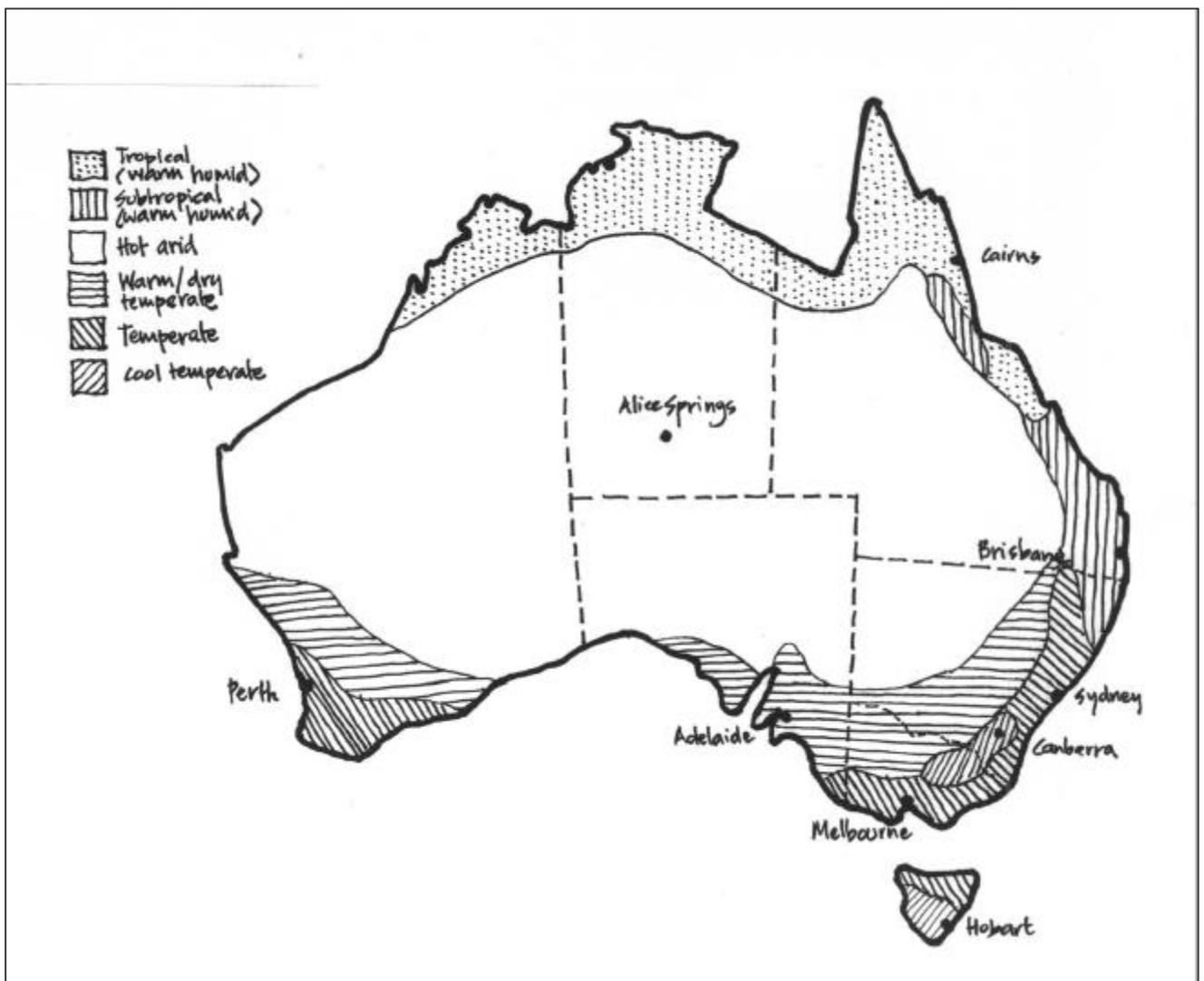


8. APPROPRIATE PASSIVE BUILDING STRATEGIES FOR DIFFERENT CLIMATES

8.1. Australia's climate zones

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has established generalised climatic zones for Australia which are determined by the different design responses required in each area (Fig. 8.1.). These climatic zones are described below. They are useful in indicating the general design approach to be followed, but they cannot take account of local variations. The borders shown between the climatic zones are only indicative. The transition between one zone and another is usually gradual.

