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BUGS FOREVER

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Leaches, ants and termites - and up to 600 people an hour. This was the challenge faced by engineers charged with designing London Zoo's newest building, the Millennium Conservation Centre. Not tricky enough? Let's insist on sustainability too.
By Jason Palmer

Some of the invertebrates in London Zoo's new Centre are extinct in the wild. This means a temperature swing could not only kill off the Zoo's collection, but wipe out an entire species in the process. A situation to make services engineers sweat.
The Zoo has the largest captive breeding facility for endangered invertebrates in the world. Unlike some other zoos, all exhibits are bred in-house, rather than simply collected from the wild. Consequently, the Millennium Conservation Centre is sustainable in many senses of the word.

The new building combines insect breeding facilities with a public exhibition about biological diversity: "The Web of Life". The exhibition is designed to illustrate the incredible range of invertebrate creatures. As Debbie Curtis from the Zoo explained, 98% of animal species are insects.

The Zoo's previous invertebrate breeding rooms, built in 1912 from converted toilets, offered little by way of inspiration for the new building designers. These rough-and-ready facilities had services that were patched together over time on a trial and error basis. A gas-fired radiator here, an inner wall air conditioning unit there, whenever resources were available.

London Zoo's financial troubles in the early 1990s didn't help. As a charity the Zoo receives no funding from central government, relying instead on sponsorship from various charities. It also does private, paid work for individuals and organisations. However, the Zoological Society of London, which owns and runs London Zoo, says it has turned finances around.

External funding was the key to constructing the new Millennium Conservation Centre, and the Zoo was able to secure a £2.2 million Lottery grant. The catch was that the grant had to be matched by commercial sponsorship and donations. Kajima, the main contractor, provided a substantial interest-free loan for the project.

Taking inspiration from nature It seems appropriate that the building should take some design cues from the invertebrates it is intended to house. Its structure, for example, mirrors that used by termites: making use of a borehole and single pass ventilation to keep cool.

Five, 5 m high ventilation chimneys jut from the building's striking rust-coloured roof, that sits well on the green canvass of the Zoo's trees and grass. Large glazed sheets drop down from the roof, punctuated at intervals by blockwork.

Public toilets and an activity area for children have been built opposite the main entrance, submerged underground, with an earth roof that forms part of the anteater paddock.

Built on the site of a former wolf enclosure, the Centre has quite a complex triangular plan, partly to accommodate a specific route from the main entrance. There are three floors: a basement housing the plantroom, the main exhibition space at ground level, and a mezzanine floor with a raised platform for the boilers. The mezzanine is mainly for Zoo employees, with a rest room, office, and a work space. Five insect breeding rooms are also located here.

Architect Phil Wharmby aimed for a flexible building, knowing that some of the Zoo's other buildings have not kept pace with changes in zoo keeping methods. Take, for example, the listed elephant house which is under-used because elephants now spend more time outside.

Wharmby also wanted a transparent building, not a black box that is separate from the rest of the Zoo. He also had to tailor the design to provide maximum display space. This requirement even extended to "displaying" the zoo employees: the office space on the mezzanine floor is glazed, allowing visitors to peer in at the zoo keepers in action.

The right materials for the job

The architect tried to use as many sustainable products and materials as possible, some with very low embodied energy.

The Centre is an unusual mix of timber frame and concrete. Fifty-two elliptical columns made from laminated pine support concrete hollow core slabs and the pitched roof. Softwood is also prominent in the design. In an unusual pitch for low embodied energy services, the return air duct is attractively crafted from a super flexible type of plywood.

The roof insulation is a French product called Actis. Just 25 mm thick, it is made up of 16 layers of low-emissivity, reflective barriers that are sandwiched between bubble-wrap. Thinness, though, is no bar to good thermal performance.

The manufacturer claims it is equivalent to 200 mm of Rockwool in winter, and 300 mm in summer - a difference attributed to the reflective properties of the material: it bounces solar gains back into the sky.

In addition to its thermal benefits, the main contractor was keen to use the material to keep down the weight of the roof structure.

Styrofoam AV was used to insulate the block walls and underground, resulting in a U-value of 0·25 W/m2k.

