suggest, instead, controlling precisely those spheres of the new which include the infrastructures, the power stations, the factories, etc. in order to mark the boundaries outside of which we could preserve all the cultivated historical land as a space of living diversification, free from the noise of those, polluted, mechanistic "reservations" enjoyed by the moderns.

It is necessary to organise a mobilisation, an attack against unsustainable architecture - not a manifesto to gather one or two intelligent and sensitive adherents around the sustainable version but a move towards eliminating all the unsustainable sawdust kept artificially alive by the current architectonic culture, by the schools, the professional studios, the architecture magazines, who are still living through the nostalgia of the Modern.

The real products of the sustainable city pursue a global quality - cohesive with the historical-cultural and physical-climatic contexts - that differentiate the architectures of various locations, making them necessarily regional. A global quality that, at least for Mediterranean Europe which concerns us most directly, our scientific research attributes to a compact city made of blocks, squares, porticoes and cultivated vegetable gardens, not dissimilar to the historical cities.

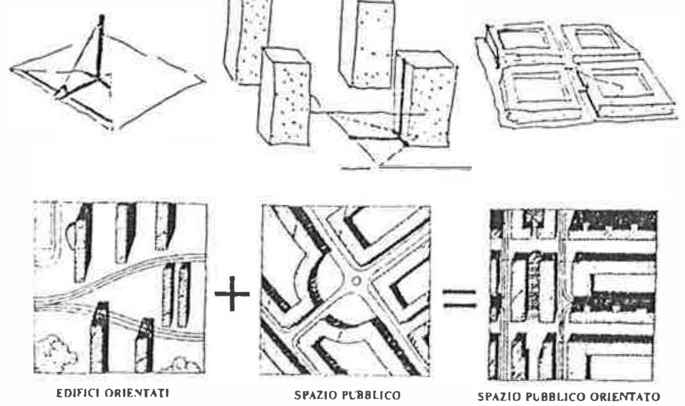

Fig. 3. The pack of building objects as atopical movable products opposed to the compact city as a composition of topical unmoveable products.

It is precisely this compact city that rejects the current formalistic, self-referential pluralism; the contiguities of any new project dealing with contemporary and historical buildings requires architects to adopt new sense of responsibility that recognises the claims of civic architecture as priorities with respect to the subjective expression of their individual idiosyncrasies. The compact city is therefore not indifferent to the architecture that creates it: it is made with a specific architecture, another one is its unmaking.

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PERGAMON

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RENEWABLE ENERGY

COOLING WITHOUT AIR CONDITIONING

The Torrent Research Centre, Ahmedabad, India

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ABSTRACT

This paper presents results from the first year of monitoring the performance of a laboratory building in the new 14,000m^2 Torrent Research Centre in Ahmedabad, India. The capital and running costs of air conditioning of non-domestic buildings in northern India are very substantial, while building costs (compared with northern Europe) are low. A cooling technique which maximises reliance on the building fabric and minimises reliance on mechanical equipment is therefore likely to be cost effective. Passive Downdraught Evaporative Cooling (PDEC) represents such a technique.

At the Torrent Pharmaceuticals Research Centre in Ahmedabad, PDEC is used to service a number of laboratories and offices within the complex. A central open concourse on three levels allows evaporatively cooled air to be introduced to laboratories and offices at each level and exhausted via perimeter stacks. In the first completed laboratory building the PDEC system has now been working for 12 months. Results from the first summer indicate that internal temperatures are 10-15°C below the peak external air temperature, good air movement is being achieved, and no complaints of discomfort have been received from the staff. The paper describes and illustrates the key features of the building and reports on monitoring undertaken during April - December 1997. © 1998 Published by Elsevier Science Ltd. All rights reserved.

THE PROJECT

The project comprises a research and development centre for the Torrent Pharmaceutical Company. The laboratories provide facilities for a range of different disciplines including Molecular Biology, Cell Biology and Tissue Culture, Histology, Biochemical analysis, and the development of disease models for screening of new compounds. The approximate size of the new complex is 14,000^2, varying from "unclean" areas like chemical synthesis labs, to "very clean" areas like tissue culture, molecular biology lab and drug design areas.