Fig. 8.1. Climatic zones in Australia



- ***Hot and dry:*** characterised by warm to mild winter days, cool to cold winter nights, very hot and dry summer days and warm to hot summer nights. This climate is prevalent in the centre of Australia, west to the coast and south to the Great Australian Bight.
- ***Tropical (hot and humid):*** characterised by very high humidity in the summer, or wet season, and high temperatures throughout the year, with cooler nights in the short winter, or dry season. This climate is prevalent along Australia's northern coast.
- ***Sub Tropical (warm and humid):*** characterised by mild to cool winter days, cool to cold winter nights, hot and humid summer days with slightly cooler nights. This climate is prevalent in coastal areas of New South Wales and Southern Queensland, and in the highlands of north-eastern Queensland.
- ***Warm dry temperate:*** characterised by mild to cold winter days, cold winter nights, very hot dry summer days and hot to mild summer nights. This climate is prevalent in the south-west of Western Australia, south eastern parts of South Australia, and the western slopes and plains of New South Wales and Victoria.
- ***Cool temperate:*** characterised by cold but often sunny winter days, cold winter nights, mild summer days with cool nights. This climate is prevalent in the highlands of the Great Dividing Range, in parts of Victoria, New South Wales, the ACT and in central and western Tasmania.
- ***Temperate:*** characterised by cool to cold winter days, cold winter nights, warm to hot summers with moderate to high humidity. This climate is prevalent in the south-east of Australia, the south west tip of Western Australia, and those areas of Tasmania that are not included in the cool temperate zone.

8.1.1. Hot and dry regions

The principal problems encountered in arid regions are excessive solar radiation, heat, low humidity, undesirable winds, wind-born dust and sand, and other air pollution.

Location and Siting. Following the principles outlined in section 7.1, the first line of protection is the use of appropriate siting. In urban settings, this would involve the close placement of buildings to afford mutual shading, especially on east and west, and the restriction of large open spaces. Compact building forms reduce external surfaces subject to solar loads, while courtyards and walled gardens increase the opportunity for the use of vegetation.

For new, freestanding buildings, locate them on lower slopes of hills to benefit from cooler air flow in the evenings. Retain cooler air with dams, barriers or shrubs. If possible, arrange the buildings as a compact cube, slightly elongated along the east-west axis, and built around a central courtyard.

Landscaping. Carefully selected planting can significantly reduce the environmental loads on the building.

Consider the strategy of traditional Islamic walled gardens: tall narrow leafed cypresses are used at the periphery to filter the dust and reduce wind speeds; cleaner, but still dry air is then humidified by a second screen of broad leafed trees. Pavilions in such a garden would be shaded by a large broad leafed tree such as a plane. One such tree might transpire as much as 500 litres of water a day; the extraction of the radiant and convective heat required to evaporate such a volume of water would typically represent a drop in temperature from say 57°C above the crown (such high temperatures result from the combined effect of air temperature and solar radiation) to 32°C in the shade, while humidity under the canopy might be raised by 30 per cent.

More radical use of plant material has been proposed and investigated. Measurements taken in the Gibson Desert in Western Australia, of a lightly clad building with a plant canopy of vines grown on a framework spaced from the walls and roof, showed net heat flow into the building to be uniform and virtually negligible. However, such a solution may not be suitable because of the problem of pest control.

If suitable water supply is available, provide for a pond or fountain as a source of natural evaporative cooling. Use lawns around the building to reduce thermal loads, but not against the walls of the museum buildings due to potential pest problems (section 7.2.3.3.). Car parks should be shaded, as should walkways and entrances to the museum.

Load control. The elimination of radiant solar load is paramount. Consideration should be given to lightweight shading superstructures, especially over the roof of a building. In any case roofs should be reflective colours, thermally massive and highly insulated.

Building construction. Conventional temperature control in buildings in hot arid regions relies primarily on the damping effect of massive construction. By careful design of exterior elements a lag exactly matched to the time difference between the incidence of greatest heat load and of lowest night temperature can be achieved. Similarly, massive internal walls absorb excess heat, and re-radiate it at cooler periods, on a daily cycle.

Walls

- Massive wall construction of mud or stone, or cavity brick or concrete to provide high thermal capacity walls will heat and cool slowly.
- Use overhangs, eaves and verandahs to provide protection from the sun

Floor

- Use solid concrete walls with deep foundations to provide a heat sink for the building.
- Isolate the walls, floor and pillars against rising damp.

Roof

- Massive roof construction of high thermal capacity is an advantage.
- Paint roof white to reflect thermal radiation.
- Keep roof clear from dust and debris which lower reflectivity.
- Consider earth cover on roof with irrigated ground covers, to reduce thermal load and actively cool by evaporation, but take care with water used on roof gardens and lawns.
- Don't locate ponds on roofs.
- If using a reliably waterproof roof, such as metal decking at sufficient slope, and if water supply is available, consider spraying the roof with water for evaporative cooling.

Windows

- Windows in perimeter walls should be small and recessed to prevent entry of direct sunlight.
- Locate windows on side of building away from the sun.
- Use overhangs, eaves, verandahs and trees to provide shade.
- Use external louvres or shutters of lightweight construction to keep out heat, light and dust.
- Use clear UV absorbing filters on the window glass; do not use heat reflecting or absorbing glass.
- More generous openings may be considered to internal courtyards.

