PART 7 CASE STUDIES

CASE STUDY 01

THE IMPACT OF HOT-DRY CLIMATE ON HOUSING

A COMPARATIVE STUDY BETWEEN TRADITIONAL AND CONTEMPORARY HOUSES, WITH SPECIAL REFERENCE TO GHADAMES CITY, LIBYA

Shawesh, Abubarker. Forum Vol. 2, 1993

This report discusses the different responses of traditional and modern housing to the hot-dry climate of Libya. It compares the performance of several traditional and modern buildings, illustrating that contemporary development has fallen short of achieving the same level of thermal comfort provided by traditional structures.

In a residents' response survey, about 97% of the population living in the traditional buildings were satisfied with the climatic conditions, whereas 95% of the population living in contemporary buildings were dissatisfied. This emphasises the importance of studying early architectural responses to similar climatic conditions to those in the Pilbara. The design strategies of these traditional structures are reproduced here an example to inform the design of buildings in the hot-dry areas of the Pilbara.

PUBLIC REALM STRATEGIES

Considerations for streets:

Use awnings etc to cover streets during the summer to reduce heat gain

Narrow streets can be shaded by the buildings overlooking them

HOUSING DESIGN STRATEGIES

Provide maximum protection for solar radiation and direct sunlight - introverted

Houses can be built in clusters/joined together to provide shade and protection from undesirable heat and wind

Use heavy and thick external/internal walls and roofs with a time-lag of several hours

Use light wells and sky lights to bring light and ventilation into the space

Considerations for openings:

Small size (in this case, less than 500x500mm)

Open on to interior light wells, shady or covered streets to capture cool air

Locate at high level

Light colours are used to keep the building cool

Courtyard

Often only a depth of one room

Multistory courtyards increases shading of the area

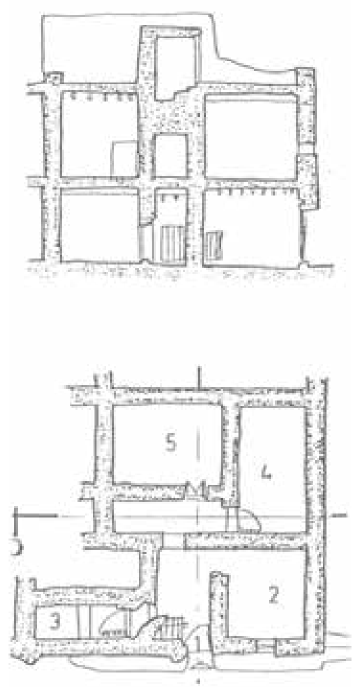
THE DESIGN OF TRADITIONAL HOUSES

In order to evaluate the climatic performance of traditional dwellings three houses were selected for examination, in which climatic conditions were measured. These three houses, which are typical of the traditional dwellings, are described below:

Sample One

This house is situated in the south of the town in the Auld Blel neighbourhood. It is located within a plot area of 31 square metres and has a covered floor area of about 64 square metres. The house is three storeys high.

From the section A-A in figure we notice: the main entrance of the house opens onto the public street which is uncovered, but the high walls on the other side of the narrow street generally keep it shady, to protect the occupants from the direct sunshine. In this house, habitable rooms are found on the ground floor, as well as on the other levels. However, during the summer nights people always use the roofs as a living area, enjoying the cool night breeze.



Traditional: Sample One

Sample Two

This house is situated in the centre of the town, in Tangzin neighbourhood, within a built-up area and has a plot area of about 26.50 square metres and a total floor are aof about 80 square metres. It is four storeys high.

From section A-A in figure we notice: the main entrance of the house, opening off the public street is completely covered, in order to maintain the temperature as cool as possible. One of the important aspects of this house is that the entire area of the ground floor is organised for storage purposes. Living areas are situated on the first, mezzanine, and second floors. However, during summer nights, people sleep on the roof, enjoying cool night breezes.

Sample Three

This house is situated to the north of the town in Mazigh neighbourhood within a plot area of 25 square metres and with a covered floor area of about 75 square metres. It is four storeys high and there is a courtyard to one side. Part of the house is also built over the street.

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From section A-A in figure we notice that the main entrance of the house opens of the public street which is also completely covered to maintain the temperature as cool as possible. The whole of the ground floor accommodation is used tor storage purposes. The living area is situated on the first floor, mezzanine floor and the top floor during the summer.

From the observation of the three traditional houses several points were noted. Mud is the main material for both roofs and walls. All the rooms are lit and ventilated in different ways. The windows which are small, open on to interior lightwells, shady or covered streets. Their opening size is not more than 50 by 50cm, located at a high level, near the ceiling are colour washed in white to keep the interior of the house as cool as possible; the walls are thick as well. It was also found that air-conditioning is hardly used in these houses.

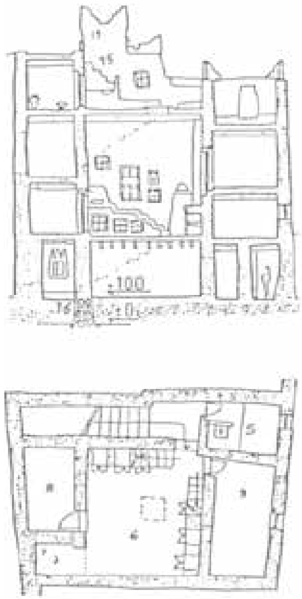
THE DESIGN OF MODERN HOUSES

The three houses of modem design which were selected for investigation, in which climatic conditions were measured, are described below:

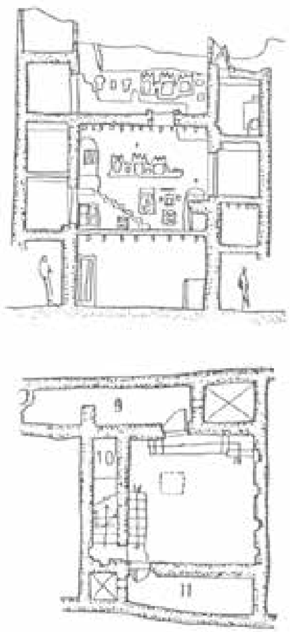
Sample One

This house is situated in the south of the new town within a plot area of about 232 square metres. It has about 187 square metres of floor area. It is one story high. The house occupies the whole width of the plot, and is built up to the boundary of the plot. There is a small garden at there centre of the house.

