ENERGY COMFORT 2000 - THE APPLICATION OF LOW ENERGY TECHNOLOGIES TO SEVEN NEW NON-DOMESTIC BUILDINGS.

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ABSTRACT

This paper describes the results coming out of the European Commission supported THERMIE Target Project Energy Comfort 2000. This was the first Target project, containing eight non-domestic buildings, started in July 1993 and to be completed at the end of 1998. The project aimed to design and construct buildings which use less than 50% of the energy of a traditional equivalent, by using passive methods, particularly to avoid the need for air-conditioning. High quality internal conditions were to be achieved. The overall conclusions are that 50% savings in energy use can be readily achieved in a variety of buildings, whilst maintaining good quality internal comfort conditions.

KEYWORDS

Passive, solar, daylighting, natural ventilation, shading, controls, atria, thermal mass, night cooling.

BACKGROUND

Energy Comfort 2000 is a THERMIE supported target demonstration project on innovative energy efficiency in non-domestic buildings. It was started in July 1993 and will be completed late in 1998. It aims to demonstrate integrated low energy solutions with good internal comfort conditions, in offices, universities and similar buildings based on design, construction and monitoring of seven new buildings in five European Countries. Horizontal activities link all the projects to share and compare experience and knowledge, and results are being produced for dissemination in the form of "Information Dossiers" on specific topics. These Dossiers form the basis of much of this paper and further details can be obtained from them.

Originally eight buildings were to be designed and built in six European Countries, however the Spanish building, a speculative office at Valladolid, could not in the end be built due to planning delays and funding problems. The following buildings are now constructed and in use:-

- Lisbon EXPO 98 Multi-purpose Pavilion, Portugal. (EXPO98)
- Anglia Polytechnic University, the Queen's Building, Learning Resources Centre and offices, UK. (APU)
- Schiedam Municipality Public Building, The Netherlands. (Schiedam)

- Two Aix en Provence University buildings, France. (Aix)
- An extension to the Tax Office in Enschede, the Netherlands. (Enschede)
- Speculative Offices at Leeds City Office park, UK. (Leeds)
- Offices for the Headquarters of AVAX SA in Athens, Greece. (AVAX)

The design objectives of EC2000 were to reduce energy consumption by at least 50% compared to conventional design, by minimising energy uses for all purposes but maintaining good internal comfort conditions. The avoidance of air-conditioning by passive design of the buildings and fittings was seen as one of the major principles. In southern countries this was interpreted as designing to minimise the use of air-conditioning, which was often seen as desirable in mid summer and under certain conditions of use.

DESIGN STAGE ACTIONS AND RESULTS

Windows

Analysis of the EC2000 buildings window designs is contained in the "Windows - the key to low energy design" Dossier. Careful design to combine good daylighting with necessary solar shading, whilst avoiding glare, has been used in the buildings. APU, Leeds, AVAX and Enschede use a combination of vision and daylight windows, with internal light shelves at APU and Enschede. All windows other than north facing windows have solar shading, and a whole range of systems is demonstrated, including vertical external moveable devices on the east facade at AVAX, pull down external perforated aluminium at Aix, venetian type blind externally at Enschede and between glazing at APU, and fixed horizontal shading at Leeds. Windows are manually openable in all buildings (except EXPO98 which is a particular use) allowing inlet and outlet ventilation, though predominantly inlet in the three atrium buildings, APU, Enschede and Leeds. Glazing is all double except for triple glazing at APU, with low e glazing used at APU, Enschede and Schiedam. EC2000 buildings demonstrate the importance of integrated window design and show some of the many possible options.

Natural ventilation

Dossier number 2 "Natural Ventilation and cooling strategies in new office designs" summarises the EC2000 ventilation designs. Four buildings are naturally ventilated, APU, Enschede, Aix and Schiedam whilst Leeds, AVAX and EXPO98 are mechanically ventilated, though all use passive assistance either with cross ventilation from windows or atrium stack effect.

The Dossier concludes:- Passive ventilation design encompases a variety of techniques, for example in APU the even distribution of air was ensured by varying the opening of windows with floor height, while in Enschede self adjusting air inlets were used. Wind creates a draw in APU by opening of windows in the pitched roof of the atrium, whereas in Enschede special ventilation cowls are used. It has been demonstrated that passive ventilation designs can be made to overcome specific problems such as noise, security and potential overheating and used in climates ranging from Mediterranean to northern climates. New design tools, such as CFD and multi-zone models, are suitable in the first design phase to evaluate different ventilation concepts and in the following phases to optimise passive ventilation solutions. Passive ventilation can be designed to fit a specific building if architect and ventilation consultant cooperate closely.