Earth shelter. Where earth sheltered or underground construction can be safely undertaken without risk of flooding, the available thermal mass is even greater. Seasonal differences in temperature can be utilised. At six meters depth, undisturbed soil remains effectively at a steady temperature equal to the annual average temperature. Nearer the surface temperature swings are greater, but even with only 600mm cover, the temperature follows that of the monthly average temperature. If the soil surface is shaded and irrigated, such temperatures can be depressed by another 7°C.

Humidification. In deserts, humidification may be achieved by quite simple means. With no tradition in Australia of integrating water into the building design, it is difficult to offer Australian examples. But even modern examples may be readily found in other regions with such traditions. The Mohenjo-daro Museum, on the Indus in Pakistan, utilises massive brick walls set parallel to the prevailing winds, and a concrete double roof. A large pool of water is

incorporated along the whole windward facade. Air passing over the pool is cooled, humidified and partially deposits sand and dust, before ventilating the museum halls. The Chandigarh Fine Arts museum in northern India employs similar passive humidification by being arranged around a courtyard with a large pool.

Better control over air flow, humidification and temperature may be achieved by more complex building forms, incorporating variations on the traditional wind catchers of Pakistan and Iran, and modern solar chimneys. At times of exceptionally low humidity, mopping the floors should be considered, as an effective way of providing a large evaporative surface.

The use of conventional evaporative coolers may be acceptable in most hot dry climates, but has the disadvantage of usually inducing larger temperature and humidity variations.

Light control. This should not rely on conventional window placement based on the practice of more temperate regions, having to be remedied by external or internal shading devices. Relatively small external openings should be strategically located for complete sun control, and to provide a combination of reflected light to floor, wall and ceiling surfaces. Where planted courts can be established, visual relief for the interior should be provided by outlook into the vegetation. The Japanese practice of placing openings low in the wall directs gaze downwards to a relatively small area, which can be highly landscaped and well maintained, perhaps inside a boundary wall. Thus contrast between the low internal light level external illumination is reduced, and glare eliminated.

8.1.2. Hot and humid regions

Design of museums, keeping places, archives and other repositories in the warm humid tropics will almost inevitably involve accepting higher temperature targets or set-points.

If, after consideration of the collection and visitor usage patterns, considerably higher than conventional temperatures are considered acceptable, design strategies will favour relatively closed, thermally massive buildings with some night ventilation the elevated temperatures being used to control relative humidity in enclosed spaces.

On the other hand, if lower temperatures, comfort ventilation, and air movement for mould control are considered priorities, lightweight, elevated construction similar to traditional housing is likely to be preferable. In this case, control of air-borne pollution will generally become a critical issue in the design and management of the museum.

Location and Siting. The priority of reducing environmental loads applies equally in the hot humid tropics. However, the implications for siting and building are different. Buildings will be generally more widely spaced, reflecting the relative ease of maintaining shade on intervening open areas by fast growing planting, and the need to encourage access to breezes for naturally ventilated buildings.

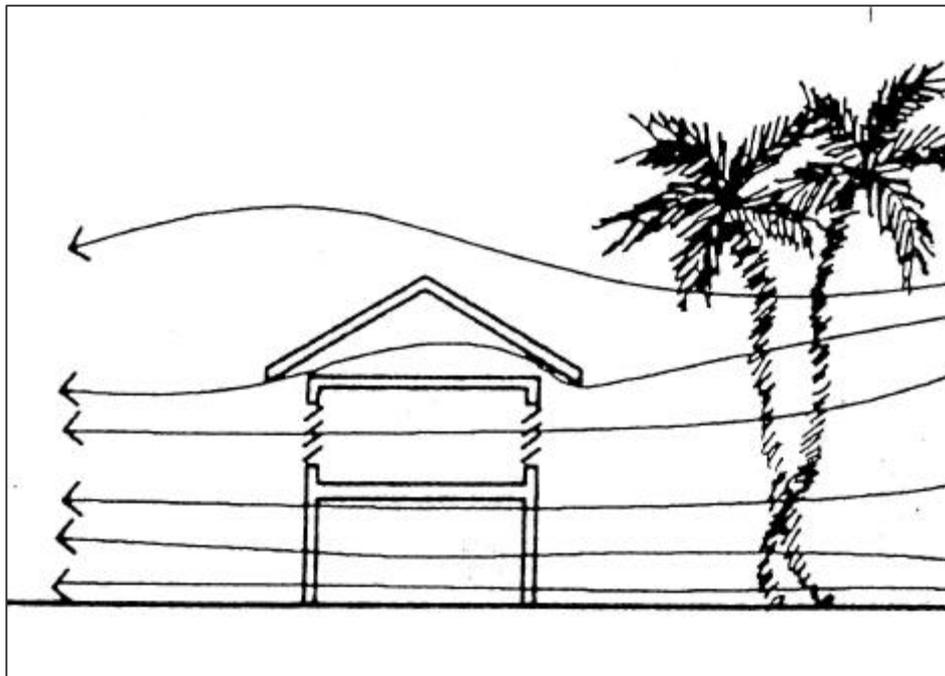
Build on the top of or the windward side of a hill, preferably on a north or south facing slope. If possible, site the museum away from sources of air pollution, eg. from industry and motor vehicles; on affected sites, utilise planting to reduce exposure.