Tailoring the daylight

Services engineer Fulcrum and architect Wharmby Kozdon spent a long time detailing the windows. The double glazed, low-emissivity glass is bonded so there is no cold-bridging - a first for Fulcrum.

"Windows are shaded on the inside with reflective solar blinds that lower the U-value," explained Fulcrum's team leader Andrew Ford. This helps to keep the heat in at night. They drop down automatically when there is too much light, responding to photocell sensors, although there is a manual override. Philip Wharmby confessed there was tension when it came to allowing natural light into the Centre. Glazed exhibits are easier to view when internal light is stronger than daylight, and there can be problems from glare reflecting on aquariums.

Exterior planting to the south and west supplements the blinds in controlling how much light enters the building, particularly in Summer, but Wharmby still expects daylighting to meet most background needs.

Internal gains from electric lighting were largely unknown at the design stage. Instead, Fulcrum made an allowance for internal gains in its preliminary design work and used this as a target for subsequent work.

Services are either so subtle they're invisible, or blatant enough to shock. Termodeck thermal slabs1 go completely unnoticed, but the return air duct, painted red, is unmissable.

For the new Centre, breeding rooms have individual temperature control, with local thermostats in each room and an override system located in the work space. The breeding rooms have full vrv air conditioning, separate from the main building services, and with a chiller unit outside.

Breeding temperatures need to be very precisely controlled: 22°C at night, and 24°C in the day. In some cases, a rise to 28°C could "kill the lot", said the Zoo's expert. A situation to focus the mind, especially when the Centre houses the last remaining examples of the Polynesian Partula snail.

Fulcrum's services provide a stable background conditioning, explained Ford. The design temperature is 21°C for the whole building, rising to a maximum of 25°C for occupied areas in Summer.

A breath of fresh air

Ventilation is clearly important for a 1250 m2 building expected to accommodate 510 people at peak periods. The strategy is straightforward: "in at the bottom, through the structure, and out through the top," said Ford.

Some clever engineering means that a single ahu feeds the whole building. Around 4000 litres/s of fresh air enters the building at ground level next to the entrance. This leads directly to the sealed plenum plantroom in the basement.

In cold weather fresh air is pre-warmed using a thermal wheel. When necessary air may then be heated with heating coils fed by water from a condensing boiler.

Air is then pumped into the building via 64 Termodeck slabs which span the whole of the ground floor, the basement, and the mezzanine. The air passes through each slab three times, and then out through Waterloo floor outlet grilles and ceiling-mounted units, each supplying 27·5 l/s of air. The air gains heat from the sun, visitors and lights on its way up through the building, and is collected at high level near the roof.

From here it is drawn through the conspicuous return air duct to return to the basement plantroom. It then enters the thermal wheel for heat recovery. Finally, having sacrificed its energy for the sake of incoming air, it is expelled to the outside.

In warm weather, air is cooled primarily with the energy stored in the building fabric. Cool air drawn into the Termodeck slabs at night purges the heat that has built up over one day, to form a thermal reservoir that is released slowly the next day.

To complement this reservoir, an extra 28C of cooling is available from geothermal energy. When necessary, an evaporative humidifier in the plenum cools outgoing air by up to 4·58C, and the thermal wheel transfers this cooling energy to the incoming air.

In this mode the building's roof vents open to the chimneys, turning the building into a simple one-pass ventilation system. The chimneys should usually remove hot air from the building through the stack effect, but they also boast extract fans for hot, still days.

When it is warmer outside than inside, the entrance doors also open - using the semi-automatic opening actuators normally used for visitors - allowing even more air to pass through the building.

In summer, all roof ventilators should open as soon as temperatures rise above the 218C setpoint, turning the building into a straight-through air supply system.

However, when the Millennium Conservation Centre was visited the roof space was very warm, and the butterfly vents were closed and showed no sign of movement. As ever, some tweaking of the setpoints will inevitably be needed.

The heating system, including the hot water supply, is located on the raised platform 'lid' to the mezzanine floor. Given the size of the building, the heating system is tiny - two Yorkpark domestic boilers, each rated at 40 kW. These condensing units provide hot water for toilets and showers as well as space heating requirements.