Control strategies

All EC2000 buildings use a mixture of manual and automatic control, except for EXPO98. For lighting, all buildings except Schiedam and Aix use automatic control with manual override. In EXPO98, APU and Enschede a daylight sensor is employed together with a timer, whilst at Leeds and AVAX daylight sensors with occupancy detection are used. For ventilation control, apart from the manual window opening referred to above, the three atrium buildings APU, Leeds and Enschede, use automatically opening vents in the atria roofs. At Schiedam there are automatically opening low level wall vents and at Enschede the high level vents are controlled by wind pressure. All EC2000 buildings use centralised Building Energy Management Systems to control several functions.

Night cooling.

The use of night cooling is an essential part of the cooling strategy in APU, Enschede, AVAX, Leeds and Schiedam, with fans used at the two mechanically ventilated offices, AVAX (20-30 ach) and Leeds (5ach). The other three rely on natural night ventilation with open vents and windows. All are controlled by the BEMS to avoid overcooling. Exposed concrete ceilings and walls have been designed into these buildings to provide the necessary thermal mass and APU has additional concrete added on the top floor ceiling to increase the thermal mass in this critical zone.

Internal heat loads

The issue of internal heat gains has been addressed in most EC2000 buildings to minimise direct energy use and so that cooling loads are not overestimated. Efficient lighting and control of lighting have been addressed as above and installed lighting loads have been estimated between 6 and 12 W/m^2. Office equipment loads have been assumed at between $15W/m^2$ and $25W/m^2$ for more intensive use in the "mediatheque" at Aix. Occupant gains are assumed at between 7.7 and $12W/m^2$.

Overall environmental assessment

The buildings were assessed using the UK BREEAM system and are of a high environmental standard, with one "Excellent" rating and five "Very Good" ratings. The high environmental scores reflect the large amount of effort put into the projects from the start, particularly with the Leeds and Enschede buildings (Enschede is only one credit away from an Excellent rating) where the buildings were originally planned to be as environmentally friendly as possible. The APU and Schiedam buildings were designed earlier then others and this may be a reason why they did not achieve higher scores. Country differences and national experience in designing environmentally friendly buildings may be the reason why the buildings in France, Greece and Portugal did not achieve higher ratings. The Aix building, bei g the result of an architectural design competition, suffered from a somewhat low priority being put on environmental issues in the or ginal concept, always difficult to make up at later stages.

MONITORING RESULTS FROM TWO BUILDINGS

All buildings are being monitored to assess their energy and comfort performance in use. Two of the buildings APU and Enschede have been monitored for a full year and the results analysed.

Anglia Polytechnic University, the Queen's Building.

Annual energy consumption	Measured energy use	Predicted energy use	Reference energy use
Gas, kWh	570,989	399,998	1,265,400
Electricity, kWh	135,071	259,246	1,111,500
Cost, £	£ 14,281	£ 19,059	£ 76,317
Difference		+ £ 4,778	+ £ 62,036

The annual measured energy consumption of the Queen's building is thus 132 kWh/m^2 of treated floor area (excluding catering) compared with 417 kWh/m^2 for an equivalent air conditioned building. This represents a 68% reduction in energy consumption and a 60% reduction in CO_2 emissions for thermal energy consumption. The Queen's building therefore exceeds the performance targets set by EC2000.

Compared to an air conditioned building, it is estimated that the building will save £240,750 in capital costs and £101,936 in running costs during it's lifetime, as well as £62,036 per year being saved in fuel costs.

The occupants' reaction was positive with a feeling of an open building with a spacious and airy feeling, whilst having a positive energy conscious design. The building users felt that it compared well their expectations and has a prestigious status.

Despite the success of the project there was scope for further improvements to the building. This included:- improved night cooling; reduced lighting energy use; passive humidification during winter; improved daylight distribution; reduced internal noise levels.

The University has since occupation expressed great satisfaction with the end result. The building has been adopted by the Queen of England and received the runner-up prize in the 1996 Green Building Award competition.

