuals. All internal lights are switched manually and convector heaters are fitted with thermostatic radiator valves. Classrooms each have a pair of thermostatically-controlled radiators, one against the north wall and one against the south wall.

Several classrooms in the east block were reported to suffer from underheating when external temperatures were unusually low, as was confirmed by several responses in the PROBE occupancy survey — including one claiming that coats had to be worn in the classroom.

Flow temperatures and control have been checked by designers, suppliers and contractors with no conclusion. Emitter sizing combined with larger-than-typical areas of exposed glazed surfaces are thought to be the most likely sources of the problem.

The dining hall suffers a specific problem of cold draughts through external doors when an eastwind blows during winter. Adding lobbies was considered, but rejected due to the cost and complexity of adapting the patent glazing system.

The leisure pavilion is serviced independently from the rest of the college. All the services and lighting systems here have sophisticated automatic controls, although the pavilion is not sub-metered for either gas or electricity consumption — allegedly a victim of budget constraints.

The swimming pool is heated from the primary heating circuit via a plate heat exchanger. A constant temperature secondary circuit serves the heating coils in the main ahus and underfloor heating coils in the sports hall.

The sports hall is naturally ventilated via large horizontal opening grilles on the north and south walls. According to demand these are slid open and closed by an attendant by way of a long pole.

The sports hall has been used for evening functions including dinner dances, during which the wooden flooring is protected by temporary carpets and boarding which isolates the underfloor heating. Air temperatures, even with portable air heaters, are consequently rather low. Air temperatures for comfort in sports halls are quite different to those in function rooms, and arguably it was a failing of the brief to specify the requirement for a multi-use hall.

Natural ventilation performance

For natural ventilation the original design studies predicted a near linear increase in air change rates with increasing internal gains, from 7 ac/h at 10 W/m^2 to 12 ac/h at 50W/m^2. The 50 W/m^2 upper limit for natural ventilation was determined more from the comfort limitation of the hot stratified layers than it was from the limits of ventilation driving forces.

Monitoring of classroom temperatures by the Building Services Research and Information Association (BSRIA) in July and August 1994, when the peak external temperature was above 26°C on two days, showed that peak temperatures in the occupied space were maintained at about the external temperature[3]. The BSRIA study monitored window and door opening — although electrically driven, the windows are opened and closed by manual switches — and found that, normally, windows remained in one position throughout the day. On only two days out of 36 were the window positions adjusted on hotter days classroom doors were used to assist ventilation when the windows were fully opened.

There are minimal interlocks between the operation of potentially conflicting systems (ventilation — heating and cooling). The designers justified the absence of overriding ventilation control on the basis of the building being lightweight and, hence, responsive, with only a small benefit to be gained from the use of night cooling.

The BSRIA study concluded that the provision for night-time precooling and daytime ventilation control could have reduced maximum internal temperatures later in the day, as classroom temperatures at 09.00 h were often above 22°C, while external temperatures were about 16°C.

During the hotter summer of 1995 no complaints were received by the Clerk of Works about overheating in the classrooms, and the anecdotal evidence from staff and students suggests that conditions were pleasantly cool. However, the findings of the PROBE occupancy survey show that support staff perceived summertime air temperatures in their working areas to be significantly worse than national benchmarks.

Lighting and controls

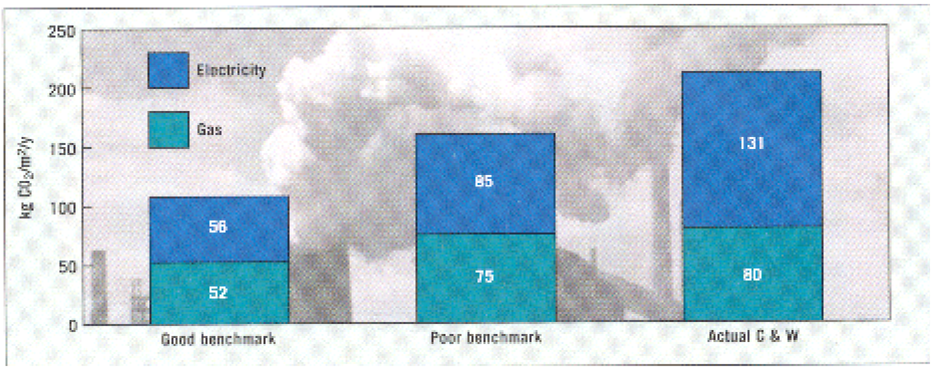
A typical classroom of 36 m^2 floor area has about 2 m^2 of high level translucent glazing to the south and a total of 8 m^2 of glazing to the north, of which two thirds is translucent. There are 81 classrooms in total (29 of which were occupied during the PROBE survey). Motorised diffusing roller blinds can cover the entire north glazing providing additional glare control — in most classrooms the white boards are positioned beneath the north glazing, but do not have their own lighting.

