ANALYSIS

GREEN BY DESIGN

When the client desires a green building, all sectors of the construction industry are ready to respond — as the finalists in a major award scheme demonstrate.

Behind every green building is a good client — for, according to the experiences of a major award scheme, the best entries are for projects that are client-driven. The Green Building of the Year Award for 1997, sponsored by the Heating & Ventilating Contractors' Association and the *Independent on Sunday*, was no exception. The four finalists were all very different types of buildings, but the primary stimulus for an environmentally aware approach to their design, construction and operation came from the client.

Inevitably, very specific solutions were identified to cope with very specific circumstances, since the short-listed projects ranged from the 98 acre Ministry of Defence Procurement Executive headquarters at Abbey Wood, Bristol, to The Centre for Understanding the Environment, an extension to the Horniman Museum in South London. In between were the Groundwork Eco Centre, an office building in Hebburn, South Tyneside and a refurbishment project, the headquarters of Xerox (UK) in Uxbridge.

Concepts

While it would be easier to highlight the building-services aspects of each project separately, that approach would fail to focus on the concepts that were effectively applied to more than one project. Nor would it adequately emphasise techniques that should be intrinsic parts of modern buildings.

Today's green buildings do not exist in isolation. They are both part of and interact with the wider world.

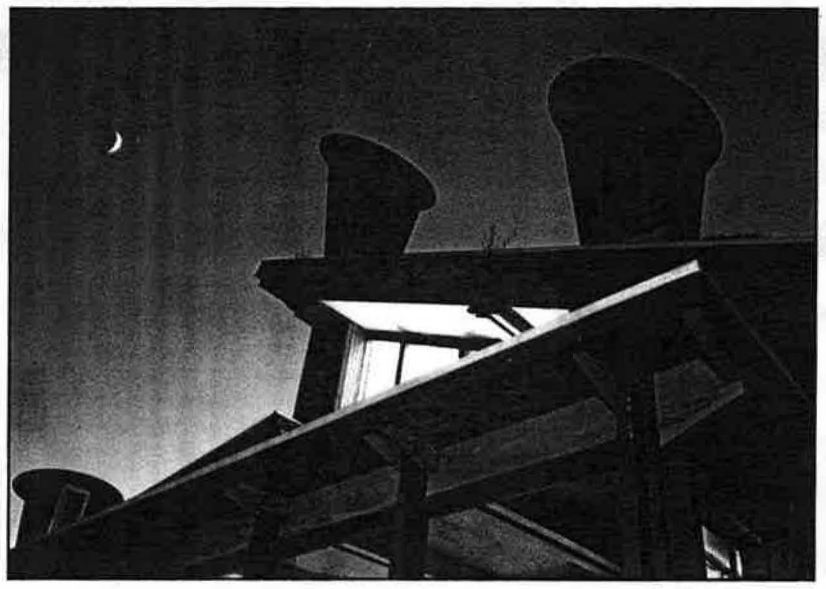
Thus this year's award winning Abbey Wood campus will eventually have more than 5000 trees and 28 000 shrubs. They will help reduce carbon dioxide emissions, which in any case are controlled by design to 76 kg/m^2 a year. All this plant life provides a habitat for wild life, as well as shelter for the 17 buildings and modification of the micro-climate.

Although situated in an urban environment near London's South Circular Road, the highly commended Horniman Museum also uses plant life to absorb carbon dioxide, as well as heavy metals — these tasks being achieved by a sloping roof of grass and wild flowers. A solar-powered pump provides the roof irrigation, which creates an evaporative cooling effect for the building when the Sun is out.

The Eco Centre features trellises with planting to create shade and habitats. Once they are established, external climbing plants will provide shading to eliminate solar gain. More dramatic on this site, however, is the large wind powered generator to produce electricity with no emission of carbon dioxide whatever. Indeed, the site is intended to achieve zero carbon-dioxide emissions and is said to be well on the way to achieving this objective. Solar panels for water heating also contribute to the twin objects of exploiting alternative energy sources and not relying on fossil fuels.

The Eco Centre has achieved its objectives without sacrificing any standards appropriate to a conventional building of this type. By utilising modest and, therefore, accessible standards, it seeks to encourage successful replication. Its power consumption is expected to be 75 kW/m^2, or about 100 000 kWh per year. For comparison, a BRECSU best-practice office would average 130 kW/m^2.

