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SUSTAINABLE AND ENERGY-EFFICIENT BUILDINGS

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The heat-energy flows through a building are bound to balance the input and the output. For efficiency, the inputs derived from fossil fuel must be kept at a minimum. Then, by good thermal design, the minimum heat inputs must be able to keep the building warm on the coldest day.

Electricity for miscellaneous use must be minimized by developing efficient appliances, freezers, refrigerators, washing machines, televisions, computers and so on.

Electricity for lighting is minimized by using efficient light sources, avoiding excessive indirect lighting and incandescent lamps. Buildings must be designed with appropriate window openings so that people do not need to use electric light when there is adequate natural light, even on a cloudy day.

One watt of energy as natural light saves 3 to 30 W of fossil fuel used by an electric light. Large windows save energy, provided they are designed and used to prevent excessive winter heat loss at night and excessive heat gain in summer.

The design of windows is a key item for energy efficiency. If little light is needed, as in a home, the windows need not be particularly big, but they must be large enough to provide enough light on an overcast day. In a building such as an office, the height of the window controls how far the light can penetrate into the room. For good lighting on an overcast day without using electricity, the depth of the room from the external wall should not be much greater than the height from the floor to the head of the window. To achieve this, if one disregards thermal losses, big windows and high buildings are a necessity and the minimum daylight factor should be 1.0% at the back of the room.

Fluorescent light should be controlled with dimmable, high-frequency ballasts. The occupants need individual control of lighting with an interface to a computer system to remind them not to be extravagant.

SHUTTERS

Large windows introduce two potential problems:

- overheating in the summer;
- a heat loss in winter, which has to be offset by heating using fossil fuel.

For the heat loss, double or triple glazing with low-emissivity coatings with a U value near to 1 W/m^2°C are achievable. During the day the energy/light from an overcast sky in the UK is typically 20 W/m^2, which more or less equals the heat loss. At night the windows should be covered with insulated, air-tight shutters that close whenever thermal energy needs to be saved. The shutters will then close at night in cold weather and when no-one is present. In the nineteenth century, houses had heavy curtains and shutters operated by servants.

Shutters can be designed to control the variability of light energy. On an overcast day, the light energy on a window is about 2000 lux (20 W/m^2), while on a west-facing window the summer peak is about 100,000 lux (1000 W/m^2) in the late afternoon.

If a room is adequately lit on an overcast day then 2000/100,000, that is, one fiftieth of the window, will provide adequate light through a west-facing window on a bright day and one twentieth provides generous light. Shutters must be designed to provide this reduction of light level while allowing some outlook.

When used in this way, shutters must be able to reject most of the solar radiation by reflecting it and/or by allowing heat to be carried away by ventilating wind. Many forms of window control are designed only to deal with light control and do not provide extra insulation.

Blinds in or outside glazing cavities, electrochromic glass and so on only aim to control light. Insulating shutters and foam blown into the glazing cavity also provide insulation.

With the windows shuttered to control the main flow of radiation into and out of the building, the other controllable flow mechanism is ventilation.

VENTILATION

Ventilation is needed to control concentrations of odour, moisture and carbon dioxide. Ventilation can represent the largest heat loss from a building, but the quantity must not be skimped. If a building is constructed without odorous materials and is kept clean, then the ventilation rate can be mainly defined in terms of the number of occupants. A building must be designed to be airtight, aiming for not more than 1 × 2 mm crack per 1 m^2 of building envelope. It should then be tested to allow not more than 0.5 air changes per hour at 50 Pa differential pressure. In the 50 m^2 elevation of a typical house the 'allowable crack' is all used up by a lobby door with magnetic seals .

An airtight building should be ventilated by mechanical ventilation with heat recovery. The power used by the fan must be minimized by using large, low-velocity ducts and