Landscaping. Use trees and shrubs to provide shade for the building and car parks; the species will depend on the type and height of shade required. Car parks should be sealed if possible to rapidly shed water and dry in the sun, reducing the moisture level of the air. Keep sources of water away from the building. Use lawns to reduce thermal load on the building. Don't plant vegetation close to, or on the building, as they attract insects and rodents, and harbour air pollutants (section 7.2.3.3.).

For unfavourably oriented buildings, vegetation-covered frames or walls to provide barriers can be used to change the exposure to ventilating breezes.

Building shape. Individual buildings may be more elongated, with their long axis east to west. This is a simple function of the ability to use roof overhangs to control overhead sun, which may come from either north or south, while the low rising and setting sun is more difficult to avoid. 'Shallow' building plans can also facilitate cross ventilation by prevailing breezes (Fig. 8.2.).

Fig. 8.2. Well spaced houses oriented on E-W axis, with narrow plans, encourage good cross-ventilation



Natural ventilation. If it is decided to deal with elevated humidity only by the traditional technique of encouraging natural ventilation, it will dictate planning, form and construction of the building.

There are two ways of inducing natural ventilation:

- Cross-ventilation due to differences in pressure on the windward and leeward sides of a building. This requires appropriate placement of operable openings, to serve as inlets and outlets (see also section 7.1.2.4.).

- So-called 'stack effect', which relies on the buoyancy of heated air, rising in a tall space and allowed to escape at a high point in the building, to be replaced by air drawn in at low levels.

Both control of mould, and the enhanced comfort of staff and visitors depend on certain minimum air velocities. Stack effects, while they are useful for air exchange, and therefore temperature control, simply do not produce such velocities. Ventilation under such circumstances can only be assured by encouraging available breezes, and building designs that encourage good cross ventilation.

Building plans must therefore be such that cross ventilation is not obstructed by internal partitioning. Orientation is not as critical as one might think, as planting and other external elements can be used to modify the distributions of high and low air pressures around the building. The placement of openings in the building fabric, on the other hand, is critical. To enhance the velocity of a light breeze, outlet openings must be larger in area than inlet openings, which in turn must be so located as to direct the air stream onto occupants and the stored objects.

Driving rain. Control over the permanent ventilation openings will become the major design parameter. Where buildings are orientated perpendicular to the direction of the prevailing wind for natural ventilation, openings are vulnerable to driving rain. Water finds a way through the smallest opening and the wind can force it up a vertical surface. Even with deep roof overhangs, penetration of water through openings designed for ventilation may be difficult to avoid. It would be best if the solution is in planning, rather than construction - areas on the periphery of the building may be dedicated to circulation spaces with finishes designed to cope with intermittent wetting. Storm shutters may be required for some extreme situations.