Artificial lighting is from eight luminaires with twin 36 W high frequency lamps arranged in four rows and switched in blocks of four front and rear, giving an installed load of 17 W/m^2. During the survey on an overcast March morning, illuminances at desk height were measured at 100 lux with no electric lighting and 400 lux with all the lights on, both with no blinds.

Daylight levels under overcast conditions seem insufficient to avoid artificial lighting, and during the visits the lighting was invariably switched on in occupied classrooms.

The classroom lights, roller blinds and opening vents are all manually switched from a column of switches near the door. During the survey the lights were on in 25% of unoccupied classrooms — the use of occupancy sensors could improve this.

Figure 1 calculated CO_2 emissions for thge Cable & Wireless College



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Occupancy survey results

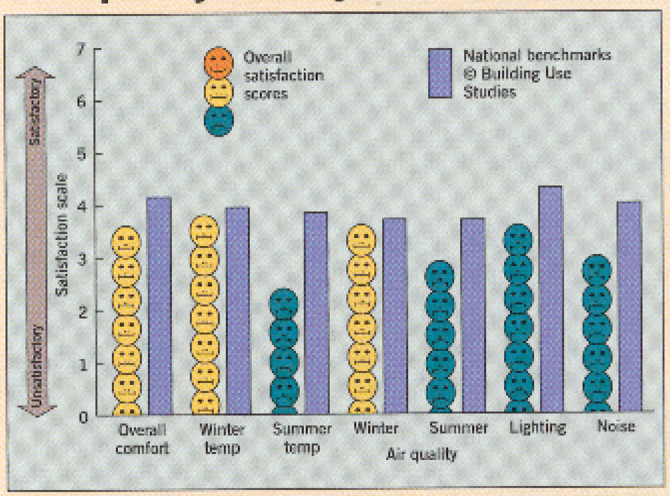


FIGURE 2: Overall satisfaction scores compared with national benchmarks.

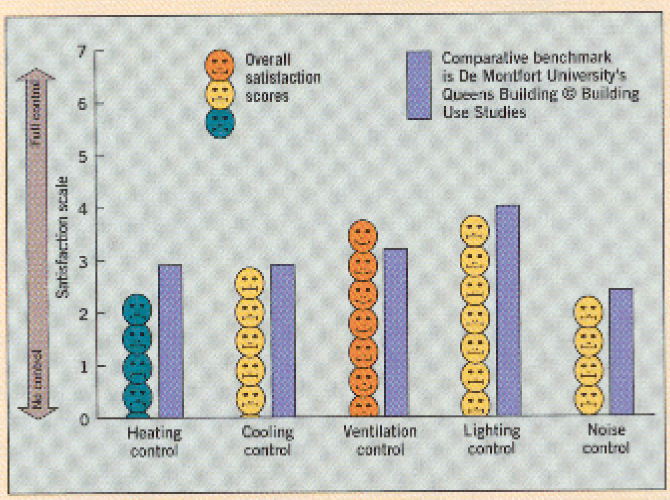


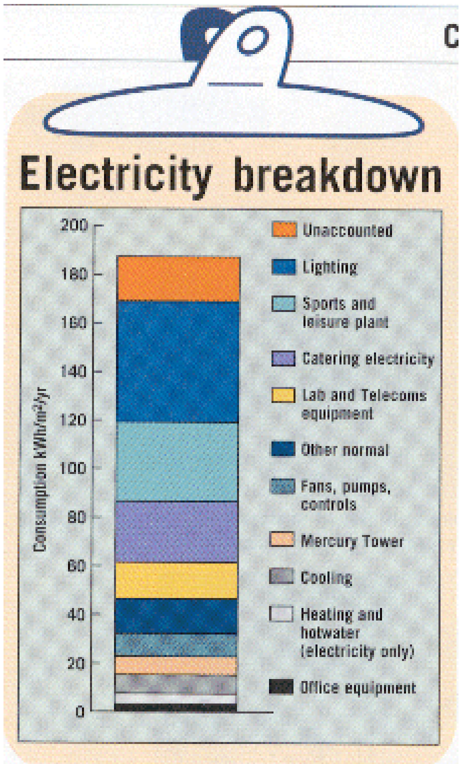
FIGURE 3: Occupancy satisfaction with control strategies – note the benchmark.