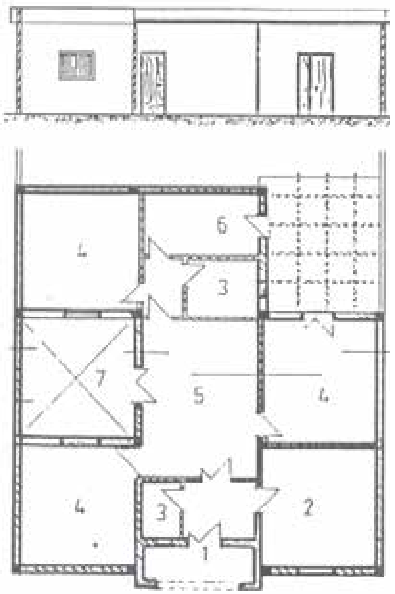
From the section A-A, in figure it is noticed that: the main entrance opens directly to outside and has no protection from the sunshine and wind, which increases the interior air temperature. It is found that in this house, many different styles and systems of construction do not suit the way of life of the residents.



Traditional: Sample Two



Traditional: Sample Three



Modern: Sample One

Sample Two

This house is situated in the middle of the new town within a plot area of about 164 square metres and a floor area of 168 square metres. It is two storeys high. The house occupies the whole width of the plot, and is built up to the front boundary of the plot. There is a small garden at the rear of house and a kitchen yard

From section A-A, in figure it can be noticed that: the main entrance open directly to the outside, facing the wide,asphalt pubic street. The ground floor is organised as a main living area, and the first floor is used as a sleeping area. However, there is no separate storage area.

Sample Three

This house is situated to the north of the new town within a plot area of about 102 square metres and a floor area of about 10 square metres. It is two storeys high. The house occupies the whole width of the plot, and is built up to the front boundary of the plot. There is a small garden, and a small kitchen yard.

From the section A-A, in figure, it is noticeable that: the main entrance opens on to the wider uncovered street, which causes an increase in the interior temperature. All living areas are distributed between the ground floor and the first floor. There is no separate storage area. The rooms are lit and ventilated through the windows which open directly on to the exterior space. From the observation o f the three modern houses we notice that: concrete is used as the main material for both roofs and walls. All modern houses are lit and ventilated through large windows opening directly to the outside without any shading devices. Each house is individually oriented and distinctly coloured. All the rooms in these houses are provided with air-conditioning equipment, and all the houses are provided with a complete infrastructure except that no landscaping has been provided for any of them.

CLIMATIC CONDITIONS

The climatic data were collected from the central Meteorology centre of the Jamahiriya in Tripoli, the Meteorological station of Ghadames and the Municipality of Ghadames, about air temperature, relative humidity, air movement, rainfall, and sunshine hours for the twenty years period from 1970 to 1990.

In addition I set myself the goal of recording micro-climatic data about indoor and outdoor air temperature, relative humidity in traditional houses in the old town and in modern dwellings in the new town.

This stage started on 1 August 1991 and lasted for 30 days. During this period, I recorded the climatic data: indoor air temperature, relative humidity in three different places in each house (near the main entrance, in the living room, and in the bed room) at six locations: three in the old town and three in the new town. These locations were chosen to cover the north, south, and central parts of the old town and of the new. I also measured the outdoor air temperature, relative humidity and wind velocity in three places in south, central, and north parts of the old town and the new. The measurements were recorded at three times daily 8.00am, 2.00pm, and 8.00pm.

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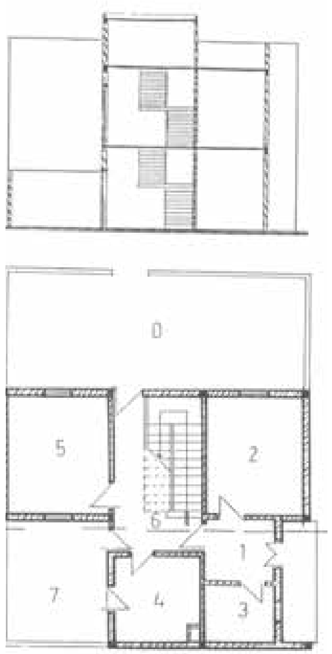
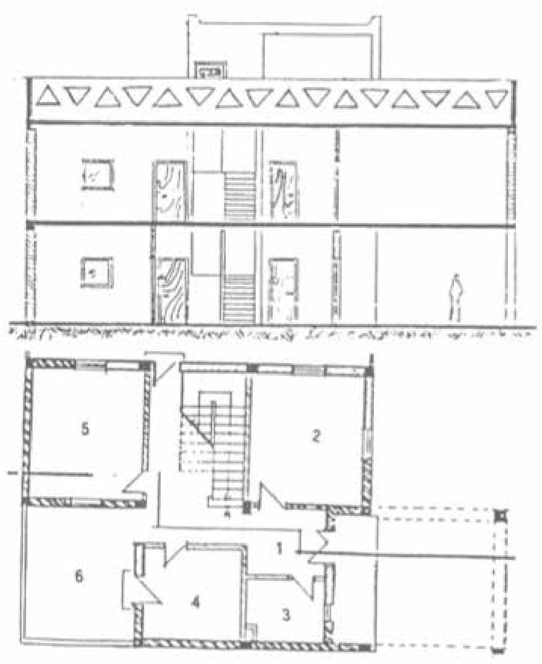


