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Indoor air quality in Brussels

Paul Appleby describes a building health investigation which gives the EEC Council of Ministers' meetings rooms a clean bill of health, but identifies a number of problems with the environment.

Above: The Charlemagne building.

Passive smoking and draught were identified as common causes of complaint amongst ambassadors and their staff in the recently refurbished meetings rooms on the 15th floor of the Charlemagne building, the headquarters of the Council of Ministers of the European Commission in Brussels.

These problems were identified by a multi-disciplinary team, brought together by Brian Colquhoun and Partners of London and now offering building health audits and design advice under the name of Building Health Consultants.

As well as indoor air quality problems, the team found uneven illumination, with glare and low lighting levels in the meeting rooms, which suffer from contrasting surface brightness and a lack of decorative embellishment.

They carried out their investigation in a number of stages: starting with an inspection of the rooms and plant and discussions with occupants and maintenance personnel, followed by the distribution of tailor-made questionnaires and surveys of the thermal, visual and aural environments, and observations of air movement, work patterns and smoking habits. Further targeted surveys were carried out after analysis of the questionnaires.

Despite there being nominally adequate rates of fresh air drawn in to central air handling plant for dilution of tobacco odours in the meeting rooms, observations indicated that the air leaving the ceiling diffusers was creating noticeable air movement in the occupied zone and tobacco smoke was tending to travel with very little dilution across the room into the faces of non-smokers. It was concluded that this excessive air movement, combined with convective and radiant cooling in winter from the very large single-glazed windows, would account for the draught.

The investigating team have suggested a number of remedial measures at various levels of expenditure. These include reducing the air movement, without reducing fresh air rate, or, at greater cost, replacing the existing supply air terminals with a system which will effectively generate displacement, or buoyancy-assisted ventilation. They have also recommended altering the lighting to provide a greater spread of illumination and reducing both glare and thermal loads by providing a part-glazed outer skin for the existing near fully glazed window wall.

The 15th-floor services

The Charlemagne building has large areas of single glazing, mostly openable, and a narrow plan floor which is too deep for satisfactory penetration of daylight. It was not designed to be air conditioned and most of the building is still naturally ventilated and heated by radiators.

The 15th floor has been adapted for meetings of the Council of Ministers. There are three large rooms, with seating for 80 to 100 people at inner and outer tables, and a smaller 60-seat room which is used intermittently. The larger meeting rooms are bordered by interpreters' cabins to three sides.

The original 15th-floor environmental services were replaced in 1985, except for supply air distribution ductwork above the false ceilings in the rooms and the circular diffusers which it feeds.

The rooms and their interpreters' cabins are now fully air conditioned, each room being supplied with conditioned air from its own separately controlled air handling unit, the supply air being made up of a variable proportion of recirculated room air and outdoor air. A nominal minimum fresh air rate of 14 litres/s per person is drawn into the plant and adjusted according to occupancy by a return air CO_2 sensor. Each set of cabins is supplied with 100% outdoor air which is conditioned in central plant and then reheated according to load requirements.

Initial observations

The complaints received by management had been non-specific, indicative of a general level of dissatisfaction with the working environment. Random questioning of occupants and observations made during meetings indicated that a number of problems with the indoor environment existed.

The questionnaire was designed to elicit information from the occupants on factors relating to their work which might exert stress on them, to obtain their qualitative opinions about their working environment and to ascertain the incidence of building sickness symptoms. The questionnaire included questions about age and gender, nature of work, journey mode and time, duration of occupancy, smoking habits, use of contact lenses, work-related likes and dislikes, thermal climate, air quality, aural environment, visual environment, furniture, physical comfort and health.

The questions concerning health referred to symptoms which disappear when occupants leave the 15th floor of the Charlemagne building. These covered the classic building sickness symptoms of headaches, nausea, dizziness, irritation of eyes, nose and throat, shortness of breath, tightness of chest, skin rashes, itching or dryness of the skin, joint and muscle aches, flu-like symptoms and general malaise, so that building sickness scores could be assessed for comparison with other studies. The incidence of other stress-related symptoms, such as irritability, depression, anxiety and frustration associated with work, was also ascertained. Further questions were designed to determine what proportion of occupants suffered from respiratory ailments and allergies.