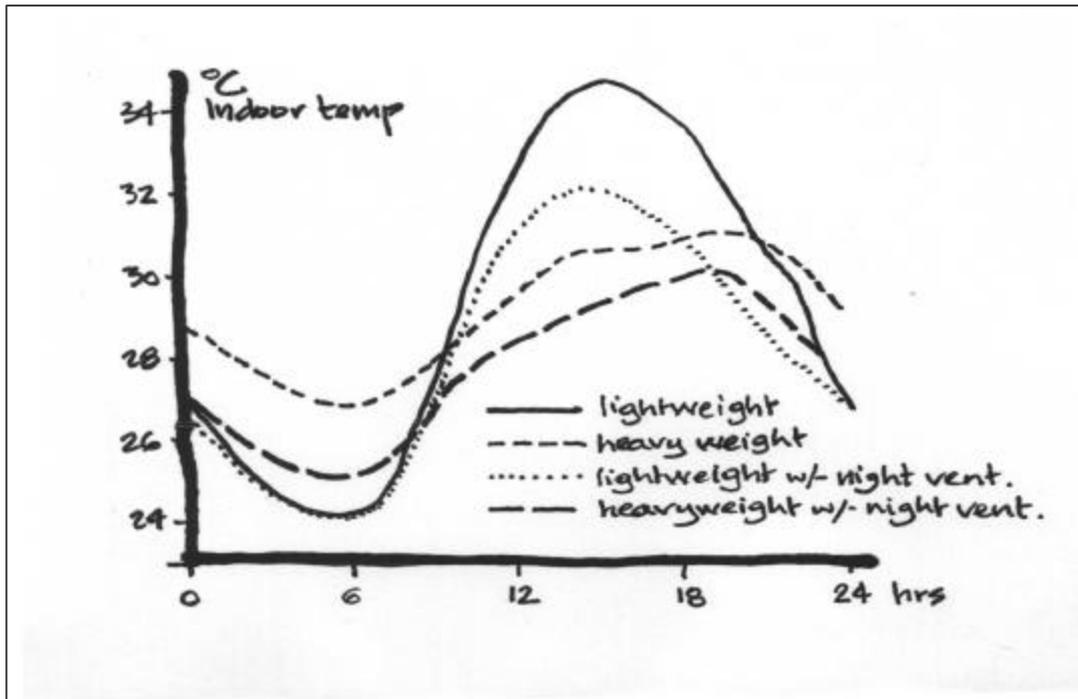
Openings and sun screening. Openings for light generally do not need to be as restricted as in the hot arid zone. Since the 1960s it has been popular in tropical climates to build grids, or screens, of in-situ concrete or specially designed perforated concrete blocks, to fully sun-screen the facades of larger buildings. These grids and screens are often referred to as 'brise-soleil' after the name given to them by Le Corbusier, the architect who was so influential in popularising this approach. However, it is better not to rely on screening conventional openings from the sun by the use of such 'brise-soleil' type grids, because they act to store the solar radiation and effectively transfer it to ventilating air passing over them on the way to the interior. If the screen is structurally connected to the building, heat will also be passed to the interior by conduction.

Thermal mass. As long as solar gain is minimised, with permanent ventilation for air movement, the thermal environment of the building will follow that of the outside closely, almost regardless of the materials of construction.

However, even with the smaller diurnal temperature swings of 5 - 10°C in a hot humid climate, the storage effect of structural mass is just about worth considering. This is particularly the case where the building is unoccupied at night as a museum typically might be since the usual criterion of rapid cooling to improve sleeping conditions does not apply.

When designing a building to give high air movement, one anticipates ventilation rates in excess of 50 air changes per hour (ac/h). This means that internal gains would be ventilated away quickly. With a reduced ventilation rate in the daytime, the building will be much more sensitive to internal gains of any kind, and much more care must be taken with shading and insulation, etc. The effects of the weight of building materials on damping the external temperature, with and without venting, is shown in Fig. 8.3.

Fig. 8.3. Result of night simulations for a building in Darwin



Furthermore, restricting daytime ventilation rate to 1ac/h, all physiological cooling effect for occupants, and any role in prevention of mould due to natural air movement will be lost. This air movement would have to be provided mechanically, typically by overhead fans. Alternatively, this approach could be suitable for a museum store, with very low occupancy levels.

Dehumidification. Where air exchange with the outside is restricted, consideration may be given to dehumidification, either by mechanical, or by 'passive' means.

Passive dehumidification at the scale of whole buildings is normally considered very difficult, because of the amounts of desiccants required to deal with the large air quantities. The more usual approach is to use a dedicated refrigerative dehumidifier. However, it should not be forgotten that a conventional wall mounted or split system air conditioner does condense water vapour on its cooling coils. Under many circumstances, it may be demonstrated that such air conditioners, with no humidistat control but set to recirculate internal air, will achieve comparable dehumidification with the additional benefit of providing some cooling. The advantage of using domestic air conditioners is the comparative ease of maintenance and service, compared to dedicated dehumidifiers.