Modern: Sample Two



Modern: Sample Three

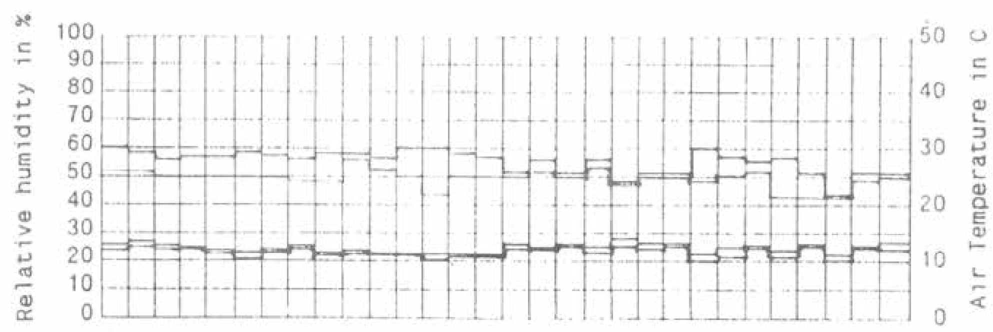


Figure 7: Comparison of Indoor Climatic Data between the Old and New Town in the Morning

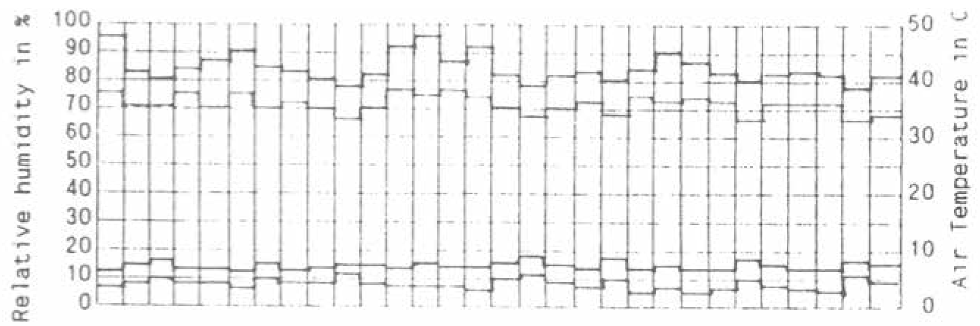


Figure 8: Comparison of Outdoor Climate Data between the Old and New Town in the Afternoon

The individual recording of climatic data produced for each house, the morning average, afternoon average and evening average of internal and external air temperature, wind velocity and relative humidity during the month of August 1991. The design analysis of dwelling construction shows a significant difference between the traditional houses and modern houses in terms of responses to climate.

The comparisons between the six sample houses examined over a period of 30 days in the month of August 1991 also shows a significant difference between air temperatures and relative humidity, as well as the interior climatic condition, as interpreted in relation to the locations from the comfort zone in the three periods (morning, afternoon, and evening). The following figures present these differences between the traditional houses and the modern houses.

Fig. 7 presents the morning average of the three readings taken inside each house of indoor air temperature and relative humidity. Both curves for air temperature reach minimum values for both the old and the new town; for morning readings,air temperature in the old town between 23ºC and 28ºC, and in the new town, it is between 23ºC and 30Cº. The relative humidity is between 23 and 29 per cent in the old town and between 20 and 25 per cent in the new town.

In the afternoon period, air temperature reaches the maximum values in both; in the old town it is between 27ºC and 30ºC, and in the new town,it is between 33ºC and 39ºC. However, the relative humidity during this period reach the minimum values, in the old town. it is between 17 and 23 per cent, and in the new town, it is between 10 and 18 per cent. During the evening period, air temperature starts to decrease; in the old town, it is between 20ºC and 28ºC, and in the new town, it is between 26ºC and 34ºC. The relative humidity also starts to increase; in the old town, it is between 20 and 26 per cent, and in the new town. it is between 16 and 22 percent.

Fig. 8 presents the afternoon average which compares readings taken outside each house of air temperature and relative humidity. During the morning period, air temperature reaches the minimum values, as well as the relative humidity. In the old town, temperature is between 24ºC and 30ºC, and in the new town, it is between 25ºC and 30ºC. The relative humidity is between 22 and 27 per cent in the old town and between 21 and 27 per cent in the new town.

CASE STUDY 01

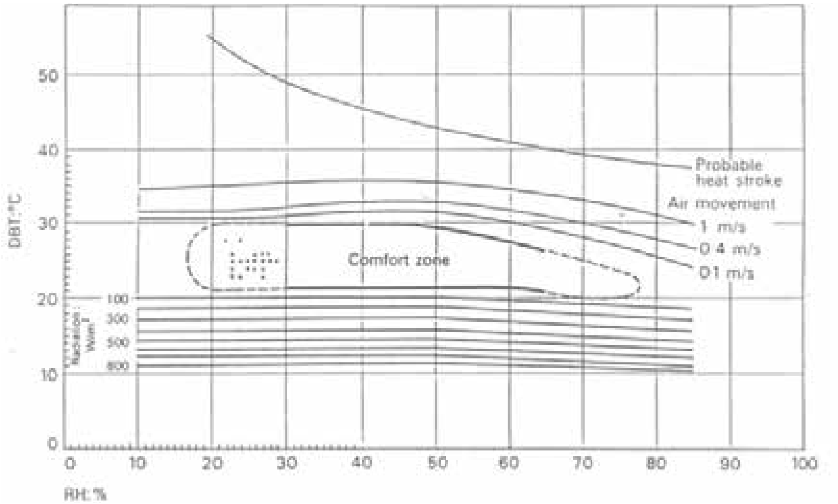


Figure 9: Bioclimatic Chart Showing Morning Indoor Climatic Conditions Related to Comfort Zone During Month of August 1991 in the Old Town