Attention to building orientation is also mandatory so as to realise the energy-saving benefits of sunlight for both heating and lighting while avoiding excessive solar gain imposing a need for air conditioning.



Featuring a roof garden that creates an evaporative cooling effect for the building is the Centre for Understanding the Environment in South London

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This objective is aided at the Eco Centre by an unusual triangular building form of 1500 m^2 that maximises light from the south east and west and reduces solar gain.

Being an extension to an existing building, there was less flexibility for the orientation of the Centre for Understanding the Environment. Its south wall is solid with no glazing, primarily to provide protection against the noisy South Circular Road to the south of the site. The north wall is totally glazed, and there are high-level clerestory windows to take light to the main exhibition space.

Abbey Wood also features different façade types on different aspects. 'Warm' façades face south and south west. They are of high-mass stone and block with deep window reveals designed to provide full shade at peak summer Sun. Solar gains are delayed by up to 8 h and do not impinge upon the occupied period. In contrast, the 'cool' façades are low-mass curtain walling with high insulation. They can make beneficial use of summer Sun, but are not unduly affected by morning summer Sun.

In contrast, the refurbished 1960s Bridge House headquarters of Xerox was already fixed in its orientation. However, even here, due regard is given to the potential for controlling and exploiting sunlight falling on the north and south elevations. A brise-soleil is designed to minimise heat gain at the peak of the summer months but to allow controlled solar gain during the winter to augment the heating system. Screening on the north elevation is reversed to reflect light into the building. Fine tuning is achieved using glare-control aluminised roller blinds to allow occupants to individually control sunlight or glare.

Analysis

Façades are, without exception, designed for low heat loss — though not necessarily to minimise this as far as possible. At Abbey Wood the analysis of the operating conditions of the various buildings using thermal analysis software was refined in such a way that the annual energy budget for providing acceptable internal environments is based on both summer and winter operating conditions. In practice, this philosophy means that the balance of insulation and thermal mass has to consider the possibility that summer heat loss may avoid the use of mechanical cooling for long periods. Accordingly, the U value of roofs and walls are less than 0.35 W/m^{2}K. Ground floor slabs are edge insulated.

"Buildings that are truly green owe more to imagination than to appearance"

Triple-glazed windows have a U value of less than 2 W/m^{2}K. Three policies contributed to the design of the façade.

- Avoid the need for additional energy.
- Retain and re-use available energy.
- Deliver the energy from gas and electricity as efficiently as possible.

The design of the Abbey Wood buildings was driven by the principle that investment in static non-maintained elements such as quality façades to defend the interiors can be more effective than controlling the internal environment using complex mechanical and electrical systems.

For the other projects, minimal U values were sought.

At the Eco Centre the figures are 0.2 W/m^{2}K for the walls, 0.28 W/m^{2}K for the floor and 0.22 W/m^{2}K for the roof.

Structural considerations at Bridge House precluded the use of curtain-wall framing, and a conventional cladding system would have been difficult to erect in the planned phasing of the construction work. Mirror or tinted glass would not have provided enough solar control for the capacity of the existing plant. The final proposal was to use a horizontal long-span insulated steel-panel system with main 'ladder' structural supports on columns to avoid putting additional load on the concrete edge beams. 100 mm of mineral-fibre provides insulation well in excess of Building Regulation requirements.

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Overall insulation levels were also helped by reducing the window area by over 30% without affecting the quality of view or entry of natural light.

The best green buildings also consider the environmental effects of thermal insulation. At Horniman Museum, insulation of recycled newspaper replaces manufactured products such as foam-based insulations.

Glazing

Mere double glazing is inadequate in such buildings. Further energy-saving features are considered essential.

Bridge House has double glazing comprising Pilkington's Antisun solar-control glass on the outside and low-emissivity K glass as the internal pane.

All glazing in the Horniman Museum has two panes of glass with a low-emissivity coating separated by a 20 mm cavity filled with argon.

The Eco Centre also has low-emissivity glazing, but with a 20 mm air gap. The tall rectangular windows can be opened. They feature splays and occupancy 30% of the wall area to optimise daylight.

Abbey Wood goes one better with triple glazed windows that can be opened. They have a U value of less than 2 W/m^{2}K.