Building sickness scores refer to the average number of workplace-related health symptoms reported per occupant. A recent study of 47 buildings in the UK by Building Use Studies[1] reported scores between 1·25 and 5·25. For air conditioned buildings they found an average score of 3·05 amongst private sector buildings and 4·29 in the public sector. The 15th floor of the Charlemagne building scored 2·9 overall from 127 regular users of the floor. Although this represents a fairly low response rate, this score would indicate that the 15th floor occupants do not suffer from more than an average number of building sickness symptoms.

Occupants' ratings of their environment, however, largely supported the initial observations of the investigating team. More than half the respondents who regularly use the rooms thought them stale or smoky, and inner table users in particular thought them draughty. Around half also voted the rooms too hot, and about the same number too noisy. Around a third of inner table users complained of glare and excessive illuminance, whilst nearly the same proportion of outer tables users had similar complaints, some 20% thought it too dim.

Room air conditioning

Despite the number of complaints that the rooms were too hot, measurements over a one-week period indicated that their thermal environment was relatively stable, fluctuating between 20 and 22°C, even with the air handling plant shut down overnight and at weekends. Radiant temperatures did not vary greatly from room temperatures. Air velocities, however, varied considerably, and in many instances exceeded the maximum recommended in *ISO 7730*[2] for comfort of sedentary occupants for the air temperatures experienced.

This may explain why some occupants complain of draught, particularly those seated under the region where airstreams from two diffusers meet and are deflected downwards and into the occupied zone. Smoke tests confirmed this phenomenon and also indicated that cold windows exacerbated it by cooling the already downward moving air which moves with increased momentum into the occupied zone. The convectors located under the tall single-glazed windows only had the effect of deflecting this downward moving airstream into the room.

Smoke tests and other observations also indicated that there was considerable horizontal movement of air within the occupied zone, which led to tobacco smoke being transferred fairly rapidly from smokers to nearby non-smokers. This is exacerbated by the observed short circuiting, whereby some 15% of the total supply air was blowing straight back into the extract system.

It can be concluded from these fairly rudimentary observations that, in general terms, the provision of fresh air rates as recommended in national standards does not guarantee an acceptable purity of inhaled air. It is essential that the method of air supply is capable of diluting contaminants to an acceptable level everywhere in the occupied zone or displacing them away from the breathing zones of the occupants. At its evolution, tobacco smoke is hot and buoyant and will tend to move upwards. An air diffusion system which has a majority of downward velocity vectors may prevent this buoyant plume from rising, whilst the plumes from other heat sources, such as occupants, meet the downward vectors and create a turbulent but mostly horizontal movement air at head level.

Above: A thermal environment survey was carried out by the investigating team, coupled with the distribution of questionnaires. Part of the problem was found to be the large areas of glazing, visible in the background.

Displacement ventilation systems[3] supply the air directly into the occupied zone at a velocity and temperature which does not produce excessive draught, and feed the convective plumes leaving the heat sources so that there is a general upward movement of air and contaminants. Hence the mainstream and sidestream tobacco smoke generated during a puff will be carried upwards and stratify above the occupant's head before being extracted. Smoke emitted by tobacco burning in an ashtray may, however, be drawn into the boundary layer of the convective plume of a nearby non-smoker.

It was recommended that this displacement ventilation principle be employed to solve the tobacco smoke problems in the rooms. There being very little wall space available on which to mount low velocity air terminal devices, it was suggested that air be supplied from high level into the unoccupied region enclosed by the inner ring of tables. It was also envisaged that a much reduced air volume would be required with the plant operating with 100% fresh air.

The visual environment

As analysis of the responses to the questionnaire had indicated, an illumination survey showed that light distribution was uneven – with the highest illuminance levels being measured at the inner tables, levels being daylight-dependent close to the window walls and inadequate along those internal walls furthest from windows. The glare is due partly to artificial and partly to natural light sources.

The warm white fluorescent lamps are mounted in a diffuser which has smoked perspex baffles at right angles to the tube axis, hence reducing the sideways light emission along its axis. Illuminance directly below these lamps and close to the windows was measured as high as 1800 lux, even on an overcast day. Whilst, at the same time, levels measured at outer desks furthest from the windows were as low as 500 lux, and on dark vertical surfaces as low as 250 lux. Hence there is a considerable contrast between the working surface, the light sources and the other surfaces in the room.