Conventional wisdom would suggest that over 50% of the volume of such a new laboratory building would require refrigerant based air conditioning, in order to meet the environmental requirements within the laboratories. This project has sought to minimise dependence on conventional air conditioning, without compromising occupant thermal comfort, in the predominantly hot dry climate of Gujarat.

The design of the buildings in the Torrent Research Centre was aimed at integrating spaces requiring highly controlled conditions with those requiring less controlled conditions, while minimising the presence of dust in the internal environment. Typically, laboratories and offices are arranged on three levels either side of an

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The objective of this monitoring programme was to obtain a preliminary understanding of how the PDEC system was working; to assist in commissioning the system, and to explore what improvements could be made prior to the application of the system in other parts of the complex.

A total of 14 'Tinytalk' sensors (10 temperature and 4 relative humidity) were located in different parts of the building. The loggers were set up to record internal temp and RH conditions every 12 seconds. The airflow through the building was monitored by recording simultaneously external wind speed around the building and air velocities at the inlets at every hour. Digital thermometers were also used to register spot temperature measurements throughout the building.

INTERNAL HEAT GAINS

The internal gains were estimated taking into account the number of occupants, office and laboratory equipment and luminaries on every floor. On the first floor laboratory there were 10-15 people (1.5kW), bench lab equipment + 2 ovens (1.5kW) and approximately 300 Lux of lighting (1.056kW). It was difficult to estimate the heat gains from bench equipment, as usage varied substantially during a typical working day. The total heat gain on the first floor is approx. 3.5kW, around 20-23W/m^2. The ground floor open plan office was occupied by 15 people (1.5kW). The lighting as in the first floor remained switched on most of the time with approximately the same heat gain (1.056kW). On office equipment there were 10 p.c.s + 1 printer, around 10 W/m^2 (1.7kW). This gives a total heat gain of 4.3 kW, (25W/m^2).

RESULTS & INTERPRETATION

Results are presented in the form of the attached graphs (Figs. 3 & 4). Results are very encouraging. The conclusion from these measurements is that the PDEC system is working well. Performance could however be improved by making a number of refinements to the system. Examination of the continuous record of temperatures and relative humidity during 5-12th April 1997 confirms this conclusion, but also reveal a number of other characteristics of the system as currently configured. Generally, internal maximum temperatures are 10-14°C below the external peak.

In thermally massive structures with small openings to the outside and low air changes we would expect the internal temperatures to be around the mean external air temperature. The graph on Fig. 3 shows that the peak internal temperature rarely reaches the mean external and the mean internal is around 5°C below mean external temperature. This depression from the mean is being achieved by the evaporative cooling.

Measurements taken from 5-8th April were made with khus mats around the outside of the inlet towers. These mats were not part of the original design, but because of their traditional use and ease of installation they were incorporated temporarily to reduce wind impact. It was noted that the wind was light and variable, and that mist from the nozzles was still very susceptible to air movement at roof level. The result was that there was a very uneven downdraught effect. Measurements of air velocities at inlets and outlets fluctuated considerably.

Nevertheless, mean ventilation rates of 9 & 6 air changes/hour over a two day period were measured at ground and first floor levels respectively based on measurements of velocity at the supply and exhaust vents. Airflow rates in the top floor were much lower. This was partly because the downdraught tends to drop past the top floor before being diverted either side of the upper level walkway. The recorded air change rates for the ground and first floor are sufficient to remove the estimated internal heat gains. Inspite of the negative impact of wind on the inlet towers acceptable conditions of temperature, relative humidity and air movement were obtained during the period 5-8th April at ground and first floor levels.

Figs. 3 & 4 show different aspects of the performance of Building 2. In these graphs we can see a very clear response in terms of temperature and relative humidity, to switching the micronisers on and off.