In fact, the heating system is intended as a backup for occasional use only. Most of the space heating requirements will come from internal gains from the exhibition and visitors' body heat. The exhibition and lighting are expected to supply 100 kWh/m2/y, while visitors will contribute about another 35 kWh/m2/y.

These 'free' heat sources are important because the heat exchanger is so efficient: rated at 74% at maximum flow. Running it at low velocity allows even more of the heat to be recovered.

Keeping control and providing power

Controls are a critical part of the heating, cooling and ventilation strategy. The Centre taps into an existing Trend bems that is networked around the whole Zoo.

The bems follows a simple, staged sequence for the new building: from fully sealed with heat recovery through the thermal wheel (in cold weather), to open doors and roof vents, combined with use of the borehole and evaporative cooling (hot weather).

Power comes from the regional electricity company supply, with a diesel standby generator that cuts in automatically using a change-over switch. Ford explained that the standby unit is "just for the insects - they're more important." Electricity comes in on two separate supplies, a permanent supply for the important exhibits and a separate supply for less important ones. Each has a radial circuit, serving groups of exhibits, and its own control panel.

Will Potter, the services project engineer: thinks of the exhibit tanks as "hostess trolleys" - in that they all look similar, but contain different equipment, and attendant needs for power. Thus a single tank may have lighting, heating or cooling equipment, pumps and motors. Although the electrical load for each tank is quite low - typically only 200-300 W - each has its own socket outlet.

Testing times

The building has been pressure tested by the BSRIA, which proved tricky because the animals needed to be protected from the smoke used in the test. Fulcrum intended to get just one air change per hour at 50 Pa. But the pressure test revealed a significantly higher air change rate.

Most of the leaks came from just one or two locations, particularly around the glass-roof join. As ever, the pressure test was a learning process for the main contractor, who subsequently attempted to plug holes. The building is due to be retested soon.

It is a disappointment to Fulcrum that the main contractor lacked faith in its passive cooling strategy. Kajima insisted on putting in the reverse cycle heat pump as a contingency while still on site, rather than having to install one later - at much greater expense - should the building over-heat.

It's a knock on the chin for low energy design, but at least the estimated one million visitors a year are guaranteed a day out in comfort.

References 1Bunn R, 'Mass control', Building Services Journal, 11/97. 2Bunn R, 'Ground coupling explained', Building Services Journal, 12/98.

Cooling's a bore

The Conservation Centre is part-cooled by a closed loop bolehole system, sunk by Geoscience, which won a separate sub-contract from Kajima. This is one of the tiny number of UK examples of non-domestic ground coupling2.
Geoscience drilled four 40 m holes into the London clay adjacent to the building, planting in each a u-tube of 32 mm thick high density polyethylene (hdpe). The tubing runs underground into the building and to the Termodeck air supply.
Effectively, the heat energy passes from the building into the water and then on into the ground. Initially, the water will emerge from the ground at 12°C, but this temperature will rise over the course of the day, so its ability to absorb heat will diminish (as water temperature approaches the temperature of the building).
In this ‘passive' mode, it is an extremely energy efficient way of cooling the building, using no more power than for a small circulating pump. But Robin Curtis, from Geoscience, thinks the

cooling ability may be short-lived in this mode: "Because there is a low temperature differential between ground and water, heat will only go into the ground slowly." As a consequence of the system's limited cooling capacity, Kajima insisted that Geoscience should also install a heat pump system. Working in reverse cycle only, the heat pump provides cooling but not heat. It will usually be bypassed, only cutting in when the passive cooling reaches its limit.

The active mode uses more energy, but it also has much greater cooling potential. First, because the heat pump can give an output of 8°C (ie more cooling potential than the water with a temperature of 12°C or more). Second, because the water in the pipeline becomes warmer, increasing the ground-water temperature differential, and so raising the potential for heat to be dumped into the ground.

Credits

Client

Zoological Society of London

Project manager & main contractor

Kajima UK Engineering

Architect

Wharmby Kozdon Architects

M&E consulting engineer

Fulcrum Consulting

Structural Engineer

Dewhurst Macfarlane & Partners

Quantity Surveyor

Peter Gittens & Associates

Planning supervisor

PFB Construction Management Services

Mechanical & electrical contractor

H L Smith

Commissioning contractor

A & C Commissioning
Borehole cooling design
Geoscience

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