Lighting

Artificial lighting for these projects is provided by high-effiency fluorescent lamps controlled according to available daylight and occupancy. Automatic control is absent at the Eco Centre on the basis that the lighting is little used during the summer and the lighting level is so low compared with conventional lighting that it would contribute very

Of the 17 buildings on the Ministry of Defence Procurement Headquarters at Abbey Wood, 16 have been awarded an 'excellent' BREEAM rating.

little to the efficiency of the building.

Horniman Museum has adopted the on/off approach for its low-energy fluorescent fittings. Lights are automatically turned off when the general illumination rises above a preset level. Users can turn the lights on again, but they are prompted to think if they really need them on.

The new lighting at Bridge House shows how far technology has progressed. The installed lighting load is just 10 W/m^2 compared with about 28 W/m^2 before, representing a major reduction in load on the cooling system. Best use is made of lighting by efficient space planning and removing partitioned offices. Meeting rooms and other necessary enclosed areas are located in the central core of the building. Perimeter space is thus freed for occupancy, and all staff have a window view and maximum natural daylight.

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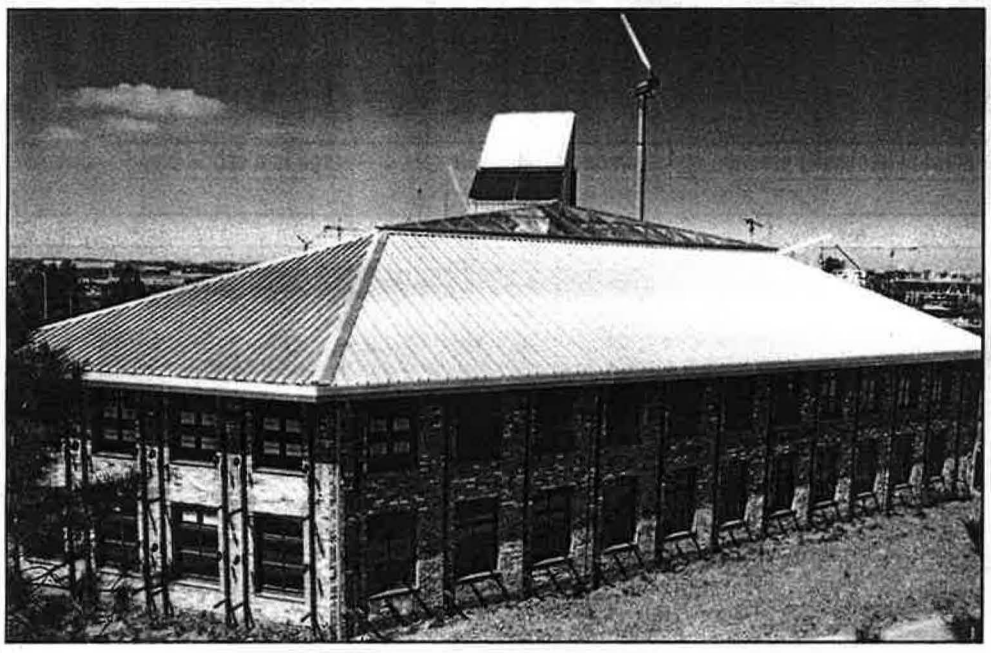
Fluorescent downlights are combined with recessed 600 mm-square luminaires incorporating high-frequency control gear, high-efficacy lamps and louvres with excellent optical characteristics to combine a pleasing appearance and glare-free illumination. Luminaires are controlled using presence detection. Long off delays prevent unnecessary switching and a shortened life. Perimeter luminaires are on only when daylight is inadequate and the building is occupied. A once gloomy building has been transformed into one in which all staff enjoy a window view and maximum benefit from natural daylight.

At Abbey Wood, the need for artificial lighting is minimised by no-one being more than 6.5 m from a window. Low-glare Category 2 intelligent luminaires are designed to deliver 350 lux at the working plane. Luminaires are individually controlled by presence detectors and daylight-linked dimming of the high-frequency luminaires. Of an installed load of 16 W/m^2 a seasonal average of 6 W/m^2 is being achieved.

Interior

In green buildings of the calibre that reach the finals of this award scheme, the interior structure is just as important as the façade in regulating the internal environment.

Horniman Museum provides an unusual example, with extensive areas of exposed timber finished with breathable organic finishes as a natural regulator of humidity. It has proved effective at improving comfort by keeping relative humidity low in warm weather.



Unconventional in its appearance but conventional in its application is the Eco Centre on South Tyneside, with minimal automatic controls and a target of zero carbon-dioxide emissions.