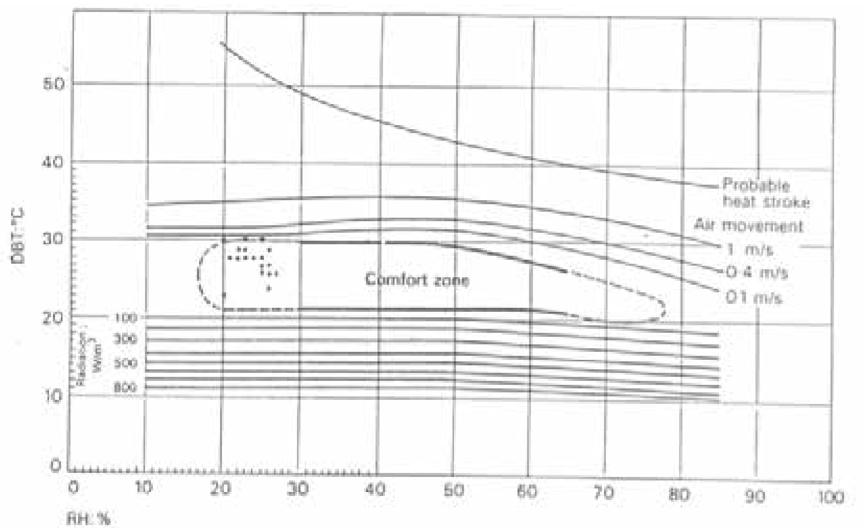


Figure 10: Bioclimatic Chart Showing Morning Indoor Climatic Conditions Related to Comfort Zone During Month of August 1991 in the New Town

During the afternoon period, air temperature reaches the maximum values, while the relative humidity reaches the minimum values. In the old town, air temperature is between 33ºC and 38ºC and in the new town, it is between 39ºC and 47ºC. The humidity is between 12 and 18 percent in the old town, and between 8 and 11 in the new town. During the evening period the air temperature decrease in the old to between 28ºC and 33ºC and in the new town to between 41 and 43. The relative humidity is between 17 and 22 per cent in the old town and between 12 and 16 per cent in the new town.

Fig. 9 and Fig. 10 present the analysis of the morning climatic conditions in both the old and the new town. The climatic conditions are comfortable during this period in both the new and the old town, because the air temperatures and relative humidity inside the comfort zone.

Analysis of the afternoon climatic data in both the old and the new town reveals that the indoor climatic conditions of the old town are comfortable because the air temperature and relative humidity are largely inside the comfort zone during this period. However, the climatic conditions of the new town are uncomfortable because the air temperature and relative humidity are outside the comfort zone.

Similarly the evening climatic data in both the old and the new town reveals that during this period, the climatic conditions are more comfortable in the old town because the air temperatures and relative humilities are completely inside the comfort zone. However, the air temperature and relative humilities are largely outside the comfort zone.

The residents' response survey indicate that about 97 per cent of the population in the old town of Ghadames city were satisfied with the climatic conditions in the old town. In contrast, 95 per cent of the population in the new town were dissatisfied with their climatic condition both indoors and outdoors. Interestingly ,about 91 per cent of the new town population prefer to live in the old town of Ghadames. This demonstrates that the built form of old town of Ghadames has responded to the local climatic conditions far better than the new town.

CASE STUDY 01

CONCLUSION

It is clear that the traditional houses were designed mainly to provide maximum protection from solar radiation and direct sunlight. However modern houses are designed with little consideration to the climatic conditions.

The bio-climatic patterns in Ghadames traditional houses appear in different stages of climatic adaptation. Firstly at the settlement structure level, houses are built in a compact mass to provide more shade and protection from undesirable heat and wind.

Secondly, traditional houses have heavy and thick external and internal walls and roofs which involve a time-lag of several hours in the transfer of heat from the external to the internal surface. In addition, the streets are narrow, covered, shaded, and winding, in width less than the height of the buildings overlooking them, which makes the streets shady most of the time.

When light and ventilation are brought in to the houses through shaft wells, sky light and limited openings lot not more than 50 by 50cm) inside the wells or the covered streets the interior of the house heats up more slowly during the daytime. They provide the houses with natural lighting and ventilation, which area adequate and comfortable. Natural lighting levels within the rooms are relatively low, but air movement is indirect throughout the house, bringing cooler air into the house from shady areas outside, and, therefore, produces good conditions for the thermal comfort.

In contrast, we have seen how the new settlement of Ghadames is climatically less well adapted. Firstly, the Ghadames new settlement is characterised by detached houses and wide open uncovered streets. Secondly, the modern houses have large unprotected glass windows on all four sides of the buildings. For this reason, air conditioning is necessary to provide a comfortable temperature inside the house. But the use of air conditioning systems has resulted in increased heat outside the house. In addition, the use of modern materials with thin light weight walls and roofs which have quick time-lag for heat transfer contributes to the poor climatic adaptation of new housing in the new town.

CASE STUDY 02

DESIGN PRINCIPLES IN THE HOT AND ARID CLIMATE OF IRAN, THE CASE OF KASHAN

Mohammad Reza Leylian, Aryan Amirkhani, Mohammad Reza Bemanian, Mahdieh Abedi, International Journal of Academic Research. Vol 2. No. 5. September, 2010.

This paper explores the climate responsive design strategies of traditional Iranian housing, specifically in the city of Kashan. It is part of a larger study that compares the thermal performance of modern and traditional houses. A brief case study evaluating the properties of a modern house and a traditional one as well as the results of a user questionnaire are used in this paper to demonstrate that traditional houses are able to maintain cooler temperatures in the summer than modern ones. The traditional design principles identified in these two reports are reproduced here and can be used to inform climate-appropriate designs in the Pilbara.

HOUSING DESIGN STRATEGIES

- High external walls can be used to shade courtyards
- Compact housing forms reduce the heat gained from sun exposure
- Water can be used as a landscaping feature to provide evaporative cooling
- Thermal mass reduces the effect of the outside temperature on the interior during the day and provides warmth at night
- Minimise of the quantity and area of windows
- High levels windows prevent solar radiation reaching the floor
- Light coloured building surfaces can reduce solar radiation
- Provide natural ventilation, especially at night
- Building into the ground will be cooler than the outer ambient temperature in summer
- Semi-open areas can be used as shady/cool living spaces during the day
- Wind towers are used for air movement, drawing cooler air into the house

DESIGN PRINCIPLES IN HOT AND ARID CLIMATE

Site and orientation of the building, space between buildings, building form and optical and thermo-physical properties of the building envelope are the most important design parameters affecting indoor thermal comfort and energy conservation in building scale.