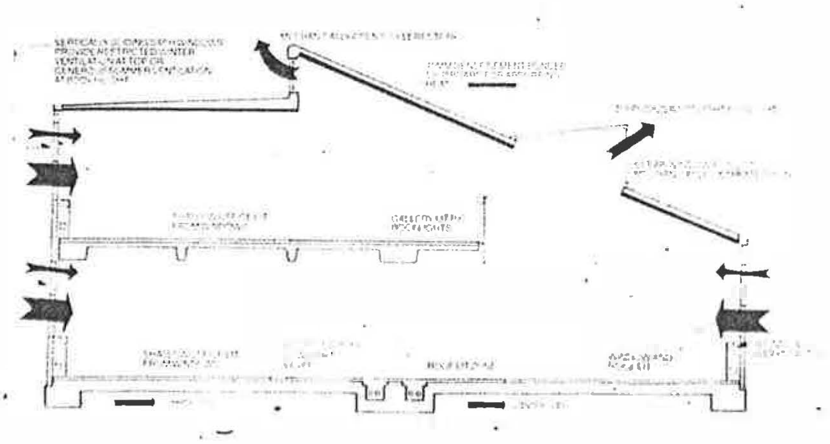

Figure 1. Sparrow Grove, Otterbourne, Hampshire; Architect: Darbourne & Darke

a large plant room, so that the air pressure loss is minimized. The plant should be designed for the minimum satisfactory air flow and fitted with efficient speed control on the fan so that the use of power is metered to correspond to the occupancy of the building. Finally, the opaque envelope should be insulated to give a U value of about 0.1W/m²°C.

These measures will produce a building where the (unavoidable) heat gain in a building should maintain a comfortable temperature on the coldest day, so that no heat energy need be added. If any heat is needed after a winter holiday, then the ventilation air can be heated to add heat to the building.

With a building designed to be comfortably heated on the coldest day, it becomes necessary to ensure that it does not overheat when there is less heat loss on a mild day and extra heat gain on sunny days. As the outside temperature rises, the night-time use of the shutters is modified so that any tendency for the building to overheat is counteracted by night-time heat loss through open shutters. The ventilation can also be adjusted by opening windows to provide a selective thermal exchange with the outside environment.

During hot summer weather the shutters are used to control light levels during the day and left open at night. At night, windows are opened to cool the building with night-time ventilation.

During the day, the surplus of heat cannot be removed by warm ventilation air. It is absorbed by the structure ready to be removed by cool night-time ventilation.

For these ideas to work, the heat gains and losses have to be balanced over a 24-hour cycle. The building should be faced internally with dense conducting materials at least 50 mm thick of, say, concrete, brick, block, or dense timber but not plasterboard, thin metal-sheet ceilings or light-weight partitions. Carpet may be used on the floor for acoustic absorption, provided the ceilings and partitions are heavy.

Using these ideas, it is possible to design a building that needs no fossil-fuel energy for heating or cooling and no electricity for lighting during daylight hours. The total energy use will depend on the brightness of light required.

CASE STUDIES

SPARROW GROVE, OTTERBOURNE, HAMPSHIRE

The perimeter of this building (Figure 1) is lit from continuous vertical sash windows. The core of the building is lit from rooflights.

Ventilation is provided manually from the sash windows and by motorized actuators for the rooflights.

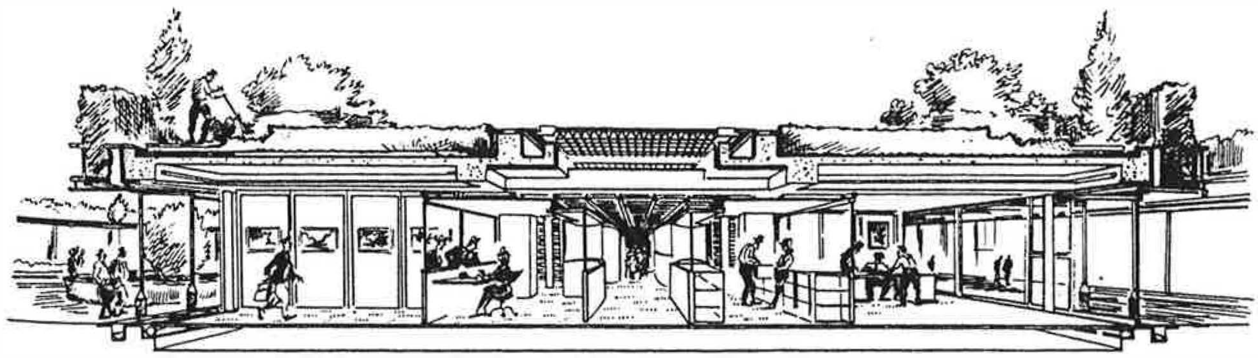

Figure 2. International Headquarters for RMC plc, Egham; Architect: Edward Cullinan