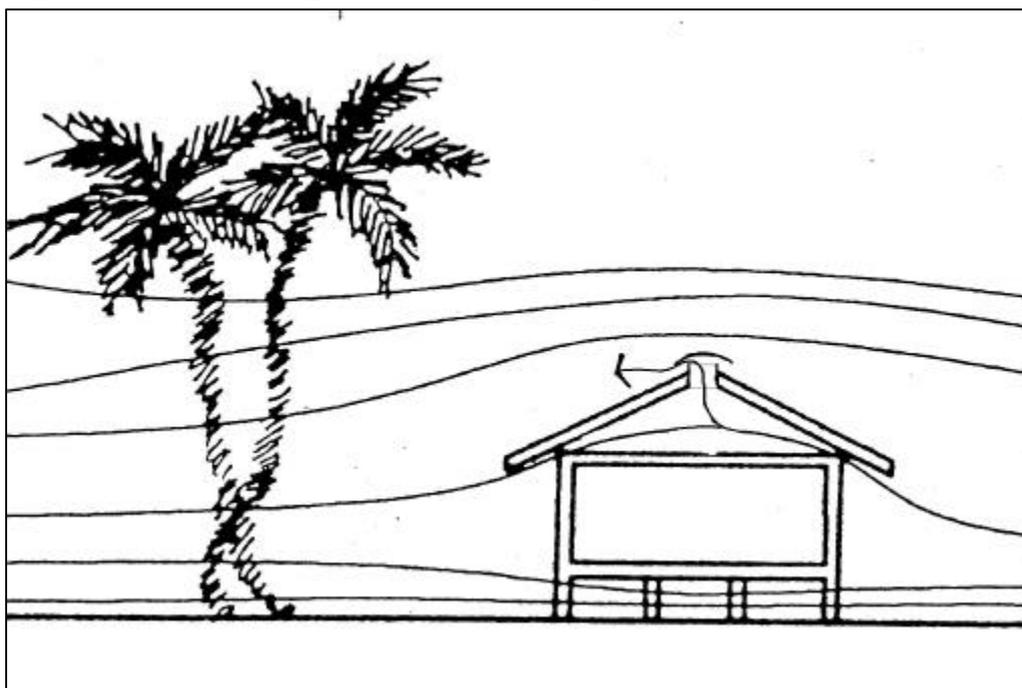
Indirect evaporative cooling. Despite high ambient RH, some limited potential for evaporative cooling does exist. However, to be utilised, such evaporative cooling has to be 'indirect'. In simple terms, the cooled but saturated air which is produced by a conventional evaporative cooler, must be passed through a heat exchanger to cool another separate stream of air without adding moisture to it. The use of such units only becomes relevant in conjunction with dehumidification, since the RH of the interior air still rises as its temperature drops. It is doubtful that any presently available system offers a significant advantage in energy costs, or in reliability, over refrigerative air-conditioning.

A specialised form of indirect evaporative cooling which may be useful where there is a plentiful supply of water, is spraying of the roof by means of simple sprinklers. Surface temperature of roofing is reduced from over 45°C to typically 28°C.

Roofs in the hot-humid zones must be designed to shed rain quickly, and will most often be relatively steeply sloping. For maximum rejection of solar radiation, use white, or light colours.

Being the major source of radiant solar load, consideration should be given to ventilated double roofs (Fig. 8.4.). The use of light metal roof as external sheeting in this case is problematic, as the drumming noise from frequent rain can exceed 70dBA and can compromise activities in the building. In normal single roof applications, thermal insulation would be placed in contact with the external sheeting to dampen this noise. But in double skin roofs, the insulation would be wasting its potential for heat reduction in this location. Therefore a rigid, massive external roof finish, such as tiles, may be more appropriate for noise control. The permanent ventilation of the roof cavity can be assured by correctly designed ridge ventilators. Additional extract ventilation may be used to exhaust some of the warm air from under the ceiling, as well.

Fig. 8.4. Eave and ridge vents allow cooling of attics



8.1.3. Cool temperate regions

Australia has no true cold climates. Even the alpine regions do not experience winter temperatures comparable to much of continental Europe or North America. Building strategies in cool temperate regions such as the Australian Capital Territory, New England, the Victorian Highlands, and much of Tasmania, need to balance dealing with winter cold, while also protecting collections and achieving human comfort during warm to hot summers.

By definition cold winters need additional heat input; therefore the best strategy is to conserve heat. But because of the availability of relatively high amounts of winter solar radiation, buildings should also exploit passive solar design principles.

Passive solar design of museums is particularly problematic, because of the damaging effects of sunlight on most museum artefacts. The appropriate use of solar heating in this specialised application is briefly discussed below.

Location, siting and landscape. South facing slopes will significantly reduce available solar radiation, and ground surface temperatures may be reduced enough to maintain frost cover long into winter days. Slopes facing up to 40° west of north would be beneficial in winter, but severely aggravate summer sun exposure. Overall, north facing slopes, up to 20° east, are considered optimal. Shelter from both cold winter winds and hot summer winds is generally required. As prevailing wind directions in the two seasons differ, shelter planting should be carefully investigated. At entrances, external wind protection is especially important. Planting should assure sun access in winter, to north elevations of buildings. Ideally, trees close to buildings would be deciduous, admitting winter sun and providing summer shade and evaporative cooling.

Building shape and orientation. Reduced surface/volume ratio of the building to minimise potential heat losses has to be balanced against optimum planning for passive solar design. A rectangular compact plan of approximately 1.5 2:1 ratio is desirable, with the long axis oriented east-west. Two storey designs improve the isolation of interior spaces from the external environment. Generally entrance and exit from the building should be by way of airlocks.