The large area of unobstructed sky seen through the windows represents a particular glare problem. Whilst they do provide daylight and a link with the outside world, the link is tenuous since it is uncluttered with scenery; the daylight provides a greater illuminance than is required close to the windows and glare to those facing the windows.

In order to provide a more even illuminance it was suggested that the smoked baffles be removed from the luminaire faces. It was thought that a more pleasing appearance could be created by the use of full-spectrum artificial daylight lamps. It was also suggested that the window area be reduced and the insulation improved by the addition to the existing wall of an outer one containing only 40% glazed vertical panels.

Conclusions

This investigation was a very good example of the effective application of questionnaires and targeted measurements and observations. It is thought that the main causes of complaint have been identified without having to resort to lengthy and expensive ventilation and contaminant surveys. These may have been required, however, if the building sickness scores had been higher, or if there had been pointers towards sources of contamination other than body odour and tobacco smoke.

Paul Appleby is an independent consultant and md of Building Health Consultants. The author would like to thank Brüel & Kjaer for the loan of instruments and help with the thermal environment survey.

References

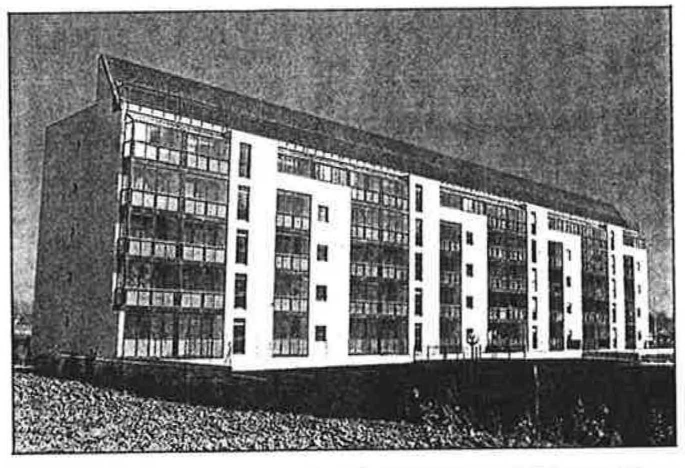
[1] Wilson, S & Hedge, A (1987). *A study of building sickness*. Building Use Studies.
[2] ISO 7730 (1984). *Moderate thermal environments - determination of the PMV and PPD indices and specification of the conditions for thermal comfort*. International Standards Organisation, c/o BSI, London.
[3] Appleby, P H (1989). *Displacement ventilation: A design guide*. CIBSE Journal, April 1989.

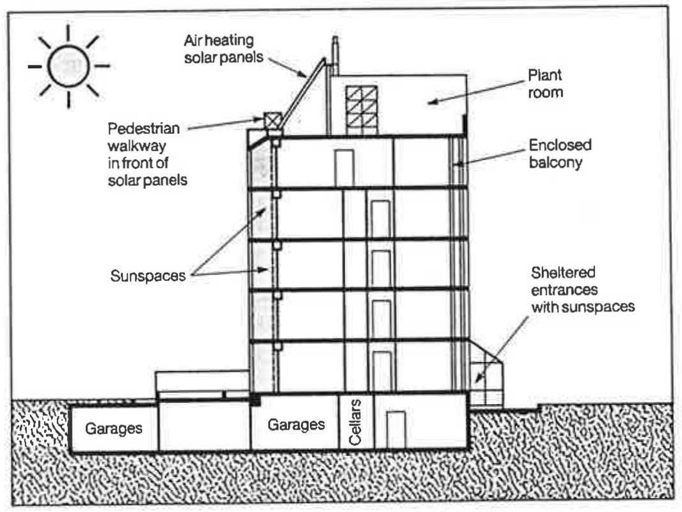
To rent or to own?

A block of apartments in Turin, Italy, illustrates the importance of user involvement and understanding in passive and solar energy techniques, reports *Stephen Ashley*.

An extensive energy demonstration scheme has been carried out in Italy by the government sponsored UPSE (Unione Piemontese Sviluppo Edilizio). In 1984, a block of apartments was completed in Turin to test the efficacy of a package of passive and active solar measures in the Po valley climate. Temperatures here average close to freezing in winter and over 20°C in summer. There is often fog and rain.