Corridors running east-west between the classroom bays are lit by a mix of twin 18 W compact fluorescent lamps and 20 W halogen lamps. Daylight comes from a series of

small domed rooflights supplemented from side windows where an outside wall is available. Each of the five corridors has an installed lighting load of 2 kW, which was all switched on during the survey ensuring light levels were not below the 100 and 300 lux recommended for corridors and entrances by the CIBSE *Code for interior lighting.* However, considerable variations in daylight availability were measured—illuminance levels between 20 and 1600 lux being recorded in one corridor with the lights off.
The halogen lamps are located around the domed rooflights, and could be switched off for the majority of daylight hours with minimal loss of light levels. For this to happen in this type of building a simple daylight responsive automatic control would be needed to switch off the halogen lights when the outside light level exceeded a given threshold. Unfortunately, from the energy perspective, it seems that the halogen lights are being used to produce the impression of strong daylight from the rooflights, and it is understood that they are only switched off late at night by a security patrol.
Artificial lighting was generally on in cellular offices despite ample daylight levels from the full height north-facing glazing. Occupants in this area find it difficult to avoid reflected glare on vdu screens from either the large areas of glazing or the multitudes of bright electric light sources.
LV halogen lamps are used extensively throughout the college. These were initially 35 W with individual 35 VA transformers. However, large numbers of transformers and lamps failed and most are now rated at 20 W. In particular, the reception lounge and library are almost entirely (and continuously) lit by these feature lamps. Delegate rooms each have twin compact fluorescent uplighters, 1v halogens and gls task lamps.
A sophisticated automatic lighting control system in the leisure centre could provide flexible lighting use, but in practice it switches all the lights on at 05.30 h and off again at midnight.

Restaurant and catering areas

The restaurant is highly glazed to the south and west and suffers from both overheating and underheating, as well as draughts. The administration support staff are located in a linear open-plan office on a mezzanine floor above the kitchen and servery, looking onto the dining area. Therefore, these staff have to suffer the distractions of the dining area and its associated smells and noises.
The kitchen, on the ground floor of the administration block, has no external fabric elements. Ventilation is therefore provided by a variety of supply and extract systems — kitchen extract, kitchen hood supply and makeup, kitchen wash-up supply and dishwasher extract. Three of these fans are fitted with adjustable speed controllers (which appear to have been retrofitted, although this has not been confirmed) which were all set to between 95 and 100%.



There have been long-running difficulties with the adequacy of kitchen ventilation. During the summer of 1995 air temperatures recorded behind the serving counters were as high as 38°C, and in the dishwash room as high as 33°C. These high temperatures have been attributed to lack of air movement and the absence of any mechanical cooling. Cooling coils are now going to be installed to the kitchen air supply.

Energy issues

The college does not fit existing categories for energy consumption benchmarks. The three distinct blocks are not separately metered, making it impossible to dissagregate the energy consumption precisely. Also, the on-site Mercury transmitter tower is not sub-metered.

To create a (weighted) treated floor area benchmark for the Cable & Wireless College, the PROBE team combined the energy benchmarks from Energy Efficiency Office data on a standard hotel, university academic buildings, leisure centres and swimming pools.

The annual energy consumption of the college (400 kWh/m^2 gas and 187 kWh/m^2 electricity) is significantly higher than the typical/poor benchmarks calculated on this basis. Total CO_2 emissions at 211 kg/m^2/y are about one third higher than the typical/poor benchmark (figure 1).

Over the 24-month period from 19 April 1994 to 18 April1996, the total annual electricity consumption averaged 2129 MWh (187 kWh/m^2 treated floor area), at a cost excluding vat of £112 000 (5.3 p/kWh). Average monthly total consumption was 177 MWh, split between a daytime (07.30 h — 00.30 h GMT) consumption of 138 MWh and nighttime (00.30 h — 07.30 h GMT) consumption of 40 MWh.