At the Eco Centre the use of a large thermal mass creates a building that is inherently stable and requires moderating in extreme conditions, so there is only minimum automatic control. Computer calculations indicated a 12 h thermal lag; in winter with minimal ventilation, this increases to 48 h.

Buildings at Abbey Wood exploit the principle of exposing thermal mass to maximise the use of passive design. The exposed soffit provides significant modification of the diurnal temperature in the offices. The opportunity for pre-cooling at night during the summer by circulating air is exploited and controlled by the BMS. In winter, the slab is used as a heat store, and the ventilation system is not run at night. Wherever possible, system demands are based on occupation rather than simple time schedules.

The harsh and reverberant acoustic environment that could have resulted by exposing the concrete soffit is avoided by obscuring it with curved ceiling plates fitted into each 1.5 m-square planning module. These plates are of perforated metal with sufficient exposed acoustic insulation to achieve reverberation times of 0.6 s. They are suspended from the ceiling so that noise can be trapped behind them.

Active services

With so much regard for passive design, active services tend to be minimal. Close attention is paid to ventilation — whether natural or mechanical. High standards of air tightness are generally achieved, as evidenced by the buildings at Abbey Wood, which were designed for and passed texts for minimal air leakage of 5 m^3/hm^2 at 50 Pa.

In the extension to the Horniman Museum the natural ventilation system is an integral part of the structure. The construction comprises a large-scale prefabricated timber structure of hollow triangular plywood box beams, glu-lam and plywood columns and stressed skin floor and roof panels, which act as the natural passive stack ventilation ducts. Simple dampers are operated by a BMS, which monitors temperatures within the building to control the extent and quantity of air movement. Air conditioning has been avoided.

Natural forces also drive the ventilation at the Eco Centre, with a wind tower creating and promoting ventilation through the offices and central atrium, which acts as a funnel for air movement.

Mechanical ventilation is provided at Abbey Wood by a displacement system providing each person with 25 l/s. Fresh air, with no recirculation, is delivered through the floor and extracted through holes in the ceiling slab positioned to support any configuration of cellular offices. There are two diffusers per person.

Air is supplied at 19°C. This temperature is exceeded for only 10% of the year so it is normally provided by direct free cooling. The air-handling plants have cross-flow heat exchangers to recover casual space heat loads. All air is filtered sufficiently to control the circulation of dust and pollen from outside when windows are closed.

Personal choice of window ventilation is allowed, although it is recommended that winter and summer peaks are best controlled with them closed. Energy use when the windows are open is not increased unduly as the supply air is mainly heated by free recovered heat, and the supply temperature is closer to external ambient conditions than in other systems.

It is notable that in most of these projects materials that emit fumes were avoided to reduce the load on the ventilation systems.

The Horniman Museum and the Eco Centre both avoid using air conditioning.

The major improvements to Bridge House have considerably reduced the air-conditioning load, even though the number of people in the building has increased from 400 to 500. Such is the extent of the improvements that during summer heat waves, occupants enjoy a cool and pleasant environment for the first time.

While the entrant's report for the Abbey Wood project specifically says, 'The buildings are not air conditioned,' they do incorporate chilled ceilings, where required. Provision is also made for all the ceiling panels to be retro-fitted with chilled-ceiling coils to provide 40 W/m^2 of cooling. It follows that the site has chillers, though these produce chilled water using free-cooling coils for much of the year and far more efficiently for the rest of the year than standard systems.

Certainly the energy consumption at Abbey Wood is well below the norm for modern air-conditioned offices — being only one-sixth to one-third of the usual consumption. Indeed, 16 of the 17 buildings on the site have been awarded an 'excellent' BREEAM rating.

When heating is required, it is provided by low NOx boilers.

A single condensing gas-fired boiler of domestic size serves the underfloor heating at the Horniman Museum. To avoid low internal temperatures, heating is provided continuously, with night setback.

Off peak electricity is used to heat the floors of the Eco Centre, with costs kept low by using electricity generated at night to drive a heat pump to upgrade the temperature of bore hole water at 11°C.

Water

Efficient use of water is also an issue in green buildings.

At Abbey Wood, the use of water in urinals is controlled by presence and use. Dish-washing equipment recirculates water. The chillers have dry coolers to maximise water conservation.

