Thermal performance of a building in warm regions

Thermal Performance of a Building in Warm Regions

Performance thermique d'un bâtiment dans les régions chaudes

Thermisches Verhalten eines Gebäudes in einem warmen Klima

H.J. COWAN
Prof. of Architecturel Science
University of Sydney
Sydney, Australia

Dr. Henry J. Cowan graduated in civil and mechanical engineering from Manchester University. He is an Honorary Fellow of the Royal Australian Institute of Architects, a former Dean of Architecture, and the author of 18 books on the design of buildings. He is currently Head of the Department of Architectural Science.

SUMMARY
The structure can be utilized for sunshading and for thermal storage at a small additional cost. This may be regarded as a passive form of using solar energy, and it should result in a substantial saving of energy. If in addition careful attention is given to daylighting and ventilation, it may be possible to avoid the use of air conditioning in buildings where it would otherwise be needed.

RESUME
La structure peut être utilisée comme pare-soleil et comme accumulateur thermique à peu de frais. Cette forme passive d'utilisation de l'énergie solaire entraine une économie d'énergie considérable. De plus, si l'éclairage et la ventilation sont réalisés correctement, il peut être possible d'éviter une climatisation dans des bâtiments où elle serait normalement nécessaire.

ZUSAMMENFASSUNG
Die Gebäudestruktur kann mit kleinen zusätzlichen Kosten für den Sonnenschutz und für die Wärmespeicherung genutzt werden. Mit solch passiver Nutzung der Sonnenenergie kann eine beträchtliche Energieersparnis erreicht werden. Wenn dabei sorgfältig auf den Tageslichtbedarf und die Lüftung geachtet wird, kann auch in warmen Klimazonen auf eine Klimaanlage verzichtet werden.

1. INTRODUCTION

The structural requirements for the design of air-conditioned buildings in the tropics and subtropics are essentially the same as for buildings in the cool-temperate zone: the fabric, including the windows, should be well-insulated, and air-leakage through the windows should be minimized.

However, air conditioning is not economically feasible for many buildings because of the additional capital and operating cost, and some people prefer the diurnal change of temperature, particularly in their residences, to the steady state of air conditioning. In developing countries, maintenance of the air conditioning is a problem, and there may be restrictions on the use of energy.

This paper discusses the design of non-air-conditioned buildings for the tropics and subtropics, and its interaction with the structure of the building.

2. SUN SHADING AND THE STRUCTURE OF THE BUILDING

In a narrow region near the equator the temperature never drops to the level where heating becomes necessary, or even desirable. In that case sun shading need only ensure that sunlight penetration is prevented, although it is still necessary to avoid overshading which limits daylight (Section 4).

In a much larger region excessive summer temperature co-exist with winter temperatures which are too low for comfort. The need for heating can be reduced, or even eliminated, if sunlight penetrates into the building. Thus the sunshade must be neither too small to allow sunlight penetration during the "overheated" period of the year, nor too small to prevent sunlight penetration during the "overheated" period of the year, nor too large to prevent sunlight penetration when it is beneficial. The movement of the sun is the same for two cities with the same latitude, and it is symmetrical about the solstices. The overheated period, however, depends on local weather conditions, and it varies from city to city, although it generally occupies more days in the autumn than in the spring. A frequently used criterion is an external shade temperature of 21°C (70°F), which would produce overheating of the interior without sunshading.

Using a suitable spherical projection, the movement of the sun can be plotted, and the overheated period can be drawn on the same diagram. The sunshading and the sunlight penetration can then be determined by graphics or by the use of a shading mask. Alternatively, models can be tested with a sun-machine, such as a heliodon or a solarscope, or a computer program can be used. These methods are described in a number of books (For example, Ref. 1, pp. 41-52).

It is desirable to place sunshades outside the windows; they are more effective if the sun cannot penetrate the window glass, even the outer pane of a double-glazed window. However, external sunshades form a prominent feature of the facade, and their appearance requires the most careful consideration.

Sunshading and sunlight penetration should therefore be considered as part of the aesthetic concept of the building. The structure also has a dominant influence on aesthetics. The two should form part of a unified design concept.

The sunshades can be integrated with the structure to save structural material. Horizontal sunshades can be provided by a cantilever projection of the floor slab, which reduces the maximum bending moments in the slab. Vertical sunshades can be utilized structurally to reduce the column loads.

There are also functional advantages in using a cantilevered floor slab for horizontal sunshades, because this provides a balcony (or at least a platform for cleaning windows where only a small projection is required in tropical latitudes), for a facade facing south (in the northern hemisphere).

Vertical sunshades are needed if the facade departs significantly from a southern exposure (in the northern hemisphere). This applies particularly to a western, or partly western exposure, because the overheating occurs mainly in the afternoon.