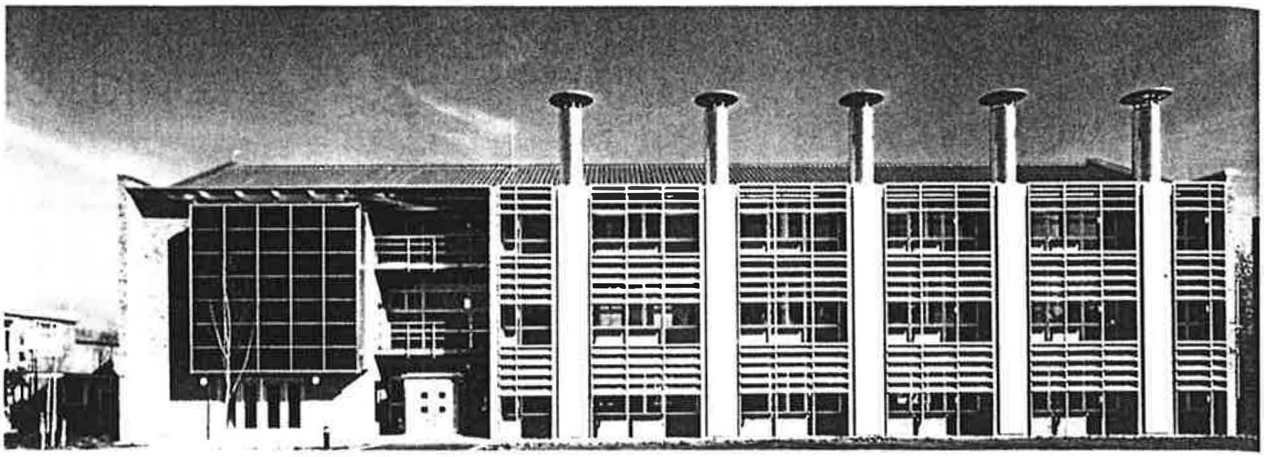

Figure 3. New offices for the Building Research Establishment, Garston; Architect: Feilden Clegg Design (photo Dennis Gilbert)

To provide thermal capacity, the roof is lined with 40 mm dense cement-bonded chipboard instead of plasterboard. The intermediate floor is a coffered concrete slab.

In 1986 Sparrow Grove received Building Services Award for a naturally ventilated office building.

INTERNATIONAL HEADQUARTERS FOR RMC PLC, EGHAM

This is a building with a very deep plan (Figure 2); it is core lit from rooflights and perimeter lit with full-height sliding doors. Night-time and winter ventilation is fan powered through the floor cavity to provide high thermal capacity. No air conditioning is used.

The roof construction is coffered concrete with insulation of light-weight porous aggregate and topsoil to make the thickness up to 1 m.

During the summer it is cooler inside the building than it is outdoors.

In 1992 this building was a highly commended finalist of the HVCA/*Independent on Sunday* Green Building of the Year Award.