Among parameters building envelope, as it separates the outdoor and indoor environment, is the most important parameter. All of parameters are related to each other and the best values of each parameter should be determined depending on the values of the others and their best combination should be determined according to the climatic qualities of the region.

The climate of the central Iranian Plateau is relatively similar to desert climate. This region represents the hot and arid area with a high temperature difference between day and night. When evaluating traditional architectural patterns, it can be seen that designers were more sensitive and they presented the most suitable design and settlement examples for each climatic region.

Site and orientation of the building

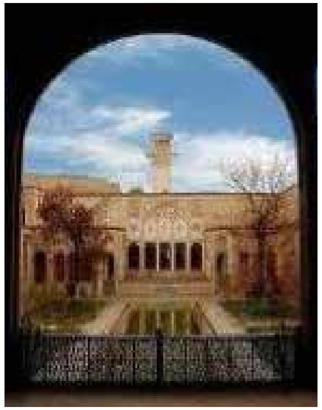
The topography is a basic parameter that determines the architecture of the hot and arid region in Iran. In Kashan, houses are situated according to the slope of a hill of the city and they are all oriented to the South-East. In Kashan, terraced and row houses do not ever let their shadows fall over the next or on the one facing or behind them.

Space between buildings to provide shady areas

In the design of traditional houses in the hot and arid area in Iran, there are several precautions taking against the hot climate. Houses are isolated from the street and surrounded by high walls. During the day, external walls of houses provide generally shady areas in narrow streets and especially in courtyards. By means of heavy and thick walls, warm environment in winter and cool environment in summer could be provided easily.

CASE STUDY 02




Courtyard colonnade arrangements provide shady areas outside

Form of the buildings

In Iran, in hot and arid climate, the most preferred plan type is the courtyard houses. In order to reduce the area affected by the solar radiation, compact forms are chosen. Shady areas can be obtained by arranging those forms with courtyards.

In courtyards, with the help of plants and water for evaporative cooling, shady areas can be obtained, the floor temperature can be reduced by the high walls surrounding the courtyard, and the open areas can be used during the day water. Channels poured out from the pool are important elements for cooling.

Water is usually spread by channels to the floors of the courtyard and evaporative cooling from the surface of the courtyard floors which are made of porous stone is efficient. Courtyards are always in the ground floor and have distinct forms depending on the landscape of the house. One of the main characteristics of arid and hot climate are flat roofs. "Eyvan" and ravagh, semi-open areas, are used to create shady and cool living spaces during the day. The "ravagh" semi-open colonnade arranged in the courtyard always provides shady areas. The "eyvan", three side closed corridor in front of the "rooms", permits a common life inside. Usually they are oriented to the south. Particularly south and east oriented eyvans are very cool and shady places for summer afternoons.

Thermo physical and optical properties

In the hot and arid climatic area in Iran where the continental climate is effective, in traditional architecture examples, to profit from the time lag of the building envelope, materials with greater thermal mass have been chosen. These sort of thermally massed envelope details are very convenient for continental climates, where the summers are very severe with high swings in daily temperature variations. This big thermal mass will decelerate the heat transfer by means of the envelope and thus higher day-time temperatures will be reached indoors while outdoor air temperature is much lower and consequently more stable indoor thermal conditions will be provided.

On the other hand this thermal mass, that has higher surface temperature on outer side will rapidly lose heating energy to the atmosphere through radiation at night to start the next day from a cooler rank. When observing traditional examples, it can be seen that the opaque parts of building envelope were constructed by the materials with a high heat capacity as thick as possible and the transparency ratio of the building envelope is chosen as low as possible.

The high heat capacity of the opaque part provides a high time lag for the transmission of the outside temperature to the internal area while the low transparency ratio reduces the direct solar radiation gained through the windows. In hot and arid climate, through the high heat capacity of the building envelope, the effect of the outside temperature is reduced and a cool internal area can be achieved during the day. Therefore, mud, calcareous rock, stone and the combinations of those materials are always preferred in this climate. Particularly calcareous rock, which is a sort of porous limestone, is a good insulator against cold and warm air and regulates the humidity of the living place. In arid and hot climate some other precautions against the solar radiation are:

- Minimisation of the number and the area of windows
- Construction of a window at a high level to obstruct the floor radiation
- Reduction of the absorptivity of the facades by light colors
- Providing natural ventilation particularly at night
- Constructing a part of the building into ground which is to be always cooler than the outer ambient temperature in summer

CASE STUDY 03

TROPICAL AND TRADITIONAL: INVENTING A NEW HOUSING MODEL FOR THE OLD 36 STREETS QUARTER IN HANOI, VIETNAM

Ota, Shoichi. Joo Hwa Bay and Boon Lay Ong. Tropical Sustainable Architecture. Architectural Press, 2006

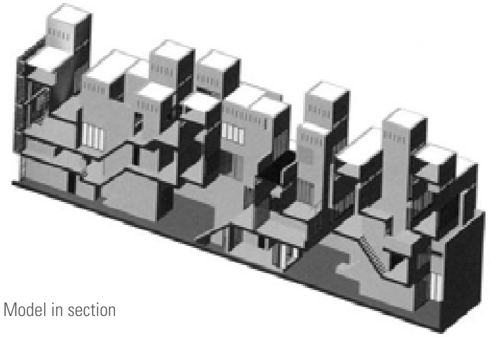
The experimental housing project in the Old 36 Streets Quarter of Hanoi was designed to accommodate local lifestyle while ensuring comfort in the tropical environment. The porous structure of this design creates wind corridors connecting several inner spaces, encouraging natural ventilation and reducing energy consumption. This project raises many considerations for designing in the tropics that are applicable to building in the Pilbara. Excerpts of this case study are reproduced here.