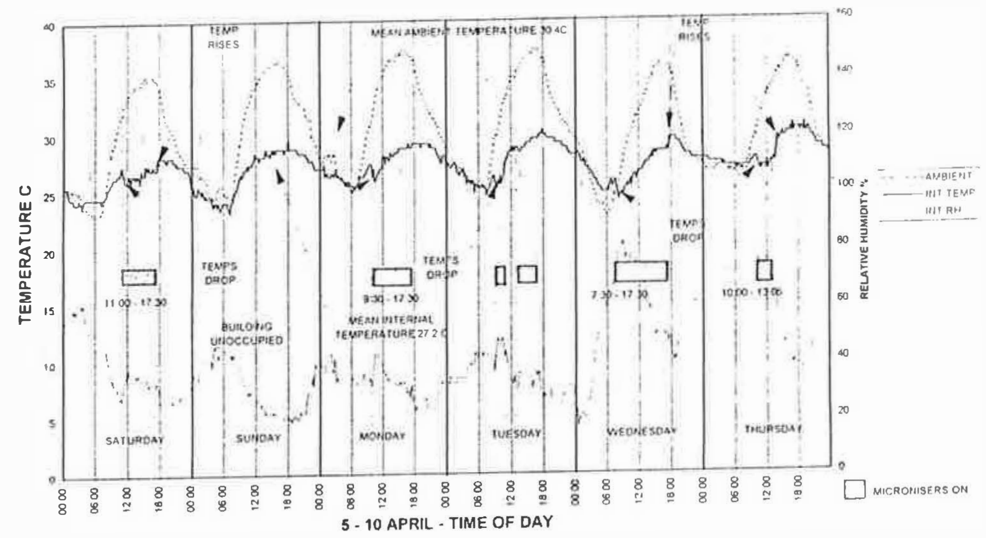

Fig. 3 First Floor Laboratory

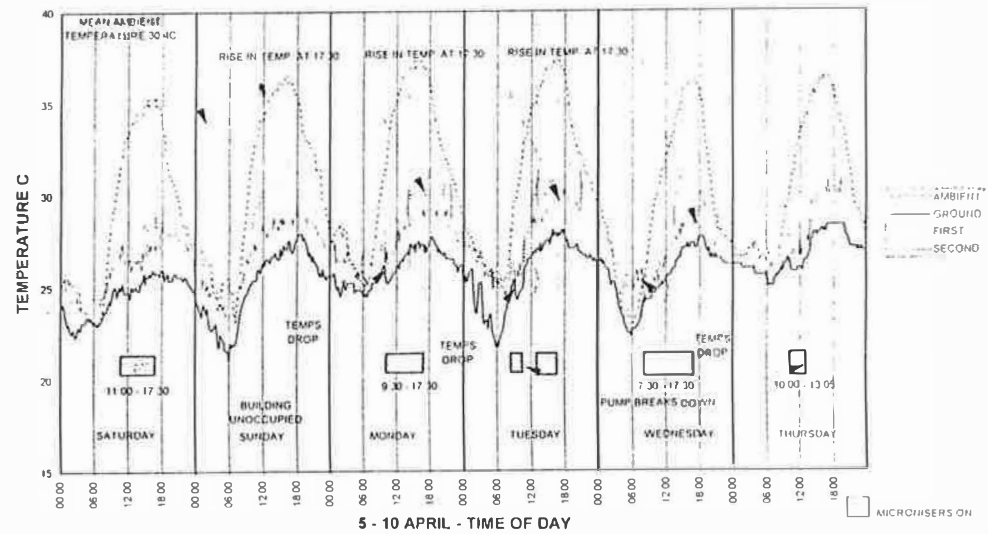

Fig. 4 Ground, First & Second Floors

When the micronisers come on their is a sharp fall in the temperature and a steep rise in relative humidity. Equally, when switched off, the temperature usually immediately rises (briefly) and the relative humidity falls. The effect is particularly noticeable on the second floor. Of course, the initiation of the cooling cycle must be triggered by both temperature and relative humidity which may vary in different parts of the building.

Results from the first year of measurements and observations of tbe building's occupants, clearly indicate that substantial savings in electrical energy (64% in the first year) can be achieved without compromising human comfort conditions. Peak recorded external shade air temperatures were 43-44°C while internally peak temperatures were 29-30°C. Generally, internal maximum temperatures were 12-14°C below the external peak. Air movement within the laboratories was also found to be acceptable.