3. THERMAL STORAGE

In climates where the temperature is both too hot and too cold for thermal comfort at some time of the day or night, the heat or coolness can be stored, and released several hours later to create a more comfortable temperature. This use of thermal storage was already known in antiquity, and it is utilized in several types of vernacular construction (Ref. 1, pp. 12 - 17). This method of utilizing solar energy is called "passive solar energy", and it received much attention after the energy crisis of 1973, particularly when it became clear that "active solar energy" (using solar collectors or photovoltaic cells) was rarely economical for heating or cooling buildings.

There is a substantial literature on passive solar design (for example Ref. 1, pp. 88 - 96). It has so far been treated as entirely separate from structural design. However, the structure can be utilized for thermal storage, the design of the building can thereby be simplified, and material can be saved and the dead load reduced.

The simplest method of passive solar design is the "direct gain" method. During that time of the year when heating would normally be required in the evening and at night, sunlight is allowed to penetrate through a large window by a suitably designed sunshade, and heat up the floor (or sometimes a wall). The floor should not be insulated by a carpet, but should be bare concrete (if that is acceptable), or covered with a hard surface, such as tiles, stone slabs, or terrazzo. The heat stored is released when the temperature falls, and this may be sufficient to heat the room adequately during the late afternoon and the evening. The effectiveness of this method depends on the thermal storage capacity of the floor. Evidently a thick structural concrete slab (for example, a flat plate) can provide this storage economically.

The thermal storage capacity can be increased if the heat is pumped into a store, and then pumped back into the room when it is required. The capital cost of the pump must be offset against the energy saved. In most passive solar buildings the heat store consists of an underground pile of crushed rock. However, the concrete structure of a building could be utilized instead, if the concrete floor is made with hollow-core blocks, or if pipes are cast into the slab.

Another effective method of thermal storage is the "Trombe wall", a thick wall of concrete or brick behind a large window, with a small air space between the two. This window, requires a sunshade to protect it from thermal radiation at certain times of the day or year (Ref. 1, pp. 90 - 91). The massive Trombe wall has appreciable load carrying capacity (which could be enhanced by suitable reinforcement), but this is rarely utilized. It should be possible to design a structural system that relies mainly on the load-carrying capacity of Trombe walls, if a passive solar design is used; a simple analogy is the structural use of the reinforced concrete service core in buildings.

The thermal process can be reversed by storing coolness collected during the night, and releasing it during the day. However, this is less effective than heating, because of the smaller temperature differential available in most climates.

4. SUNSHADING AND DAYLIGHT

In the tropics and subtropics the length of the day varies much less than in the temperate zone, and many buildings are thus occupied only during the hours of daylight. It is then possible to confine electric lighting to general background lighting, and emergency lighting, if the building is designed to admit adequate daylight.

Sunshades exclude not merely heat, but also light. However, the luminance of the sky increases as the latitude decreases, and reflected daylight provides adequate illumination; otherwise we would not be able to read in a room if we could not see the sky through a window.

The design of sunshades should therefore include an analysis of the reflection of daylight from the various surfaces, including the soffit of sunshades. Those required for reflection should be treated accordingly. A durable reflective finish for structural concrete is provided by white cement and/or exposed white aggregate. White paint is also a good reflector of daylight, but it must be renewed periodically.

5. TASK LIGHTING AND TASK VENTILATION

Most office and factory buildings need at least some electric light because of the depth of the rooms. At present this is generally provided by uniformly spaced luminaires which give a constant level of lighting over the entire room. Both fluorescent lamps and incandescent lamps produce heat as well as light; the ratio of heat to light is higher for the latter. In cold weather the heat is useful, although it can be more efficiently produced by other means. In hot weather it has to be removed. It is a major source of the heat load for an air conditioning system. In buildings without air conditioning the removal of the heat due to the lamps can be very difficult. The heat load is greatly reduced if task lighting is used in conjunction with low-level uniform electric lighting, or even in conjunction with daylight only.

Task lighting requires planning of the operation of the building, when work processes are altered.

Task ventilation by the use of ventilators, strategically placed near each task, also requires careful planning of the operation of the building, and provision for the relocation of the ventilators when work processes alter.

7. CONCLUSION

The recommendations made for the utilization of the structure to provide sunshading and thermal storage are equally applicable to developed and developing countries. The cost of the structure is increased by making it perform the additional functions, but this will often result in a substantial saving of energy.

The elimination of the need for air conditioning is of particular value for developing countries. Apart from saving initial and maintenance cost in a country with limited resources, it provides a better building. Air-conditioned buildings frequently become unusable if the system breaks down. In many developing countries one should allow for the failure of the electricity supply, or a breakdown of the equipment due to inadequate maintenance or a lack of spare parts.

REFERENCES

1. COWAN H. J. and P. R. SMITH, Environmental Systems. Van Nostrand Reinhold, New York 1983.

2. MARKUS T. A. and E. N. MORRIS, Buildings, Climate and Energy. Pitman, London 1980.

3. KOENIGSBERGER O. H. et. al., Manual of Tropical Housing and Building, Volume I - Climatic Design. Longman, London 1973.

Leere Seite
Blank page
Page vide