Interestingly, the monthly night-time consumption of 40 MWh represents an average load of approximately 190 kW. If this is assumed to be the baseload over 24 h then it accounts for 137 MWh or 77% of the total monthly consumption of 177 MWh.

The high specific electricity consumption is greater than expected for a building of this type. Unusual equipment loads related to the telecommunications account for only 10% of this consumption, about 20 kWh/m^2.

The energy data for fans, pumps and controls includes all heating and cooling circulating pumps and toilet and bathroom extract fans as well as their controls in the residential, teaching and administration blocks. The lighting consumption level, measured at 50 $kWh/m^2/y$, includes all of the internal lighting.

SERVICES CONSULTANT FEEDBACK

The PROBE study into the Cable & Wireless College is welcome as, for the first time, an attempt is being made to understand how buildings really perform, *writes John Berry.*

Engineers can only present the opportunity to conserve energy, while it is the users who eventually manage that opportunity to their advantage, or not. The BRE has confirmed the efficacy of natural ventilation for such deep-plan teaching rooms, which incidentally would otherwise have been mechanically ventilated.

To be fair, it is only the teaching wings at Cable & Wireless which have had any particular claim to energy efficiency, and even that has been limited to the novel form of natural ventilation. The rest of the campus is conventional in engineering terms. Apart from the summer of 1995 being the hottest on record, which may cast some doubt on the performance indicators, the teaching wings perform well. The overall performance is distorted by complaints from the kitchen and dining areas.

Obviously communication is an important factor in the success or otherwise of a project. Despite the client being told of the BSRIA study which discovered that opening windows at night would be beneficial to comfort, the message apparently failed to percolate down to the workplace. Likewise with the low winter temperatures, where a single tweak of the compensated water temperature is all that is needed. In any situation where the user has control, which we still believe to be the best way forward, education is essential. There is clearly room for improvement here.

With hindsight some degree of automation would have been beneficial, particularly for lighting. However, buildings are not static objects and improvement in use should be a continual process.

There is no question that the energy use results are disappointing, but a single number does not tell the whole story. In a mixed campus setting it is essential to understand where the energy is going before even thinking about conservation issues.

Lack of submetering is a lesson for all because the college is not alone in having a single point of measurement. We believe that the catering and leisure facilities influencing the readings to a large degree, because they are large energy consumers or not operating at their peak. We believe the building fabric to be sound.

It is important that lessons are leaned from such PROBE investigations, for example electrical consumption. Unified energy management and improvement policy for the college should reap large rewards, and shift the energy consumption to the good area where it rightly belongs.

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Office equipment includes all management and teaching pcs, printers and photocopiers and reflects the low density of their use. Catering and vending includes kitchen consumption based on 1500 W per meal served (an average of 400 meals are served per day), kitchen ventilation and use of the 24 h vending facilities.

The leisure pavilion electricity consumption, measured at some 33 $kWh/m^2/y$, includes all pumps, fans and controls and assumes 18·5 h operation, except for the main pool hall ventilation.

Based on spot current readings, the Mercury communications tower was assumed to

represent a 10 kW load running continuously.
Despite a thorough survey of the site and what are believed to be reasonable assumptions about equipment power loads and usage, it has not proved possible in the time available to account for 10% of total annual metered electricity usage.
The majority of gas meter readings over the past two years have been estimated by the gas suppliers. For the 11 month period to March 1995, weekly meter readings were made by the maintenance staff. Combined with meter readings made since March 1995, this means that two years of monthly consumption data is available.
For the 24-month period running from 19 April1994 to 18 April1996, total gas consumption for the whole site was 9104 MWh (4552 MWh/y or 400 kWh/m^2/y treated floor area). In July 1994 average daily consumption was 4600 kWh. In the winter period 26 November 1995 to 14 March 1996 average daily consumption was 15 140 kWh.
This relatively high annual consumption maybe accounted for by long hours of heating operation combined with a high surface area to volume building form which incorporates extensive areas of glazing.
The client reports that billing costs are checked using simple trend analysis to determine erroneous bills, but apart from this the college does not apply formal energy management techniques.