The measurements made over the last year have helped in understanding the detailed performance of different aspects of the building. The initiation of the evaporative cooling cycle has an immediate impact on the temperature and relative humidity within the building. Of course conditions may vary in different parts of the building, so the location of control sensors will have an impact on the response of the system. As greater knowledge about the performance of the building is obtained, the controls can be refined to further improve performance.

Although further improvements will undoubtedly be made, the technical and economic viability of this passive cooling design strategy has been demonstrated. In its application to a major new laboratory development.

CONCLUSIONS

In the first year since its occupation the completed building bas used approximately 64% less electrical energy than the equivalent conventionally air conditioned building, without sacrificing comfort conditions for the occupants. The additional capital cost of 4% over the air conditioned equivalent will be paid back in the first year by these energy savings, and it has been estimated that the entire capital cost of the complex will be recouped in 15 years! Expenditure on plant was reduced by 36%, which will provide further savings in maintenance costs.

The staff have reported that last summer the laboratories were comfortable without fans and were not stuffy or smelly, as most chemistry labs are, even when air conditioned. During the monsoon, as expected, the labs were muggy, so fans were installed to provide comfort for these 2-3 months.

This project is probably the largest demonstration of the technical and economic viability of passive cooling in India. It has been achieved by a partnership between an enlightened client (who had the courage to support an innovative project), and highly motivated architects (who fully recognise the environmental responsibilities of their profession).

In the context of the world-wide commitment at Kyoto last year to reduce CO_2 and other green house gas emissions, this project is a significant demonstration of an approach to energy efficient building design which could be applied throughout the hot dry regions of the World.

CREDITS

The Client team was led by Dr. C. Dutt of Torrent Pharmaceuticals Ltd. The Architects for the Torrent Research Centre were Nimish Patel and Parul Zaveri of Abhikram Architects, Ahmedabad. Brian Ford (formerly of Short Ford & Associates) was Environmental Design Consultant, with advice from Dr. C.L. Gupta of the Sri Aurobindo Ashram. Mark Hewitt assisted with performance monitoring.

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RENEWABLE ENERGY

ANGULAR SELECTIVE THIN FILM GLAZING

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ABSTRACT

Angular selective control of daylight, solar heat gain and visual performance is the aim of a variety of emerging technologies for windows, roof and wall glazing. Certain oblique thin metal and metal/insulator films on glass have transmittance as a unique function of direction of incidence and they are also spectrally selective. A variety of angular selective control options result according to choice of film materials covering one or a combination of (i) light and glare from high angles (ii) solar heat gain (iii) visual amenity (iv) glare from lower angles (iv) emittance control. They are thus able to be adapted by materials choice to the needs of different latitudes and window orientations. A new and simple way of categorizing performance will be presented.

KEYWORDS

Angular and spectral selectivity, windows, thin films, cermets

INTRODUCTION

Angular selectivity is a term of increasing generic use in the solar energy and architectural community to describe various systems for blocking direct heat and light from the sun especially in summer, while maintaining reasonable light input. In the preferred options a clear view to the outside remains. Its manifestation in glazing and translucent products for windows, walls and roofs, apart from louvres and awnings, is quite new with few products (but some) available. Three physical mechanisms can be used, reflection, absorption and scattering but in all cases the response must depend strongly on the direction of incidence of rays onto the surface. The basic scheme is in figure 1, with two ways of blocking by reflection shown. Scattering cannot maintain view but is desirable in walls and some windows. Reflection is achieved via total internal reflection using structures within a polymer sheet such as laser cut PMMA panels (Reppel *et al* 1998, Edmonds, 1997). Absorption is achieved with special vacuum deposited thin films on glass which are the main subject of this paper. There have been two recent literature reviews on this topic (Mbise *et al*, 1997, Smith *et al* 1998), the second covering work done under IEA task 18 on advanced glazing. Here we stress some new aspects of these systems.

Car windscreens and vertical windows are also of interest, with the benefit in vertical windows differing with latitude and window orientation. Glare reduction and light control may be the prime focus in regions more removed from the equator or for west facing windows. The work on thin films has focussed on light control because angular selectivity in many thin films is very spectrally sensitive and was easier to achieve in the

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