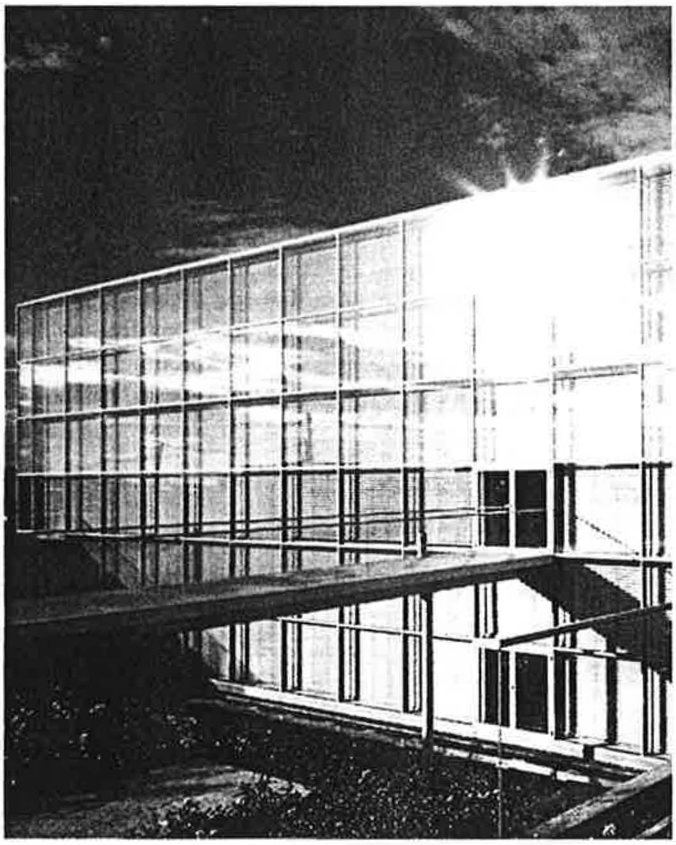

Figure 4. Götz Sol-Skin Headquarters Building, Würzburg

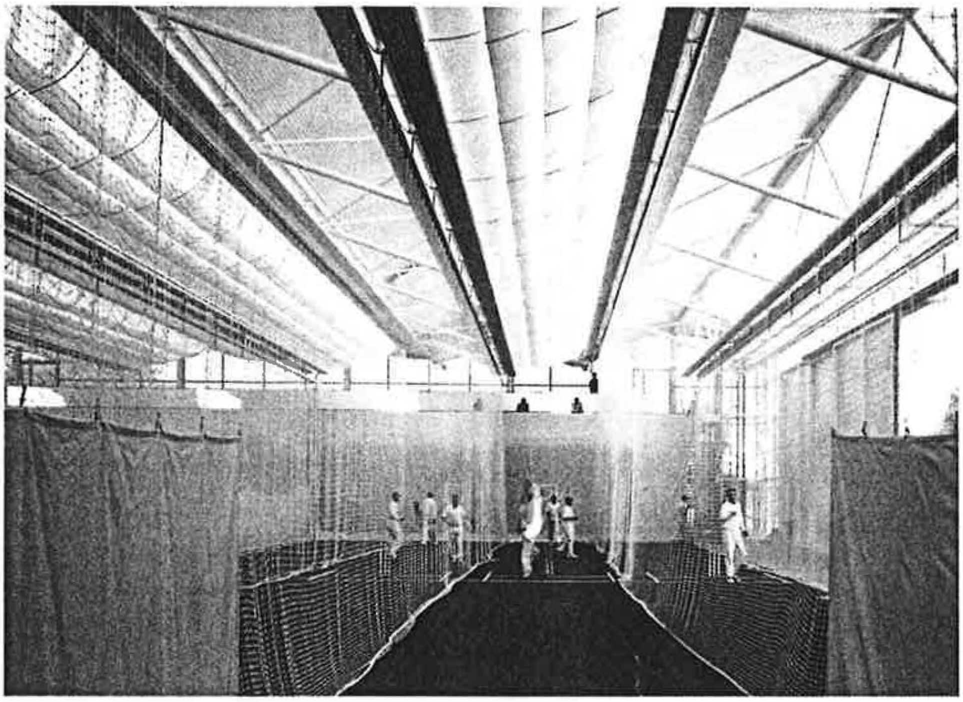

Figure 5. Indoor Cricket School at Lord's Cricket Ground; Architect: David Morley Architects (photo Dennis Gilbert)

NEW OFFICES FOR THE BUILDING RESEARCH ESTABLISHMENT, GARSTON

The building (Figure 3) is naturally lit from the perimeter. Electric lighting uses computer-controlled, dimmable high-frequency ballasts.

The offices are naturally ventilated with opening windows and openings to ventilation stacks controlled by a Building Energy Management System. Air flows through a duct in the concrete floor cavity to provide pre-cooling in summer and pre-heating in winter.

The ceiling has an attractive curved profile of exposed concrete, which provides thermal mass. Pipe coils in the concrete provide winter heating and well water is circulated for summer cooling.

GÖTZ SOL-SKIN HEADQUARTERS, WÜRZBURG

This is a two-storey building with a basement (Figure 4) and covers an area of 36 m^2. There is a lightwell of area 12 m^2 with a removable roof.

The walls are 100% glass and the daylight factor is 8%. The internal skin of the walls is made up of double glass with low-E coating, forming a 800 mm cavity with solar blinds. The outside skin is double glazed and not coated.

Ventilation is provided by the 12 × 12 m rooflight, which opens completely. The internal skin has manual sliding doors with tilting windows above the transom rail. The external skin has 250 mm high louvres at ground and roof level.

Cooling is provided by water circulating in the floor structure and ceiling grid. Heating is needed only on very cold days.

INDOOR CRICKET SCHOOL AT LORD'S CRICKET GROUND, LONDON

Play requires illumination of 1500 lux without glare. The roof design provides 1500 lux whenever the external light level exceeds 7500 lux, i.e. for 85% of the working year.

The new school (Figure 5) saves 45% of the electricity used in the old black-box design. It uses 150 kWh/m^2/year, saving 120 kWh/m^2/year, with reduced production of CO_2 of 90 kg/m^2/year.

The winter internal design temperature is 10°C, so heating energy used is negligible.

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