Occupancy issues

Two questionnaires were administered during the PROBE occupancy survey — a standard questionnaire as used in the previous PROBE office surveys was distributed to 47 permanent staff (with 44 returned), with a condensed version given out to 48 course delegates.
As the majority of the results refer to permanent staff, in the main the data refers to conditions within staff working areas rather than the teaching classrooms.
These permanent staff consist of management, support staff and teaching staff. Management staff are generally accommodated in individual cellular offices with opening windows. Support staff are located in a corridor style office space on a mezzanine level open to the restaurant area.
70% of permanent staff have worked in the building for more than one year, and 42% had been in the same work area for over one year. Although 95% worked a normal five-day week with 80% spending more than seven hours a day in the building, only 56% spent more than seven hours at their desks, reflecting the highly mobile nature of the lecturing staff. A relatively low 42% said that they sat next to a window.
For permanent members of staff, perceived overall comfort, winter temperatures and winter air qualities are not significantly different to reference benchmarks, but perceived summer temperatures, summer air quality, lighting and noise levels are all significantly worse (figures 2 and 3).
In general, delegates were far more satisfied with internal conditions than staff. This is consistent with other surveys which show higher response by visitors and students compared to permanent occupiers, but it may also reflect the fact that most of the delegates surveyed would not have experienced mid-summer or mid-winter conditions.
Compared to the reference benchmark, staff reported significantly less air movement, more humidity and stuffier and smellier conditions in summer. In winter they reported significantly more draughts and stuffiness than the reference benchmarks.
Staff members also reported that lighting tends to be unsatisfactory, with probably too much artificial light and too much sun and sky glare. (This would seem to be backed up by the general impression of highly glazed areas adjacent to working areas, in

conjunction with large numbers of artificial lights that are in operation).
Overall, the members of staff at C&W feel that the building causes a productivity loss of around minus 8%. However, dissatisfied and neutral staff report a productivity loss of minus 14%. 33% of staff questioned said they are satisfied with comfort, while 66% said they are dissatisfied.
The generally low satisfaction of permanent staff regarding internal conditions is quite surprising, considering the very attractive architectural nature of the building, and it maybe that other effects are present.
However, it is difficult to be definitive because of the relatively small sample (44 staff) and varied nature of working areas across the site, including the undeniably poor environment in which the office support and kitchen staff work, which might act to drag down the average response.

References

[1] Anon "Where delegates go to have fun", *The Architects' Journal,* 11 August 1994.

[2] Brister A, "Cable talk", *Building Services Journal,* November 1993.

[3] Martin A 1, "Control of natural ventilation", *BSRIA Technical* Note *TN 11/95,* BSRIA, 1995.

The authors would like to thank Gordon Cox for his help on site, and Adrian Leaman of Building Use Studies for administering the occupancy survey.

key design lessons

The architect has devised an elegant and visually appealing form for the classrooms.

Architectural design

The building is unquestionably an architectural delight. The ingenious building form of the classrooms has proved an elegant and largely environmentally successful solution to the problem of naturally ventilating what is a very deep-plan space. In some other parts of the C&W College the environmental (and energy) consequences of the architectural design are disappointing.

Restaurant and administration areas

Extremely high glazing areas contribute to summer overheating and glare in the restaurant and mezzanine office areas. Typically, the environmental problems created by such a design might be solved by air conditioning. Without it, the comfort of the permanent members of staff has been pushed to the limit.

View of the dining area with the mezzanine on the left. Note the high area of glazing.

Low energy design

The naturally ventilated classrooms with waveform roofs, which have earnt the college a low energy label, seem to be its only energy saving feature. Actual energy consumption significantly exceeds a typical or even poor benchmark for such a complex, possibly due to lack of effective lighting controls, a high surface area to volume building form and overglazing. It seems unfortunate that neither condensing boilers nor small-scale chp have been used. The college's annual energy consumption is significantly higher than that of the typical/poor benchmarks, while total CO_2 emissions are about one third higher than the typical/poor benchmark levels.

The energy consumption of the teaching rooms exceeds typical benchmarks.

The sports hall and its lighting system. The electrical consumption of 187 kWh/m² is significantly higher than the typical/poor benchmarks.

Lighting

Installed loads average 15 W/m² which can be considered reasonable but not low energy. Manual control of lighting in the classrooms seems to be reasonably effective, but classroom corridor lighting consumption could be reduced by simple automatic switching in relation to outside light levels. The automatic lighting control of the sports pavilion breaks all efficiency rules by switching all lighting on for over 18 h every day despite highly variable usage. It appears that its complexity and lack of