HOUSING DESIGN STRATEGIES

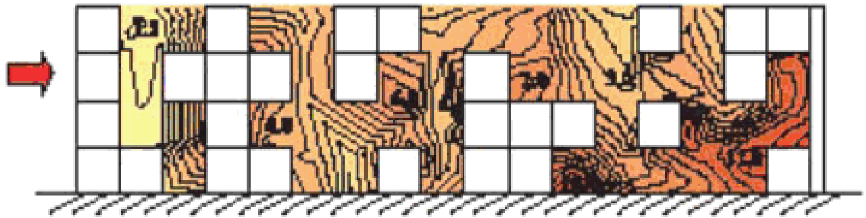
- Enhance existing outdoor way of life
- Design to block out radiant heat from direct sunlight
- Insulate roofs to reduce solar heat gain
- Use wind corridors for cooling
- Openings which extend to a high level help ventilate heated/polluted air
- Build on local/existing construction methods and materials to keep costs low
- Passive environments may require added value to overcome the status of air conditioning
- Designs must respond to local contexts and conventional architectural characteristics

Environmental Measures

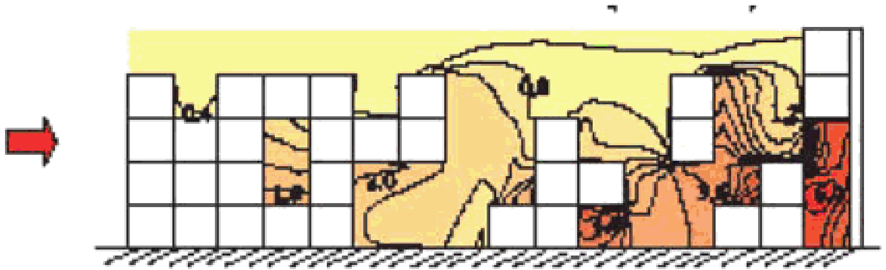
The biggest theme for our project was to propose a new housing model providing comfort by decreasing environmental loads in a tropical climate. To achieve this, the model employs a passive climate control system. Existing active control by air-conditioning consumes too much energy and is limited by the electric power supply in the area. Moreover, it does not fit with the present Hanoian way of life spending much time outdoors.



Model in section



Distribution of air age at the first stage study



Distribution of air age at the final version

Evaluation of ventilation - distribution of air by age

CASE STUDY 03

The porous model is designed to increase natural ventilation by creating a wind corridor, placing a radiating cooling panel in the wind corridor, and blocking heat from direct sunlight by using double roofs. Windows and doors on the wall open as high as the ceiling for efficient ventilation, sweeping away the heated and polluted air in the room. All of these methods harness natural wind ventilation to reduce air temperature inside. A series of studies was carried out to identify the most effective way to create this wind corridor.

Construction Process

Vietnamese construction firms undertook the construction work under the supervision of Japanese architects. All of the construction materials were sourced within Vietnam, except for some unique equipment such as radiating cooling panels.

The experimental house was built using a reinforced concrete structure. At first, frames made from reinforced concrete were erected, then bricks filled each span of the frame to make a wall. Careful supervision was required, especially in using a cantilever structure to form the vertical courtyard. The completed building was surfaced with mortar and finished with white paint. These construction methods are exactly the same as for ordinary housing construction in Vietnam, which allows relatively low-cost construction.

Thanks to the efforts of the construction workers, the experimental house was completed at almost the average cost of ordinary house construction in Hanoi, which is important for dissemination of this model.

Completion and Evaluation

The Hanoi experimental house was completed in September 2003. Through the model that the team presented, an architectural example was offered that respected the way life around an inner courtyard, and able to cope with the urban structure and narrow lots in the Quarter. The model is designed to reflect local open-air lifestyle, to ensure comfort in a tropical environment. Empirical proof of the concept continues.

Modern active climate control, using air-conditioning in enclosed interior spaces, is gradually spreading in Vietnam. From the physical point of view, the spread of this system will be limited according to the electrical supply or environmental capacity. In a social context, on the other hand, having air-conditioning can be regarded as a success symbol showing the affluence of the owner. Whether our model has a value surpassing this, and how the inhabitants evaluate it, are questions that could determine the destiny of the experimental house.

It is not enough for new housing for tropical regions just to be novel. Whether it is in the tropics or elsewhere, there are local contexts and conventional architectural characteristics to be observed. Only a model responding to and articulating these particularities can take root, otherwise it will not be worth constructing in the real world.

Porous model house designs increase natural ventilation via wind corridors

CASE STUDY 04

ASSESSMENT OF CLIMATE RESPONSIVE DESIGN

PLACE, PLANNING & DESIGN PROPOSAL FOR 929 LOT RESIDENTIAL DEVELOPMENT

Aynsley, Richard. Thuringowa City Council. May 21, 2007

This report discuss strategies for climate responsive design in the tropical regions of Australia. It examines looks a proposed subdivision in Kelso, Thuringowa City from a climate responsive design perspective and provides on overview of various climate responsive design strategies, followed by an assessment of, and recommendations for, the proposed subdivision. The second report - "GUIDELINES FOR ENERGY EFFICIENT HOUSING IN THE TROPICS" - expands on these strategies, providing a brief overview of historic housing models and setting out general guidelines that can inform contemporary sustainable housing in tropical regions. Excerpts from these reports have been reproduced here to inform designs in the Pilbara.