Secondary use is made of water at the Eco Centre by irrigating plants with grey water and liquid effluent from composters. Water use is minimised by composting human waste in a Swedish system that has been used for the last 30 years in Sweden and the USA.

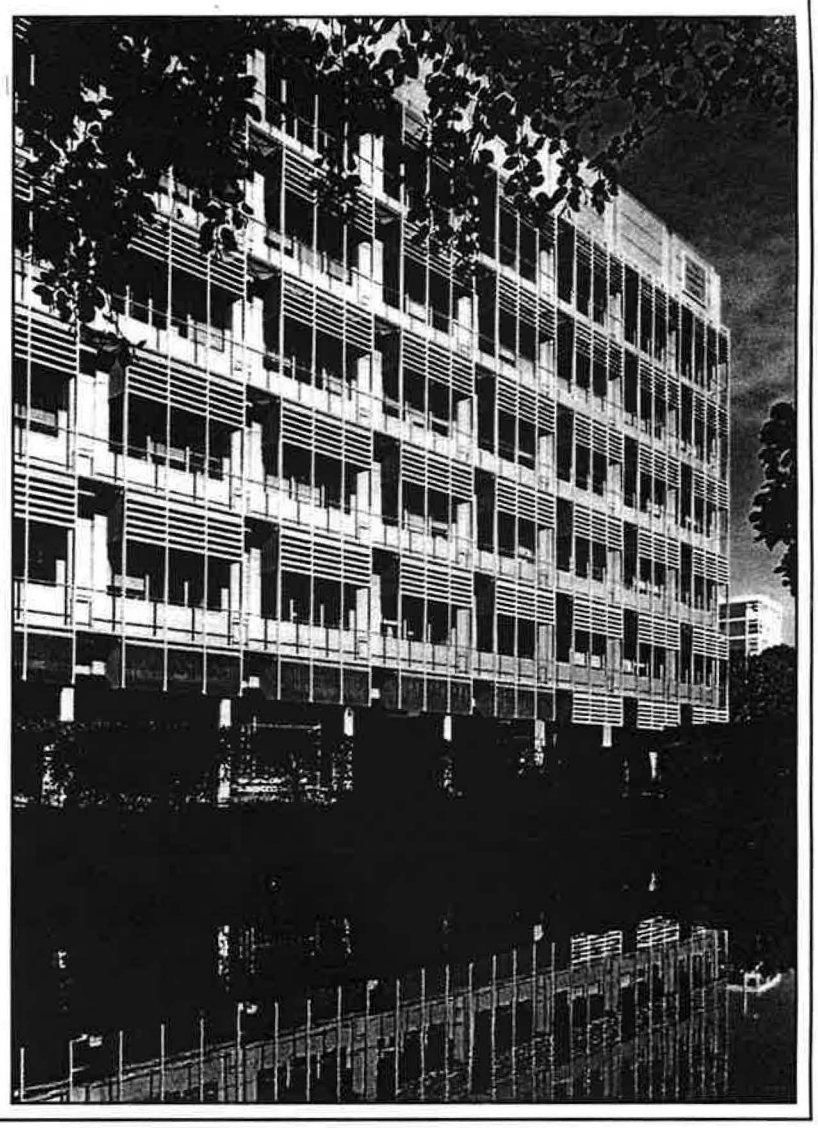
At the Horniman Museum, rainwater is collected from the roof. In the future, grey water from wash basins will also be collected. This water is cleaned through reed beds and stored in ponds for re-use in the building and for irrigating the living-grass and wild-flower roof.

Demonstrating that even the most blatant green building is not prohibitively expensive is the Eco Centre. It is thought probable that the client paid just 5% extra for the environmental specification on a building costing just over £1 million. Given the low running costs and the perceived quality, the client considers that this represents value since one of his objectives was to reduce lifetime costs.

Indeed, even the winning entry did not set out to achieve greenness at any price. At Abbey Wood, combined heat and power was seriously considered, but the cost of electricity for a major site defeated life-cycle costings.

Credentials

These examples of environmentally aware buildings demonstrate that quite normal looking buildings can have very green credentials. While two of the entrants have more visually green appearances, surface veneer is no guarantee of broadly based environmental awareness. Buildings that are truly green owe more to imagination than to appearance.



Showing how even a refurbished 1960s building can exploit many of today's green-engineering principles is the Bridge House headquarters of Xerox in Uxbridge.