The results of the three year monitoring programme underline a very important lesson. In identical apartments, owner occupiers were able to save some 34% of the primary energy that would be used for space heating in a conventional version of the block while tenants saved little or nothing at all.





Top: Solar block, exterior view; *Above:* South-north section.

Solar design

Two blocks were built, facing each other along an east-west axis with a 15° tilt towards west, but only one was adapted for solar energy. The main energy features were orientation and space planning, sunspaces, insulation and solar panels. The 56 apartments vary from one to three bedroom units and all but the smallest have views to north and south. Kitchens are on the north side and have small enclosed balconies which act as storage space in winter and cool shaded balconies in summer. Bathrooms in the centre allow all the living rooms to have good daylighting. Sunspaces are included on the south façade.

Construction is typical of the continental tunnel system approach and comprises a mix of *in situ* and prefabricated components. Heating pipework is cast into the walls, bathrooms have a false wall for services access and the 150 mm concrete walls and floors work well both acoustically and thermally. Outer walls are insulated with 60 mm of polyurethane foam. The south façade is of prefabricated concrete panels, 230 mm thick, with an inner layer of 60 mm polystyrene. All windows are double glazed and well sealed.

Sunspaces 3·5lThm by 1·4 m or 1·9 m and 2·7 m high lead off the south facing rooms. Their windows are single glazed and can be folded back to completely integrate the sunspace into the room. There are manually operated blinds and awnings for shading. The sunspaces allow the entry of winter sun but no direct summer sun. Ventilation is good with cross ventilation supported by fans in the bathrooms and kitchens.

The same heating system has been used as in most of the UPSE demonstration projects. Air is preheated in the roof-mounted solar collectors and, when necessary, is further heated by a central gas fired boiler. This heated air is distributed by ducts and grilles. Radiators are used in kitchens and bathrooms as Italian building codes do not allow air heating in these areas.

The average area of solar panel for each apartment is from 6 to 7 m^2 with a total air flow rate between 270 and 350 m^3/h. In winter a third to one half of this flow is used for ventilation preheating with the remainder used for water heating. In summer the air flow is used entirely for water heating.

Monitoring results

Monitoring carried out over three years involved hourly readings of the main energy parameters. The owner occupiers are reported to be very happy with their apartments while the tenants complain about theirs. In the rented section routine maintenance is not carried out on the heating system leading to failures and complaints. Tenants are not instructed on what solar features are provided and on how to use them. They have no financial interest in saving energy as they pay a fixed cost for heat regardless of how much they use. Because of these essentially management failures, virtually no savings have been recorded over a conventional block.

Taking the owner occupied apartments, passive solar gains contributed 16% to the gross space heating load and the active system contributed a further 6%. The shading and ventilation measures worked adequately against overheating. Overall this part of the building saved 34% of the primary energy necessary to heat a similar building built to Italian building codes. The solar measures are estimated to have cost 2·7%, and all the energy saving features some 8·3%, of the total building cost. Using current gas pricing, savings due to the solar measures have a simple payback period of 20 years.

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Project data

Collegno, Via F Parri, Torino, Italy.

Building details
Volume of whole block: 15 646 m^3
Number of floors: 5
Number of flats: 56
Total floor area: 5142 m^2
Roof area: 934 m^2
Window area
Total: 938·5 m^2
South: 626·5 m^2
North: 626 m^2

Sunspaces
Volume: 1055 m^3
Floor area: 398 m^2
Glass area: 613 m^2

Solar collector area: 389 m^2

Thermal characteristics
Roof: 0·65 W/m^2K
Floor: 0·65 W/m^2K
North/east/west walls: 0·50 W/m^2K
South wall panels: 0·56 W/m^2K
Windows: 2·5 W/m^2K
Global heat loss coefficient: 7200 W/K
Infiltration rate: 0·5 ac/h
External design temp: −8°C
Net heat load: 41·2 kWh/m^2

Site
Altitude: 302 m
Latitude: 45° 5'N
Average ambient temperature:
January: 2·4°C
July: 21·6°C
Degree days: (base 19°C) 2570
Global irradiation on the horizon: 1372 kWh/m^2
Sunshine hours: 1979 h/y