URBAN PLANNING STRATEGIES

- Avoid Heat Gain and Urban Heat Islands
- Shade ground surfaces, such as with shade trees
- Use reflective treatments, such as light-coloured paints
- Avoid continuous concrete or black bitumen in favour of mulch and ground covers, light-coloured gravel, bitumen or block/brick paving.
- Permeable paving allows evaporative moisture exchange between the ground and the air
- Choose vegetation that can survive in the climate/have minimal limb-shedding in cyclones
- Ensure lot sizes and orientation allow houses to be oriented to shade from the sun
- Encourage air movement and natural ventilation
- Stagger buildings to enhance air flow through s development (for example, mix small and large lots)
- Chain wire fencing is more compatible with natural ventilation than wooden paling.
- Provide sufficient setbacks to encourage airflow between buildings
- Be aware of wind shadows that may affect wind speed/direction

HOUSING STRATEGIES

- Reduce heat gain through shading, reflection and insulation
- Design/orient for maximum shading of roofs, walls, windows and doors from direct sun
- Orient the long walls to the north and south (as these are the easiest to shade) rather than orienting for wind, as breeze catching strategies can be used instead
- Shade north/south facing walls with eaves. In two storey buildings, horizontal overhangs at first floor level shade ground floor walls and encourage air flow into the house
- East/west walls are harder to shade because the sun is lower in the sky, use screens and shrubs
- Optimum housing shape is an elongated rectangle with a ratio of 1:1.7
- Insulation/a radiant barrier in the roof can reduce radiant heat gain
- Lighter coloured walls/roofs absorb less solar radiation
- Use a radiant barrier in the roof
- Reduce solar reflection and absorption with shading from trees and ground cover
- Use ground cover and/or light coloured gravel, bitumen or paving
- Permeable paving allows evaporative moisture exchange between the ground and the air
- Encourage air movement and natural ventilation
- People living in naturally ventilated houses have a higher adaptive thermal comfort zone than people living in an air-conditioned houses and experience less heat stress outside
- High ceilings (2.74m high with 0.45m clearance for fans) improves the efficiency of ceiling fans
- Openings that extend to a high level help vent hot air
- Open plan spaces encourage air flow
- Deflect wind into the house with: wing walls at the leeward end of windward walls, casement windows/hinged doors hinged on the downwind side of openings, recessed openings
- Stagger walls to encourage air flow
- Put wall openings on both the windward and leeward side. Large leeward openings encourage more air to be drawn through the house.
- Provide a shaded outdoor living space cooled by prevailing breeze/has ceiling fan
- Reduce window sizes to minimise heat gain, but maximum openable area
- Consider row housing for narrow lots
- Two storey row houses can keep the distance between north and south walls to a minimum, eliminate many west-facing walls, and improve the potential of natural ventilation

CASE STUDY 04

NATURAL VENTILATION THROUGH HOUSES AND SUBDIVISIONS

There are two considerations required of ventilation:

- The health requirement of the air change rate between indoors and outdoors to reduce concentration of CO2 and other indoor contaminants.
- Indoor air velocity that can offset high indoor air temperature by the cooling effect of air movement over occupants.

Natural ventilation of houses in humid tropical climates is principally about the latter. The air flow rates needed to enhance indoor thermal comfort in humid tropical regions normally more than adequate to meet the former requirements.

Air Conditioning in the Warm Humid Tropics

The thermal comfort zone was calculated for people in air conditioned houses in Kelso. Comparing the adaptive thermal comfort zone for sustainable naturally ventilated houses with the comfort zone for more energy-demanding air conditioned houses shows the latter is narrower. People living in naturally ventilated houses adapt to the external environment as temperatures and humidity change from month to month. They do so by more purposeful choice of clothing, and organising their activities to avoid unnecessary summer heat stress. People in air conditioned houses have the expectation of throwing a switch and having the gratification a cooling breeze from their equipment. Most of the difference between the two comfort zones can be traced to the occupant's "expectations".

There are consequences for choosing an air conditioned lifestyle in the warm humid tropics. For people who wear spectacles leaving air conditioned space during a hot day the wet season they will be temporarily blinded as moisture condenses on their lenses.

But more seriously, they will experience greater heat stress when they are forced to leave air conditioned space and enter the real world. The additional heat stress comes from their compromised adaptation to the local climate.

Solar Orientation

Solar orientation is much more important in tropical regions than in southern temperate climate states. Basically north and south facing walls on single storey houses can be shaded for most of the day by simple eaves overhangs. This significantly reduces internal solar heat gain through glazed wall areas. In the case of two storey houses north and south facing walls need projecting overhangs at first floor level to shade the ground floor walls. These horizontal overhangs do not interfere with natural ventilation but in fact enhance it as they encourage air flow through the house rather than over the house. Solar orientation in warm humid tropical regions is always more important than orientation of long walls toward prevailing winds because a variety of techniques allow capture of prevailing breezes at inclined incidence to long walls.

East and particularly west facing walls are much more difficult to shade due to the sun being lower in the sky in these directions. Secondary screen walls or dense shrubbery are the principal shading techniques for these walls. East facing walls are less of a problem than west facing walls because these are exposed to morning sun when air temperature are still moderate, while west facing walls are exposed during the hotter period of the day. Effective sun- shading of west facing walls reduces the potential for natural ventilation as by necessity the shades obscure wall openings.

Heat gain analysis has shown that the optimum rectangular plan shape for a house in the warm humid tropics is 1 - 1.7 (Olgyay, 1992). The long walls should be oriented toward the north and south, and buildings in a staggered pattern enhance air flow through the subdivision.

The most challenging current problem in designing houses for effective natural ventilation is the cost of residential land. Rising costs of residential subdivision development, particularly road works and provision of services has led to an increasing number of small lots of 450m2 or less, some with narrow frontages of only 15 m.

It was not that long ago that a standard housing lot in Townsville was 600m2 with a 20m frontage facing north or south. Now in order to minimise development costs the frontages are often 15m facing every which way for site drainage and stylised curved roads with very little opportunity for orienting long walls of houses to the north and south.

Orientation to Prevailing Breezes

Wind direction, unlike sun movements, is less predictable. Some pattern of prevailing wind directions for each month can only be evaluated statistically over a number of years.

Wind direction is rarely constant as the air moves in large eddies that result in constant variation of up to 20 degrees about a relatively constant prevailing direction.

When it comes to priority solar orientation is more important than orientation of long walls to prevailing breezes. Projecting wing walls at the leeward end of windward walls are very effective at capturing breezes for natural ventilation. A similar effect can be achieved using casement sash windows or hinged French doors hinged on the downwind side of window openings and doorways. Recessed windows also increase the efficiency of louvred or sliding windows. In the case of recessed sliding windows the sliding pane should be on the downwind side of the recess. Wing walls should be avoided at the upwind end of windward walls as the shield the wall.