The Tax Office Extension, Enschede.

Usage, kWhr/m2, primary energy	Measured energy use	Predicted energy use	Reference
Heating	95	69	75
Lighting	7	12	70
Equipment	39	84	81
Fans	0.1	0	81
Cooling	0	0	34
Total energy	141	165	342

The project thus succeeded in having a overall use of primary energy below the target, with a monitored saving of 59% compared with the reference building. Electrical use of equipment was below the target, which can partly be explained by the offices only being used for approximately 65% of the time. The energy use for lighting was also below the target, which apart from the partial use of the offices, can be explained by the very good daylighting conditions. The energy use for space heating was above the target level, partly due to the internal gains being lower than expected with a consequential saving in electricity. However, extra energy use for space heating was caused through air leakages and insufficient floor insulation. These problems were solved in the summer of 1997, after which the energy use is expected to be reduced further.

Daylight measurements proved that the daylight window and lightshelves performed very well, and if shading in front of the lower vision window is lowered, the room receives daylight from the daylight window only. Measurements show the daylight factor is about 1% to 2% distributed evenly up to a depth of 4.5 metres. Occupants were very satisfied, with 96% were satisfied with the amount of daylight and 88% satisfied with the control of daylighting and artificial lighting levels. The number of people having occasional problems with glare or screen reflections was lower than the old building, at 58%.

The passive ventilation of the offices worked well, only during unusually warm weather conditions during May, July and August was the mechanical exhaust used. The resultant energy use of the extract fans is very low. CO_2 levels were also monitored, as a indication of air quality and ventilation efficiency. It was found that the average CO_2 level is between 300 and 600 ppm, which is just above background level. The maximum level found was 1200 ppm (for 5 hours per month, in occasional offices). This level is still below the maximum of 1500 ppm permitted during an 8 hour workday. In summer, night-time cooling is used with 4 air changes per hour (200 m^3/hour). This was monitored during a two week period with passive tracer gas measurements. It was concluded that the average air change rate was 3.75 ac/h, close to the design value. No 'dead corners' were found, with little cross flow of air between clean and polluted air.

In general, the users of the building are very satisfied, with the following observations:

- There were high ratings by the users for control of ventilation, lighting and heating. There are less problems with cold draughts and the indoor air quality is better than the previous building.
- The acoustic climate has improved, relative to the old building with the number of complaints reduced from 36% to 11%.
- The percentage of absenteeism has lowered by 25% to 30% for occupants who moved from the old to the new building.
- The number of building related health complaints has decreased by about 50% relative to the old building. Relative to other Dutch office buildings, the number of health problems is 70% lower.
- There were some complaints about fumes caused by the diesel train running twice hourly in front of the building.

PUBLICATIONS

"Partial Final Reports" on all eight EC2000 projects, including the INTECO design project in Valladolid, Spain, were printed in may 1998 and are available on request. Eight "Information Dossiers" are completed and available:-

1. Fire safety in Atria.
2. Natural Ventilation and cooling strategies in New Office Designs.
3. Energy efficient buildings- the Client's view.
4. Control Strategies for passive Buildings.
5. Windows - The Key to Passive Design.
6. Design Standards for Low Energy Offices.
7. Environmental Assessment of seven new buildings.
8. Energy efficient building technologies explained.

Four more Dossiers are planned for the end of EC2000:-

9. Climatic Sensitivity of Designs
10. Cost Effectiveness of EC2000 Buildings.
11. Energy Consumption of EC2000 Buildings.
12. Comfort and Quality in EC2000 Buildings.

PROJECT COMPLETION

Monitoring of the other five buildings is continuing at the time of writing this paper but all results are to be collected and the whole of EC2000 completed at the end of 1998. Further "Information Dossiers" will be written as above comparing the monitored results of all projects, the energy use, comfort and occupant and owner reactions.

CONCLUSIONS

The first two EC2000 projects to be completed and monitored have demonstrated that the ambitious design targets of reducing energy consumption by 50% can be achieved in practice. Comfort conditions achieved are reasonable, with occupants particularly appreciating local control and the daylighting and airy feeling of the buildings. Current indications are that these trends will be repeated in the other buildings. EC2000 are not research buildings, they are part of the current generation of environmentally friendly buildings to provide for everyday use - as offices, universities and public buildings. They demonstrate the way forward for much of the future non-domestic building stock.