External envelope. In order to reduce winter losses and summer heat gains, insulate the building envelope to high standards. Windows should be moderate in size, and double glazing will usually be justified on other than the northern orientation. Construction should be air-tight, compatible with the requirements for minimum ventilation. External doors and windows should be weather striped. Consideration should be given to simple heat exchangers to retrieve heat from exhaust air, in order to preheat incoming air.

Building mass. Though the building may not be continuously occupied, environmental conditions are expected to be maintained on a continuous, rather than intermittent basis.

Therefore, there is an advantage in having an appropriate amount of internal thermal mass, to reduce the internal temperature swing to a minimum. A winter temperature swing of less than 4°C without supplementary heating should be considered an appropriate standard for the construction.

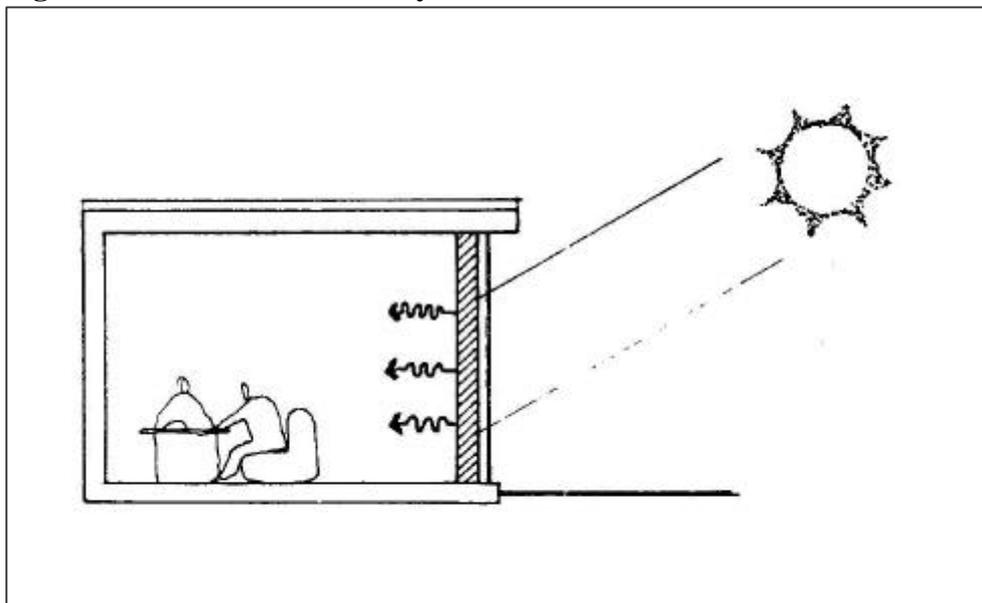
Thermal mass is a necessary component of passive solar design. It absorbs excess heat during the sunlit period, and returns it to the space at night. For maximum effectiveness, thermally massive elements should have a large surface area, and a thickness based on their optimum diurnal heat capacity.

Thermal mass is also beneficial during the summer. During the day, it takes up heat from the interior, moderating any temperature rise. During the night, it can give up its stored heat to controlled ventilation.

Passive solar design. Where good winter sun is available, glazing should face the equator, with insulated shutters for control of conducted heat losses at night. However, except for areas separate from display and storage, conventional 'direct gain' solar collection is unacceptable. Alternative systems include:

- Thermally massive collector walls, such as the *Trombe* wall (Fig. 8.5.). The material and thickness of the wall may be adjusted to achieve the desired time lag, in order to provide the majority of heating during the evening and night periods.

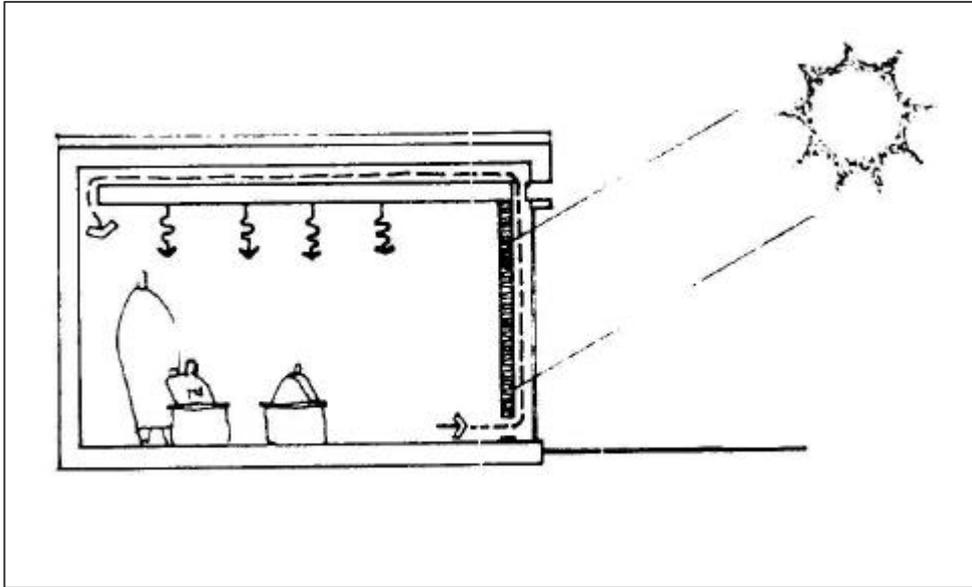
Fig. 8.5. The Trombe Michel system



- Light-weight collectors generating overheated air, such as the *Barra-Constantini* collector wall (Fig. 8.6.). Heated air supplied by the collector is usually supplied to spaces remote from the sunward facade, by natural convection, or small 'parasitic' fans. If warmed air is routed through spaces

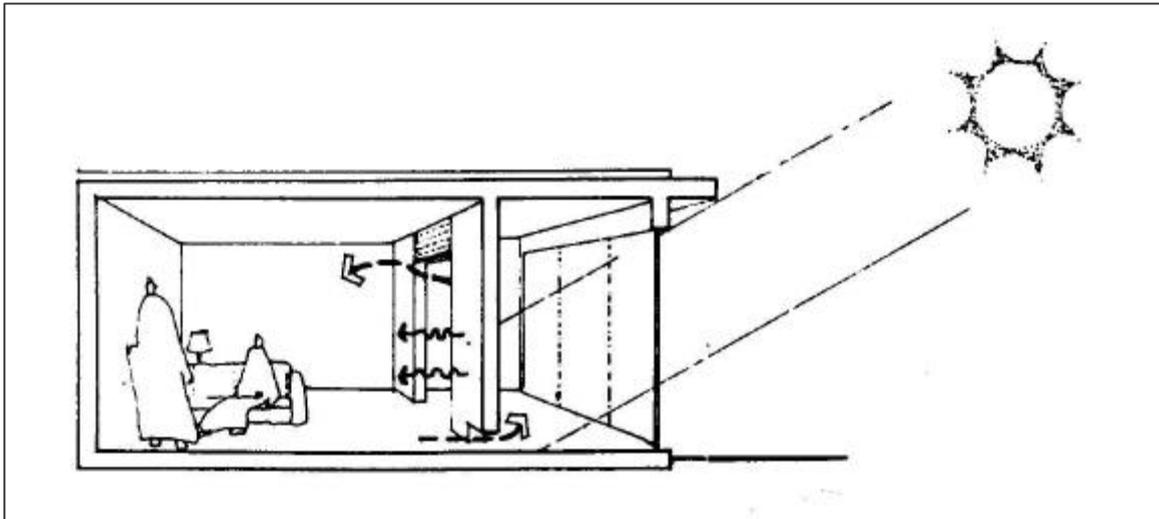
in a thermally massive structure, some delayed heating at night is also achieved.

Fig. 8.6. Light-weight collection panel: the *Barra-Constantini* system



- Attached sun spaces. Such spaces may be of quite varied configuration. Typically, they would accommodate ancillary functions such as circulation, or even a cafe in a larger institution. They work on the basis that they ‘over-heat’ during sunny weather, and cool below acceptable limits at unoccupied periods. Even during such periods, they still represent an intermediate environment between the interior and the exterior, thus reducing heat losses in winter. Passage of heat from the sun space to the display or storage spaces may be by way of a thermally massive wall with a calculated time lag, a lightweight insulated wall, or natural or assisted convection of air. Attached sun spaces must be carefully shaded and well ventilated during the summer months (Fig. 8.7.).

Fig. 8.7. Attached sun space with mass wall and ventilation openings



In each of the above systems, direct sun penetration in the heated space is completely avoided.

8.1.4. Temperate regions

Most design principles described for cool temperate climates apply.

Winter requirements are similar to cool temperate climates, but because the underheated period is not as severe, surface/volume and insulation standards are not as rigorous. Solar heat input in winter is desirable, so orientation and other considerations are the same as for cool temperate.

As overheating in summer is possible, structural sun control is necessary. Cut-offs between winter heating and summer sun exclusion depend on average monthly temperatures. Consider the use of deciduous vegetation for automatic shading discrimination between winter and summer.

As night temperatures are often below appropriate, even in summer, thermal mass is desirable. The thermal mass is, of course, also beneficial for passive solar design for winter. Summers are generally more benign, with lower maxima and less frequent extreme days. Ventilation can cope with most summer overheating by removing the surplus heat. But if shading is adequate, such overheating should rarely occur. However, on a few extreme days, severe overheating may combine with elevated humidities to produce conditions worse than those in the tropics. On such days, additional care needs to be taken with reducing solar gain and air exchange rates, to limit the extent of internal temperature and humidity rises.