Small lots with narrow frontages rarely permit long walls to face north and south. Even when this can be done, these walls intended for ventilation openings, face the neighbors house a few metres away. This effectively shields them from many breezes.

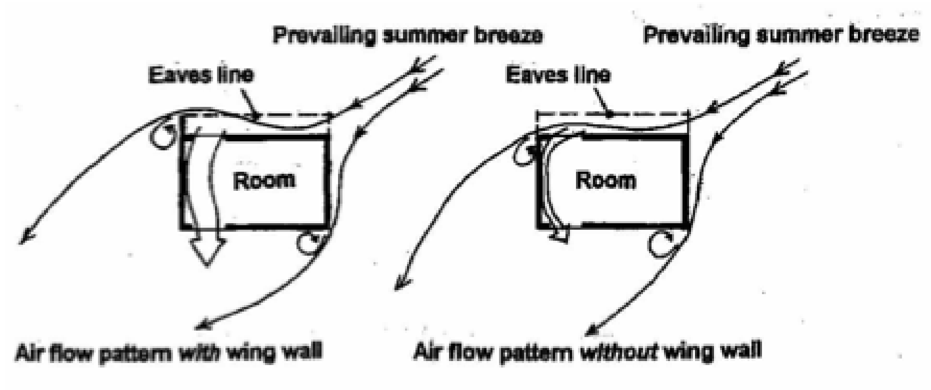
Fences

Local government authorities have required substantial boundary fences between lots to increase visual privacy. These wood paling fences may have staggered palings to increase their porosity to breezes, but wind tunnel studies of subdivisions with such fences have shown that they significantly impede natural ventilation (Lee, 1998) (Su, 1999). Where fences are necessary, the chain wire type, common to earlier subdivisions, are more compatible with natural ventilation.

Month	Max. Monthly Temp. °C	Monthly Max Temperature Minus Upper Limit of Adaptive Thermal Comf. Z	Monthly Max Temperature Minus Upper Limit of Air Conditioned Therm Comf. Z
November	36.7 °C	36.7 - 28.9 = 7.8 °C	36.7 - 25.4 = 11.3 °C
December	33.5 °C	33.5 - 29.2 = 4.3 °C	33.5 - 25.4 = 8.1 °C
January	34.7 °C	34.7 - 29.6 = 5.1 °C	34.7 - 25.4 = 9.3 °C
February	38.3 °C	38.3 - 29.3 = 9.0 °C	38.3 - 25.4 = 12.9 °C

Difference between maximum monthly temperatures and upper limit of comfort zone for naturally ventilated houses ("adaptive thermal comfort") and air conditioned houses ("conditioned thermal comfort")

CASE STUDY 04



Airflow with and without wing walls

Skimming

Air flow around groups of similar sized objects such as houses have been studied. The most relevant study was by Lee et al (1980). Significant differences in air flow characteristics were noted between objects arranged in Roman grid pattern when compared to the same objects arranged in a staggers pattern. The study indicated the reduction on wind pressure difference between the windward and leeward walls, a measure of the natural ventilation potential.

The pressure differences were referenced to the dynamic pressure of the gradient velocity which is 1.59 times the 10 m airport velocity. This potential was shown to decrease significantly with the along wind spacing, Sc, to the height of the objects, H. This ratio was found to correlate with the plan area density of the objects relative to the ground plane.

Three flow regimes were identified; A Isolated Roughness Flow Regime - where air flows over an object and descends back to ground level; B Wake Interference Flow Regime - where air flows over an object and impact the upper portion of the downwind object creating a rotating eddy between the two objects; and C Skimming Flow Regime - where air flows over an object and passes over the top the downwind object creating a rotating eddy between the two objects.

Wind Shadows

The Kelso site is in the wind shadow of Mount Stuart (to the east) and Hervey range (to the south and west). As a result for many wind directions, wind at the site is calm although wind at the airport can be 12 km/h. The only directions for significant wind at the site are from the N and NE. Fortunately winds from the NE have a high percentage of occurrence over time.

Row Housing in the Warm Humid Tropics

One approach to this dilemma, of narrow lots with frontages facing N or S, is to build to the boundary on both sides of a lot to eliminate the narrow side passageways seen in many recent subdivision developments. This eliminates one west-facing wall for every two houses with a party wall, two west-facing walls are eliminated when three houses have two party walls etc. There is another reason to consider this option, "sound privacy". This is an important social consideration in the tropics when natural ventilation is promoted for long term sustainability.

The continuous blockage of row houses across the wind should be compensated for by a minimum back to back downwind spacing of 13m for single storey houses with a roof pitch over 20°C, and 20.3m in the case of two storey houses with a roof pitch over 20°C. These spacings will restore downstream air flow to the isolated roughness condition and significantly less than the seven heights currently required by Council regulations.

With row houses, the party wall needs to be fire rated to impede progress of fire in one house spreading to neighboring houses. These walls also serve as very effective acoustic barriers and provide visual privacy between adjoining houses. This approach can eliminate many west-facing walls, and provide greater energy efficiency from natural ventilation. Sunshading and verandah overhangs enhance ventilation through north- to south-facing walls.

By designing two storey row houses one can keep the distance between north and south walls to a minimum and provide more rooms with excellent cross ventilation. Maintenance access for vehicles to the backyard area (to install a swimming pool etc) can be provided by drive-through garages.

Singapore had many such houses built as shop-houses for Chinese family businesses. They were developed during the colonial period under the guidance of Sir Stamford Raffles, the modern founder of Singapore. In the hectic pace of redevelopment in the 60sand 70s many of these rows of shop-houses were demolished (Powell, 1989). The few remaining examples are currently valued up to $20,000,000.

Boundary Setbacks

Council setback requirements are 6m at the front and 1.5m at each side and the back. On the basis of wind penetration through the development the front boundary setback is not critical as the width of the roadway separating houses will provide more than adequate distance for wind to regain speed.

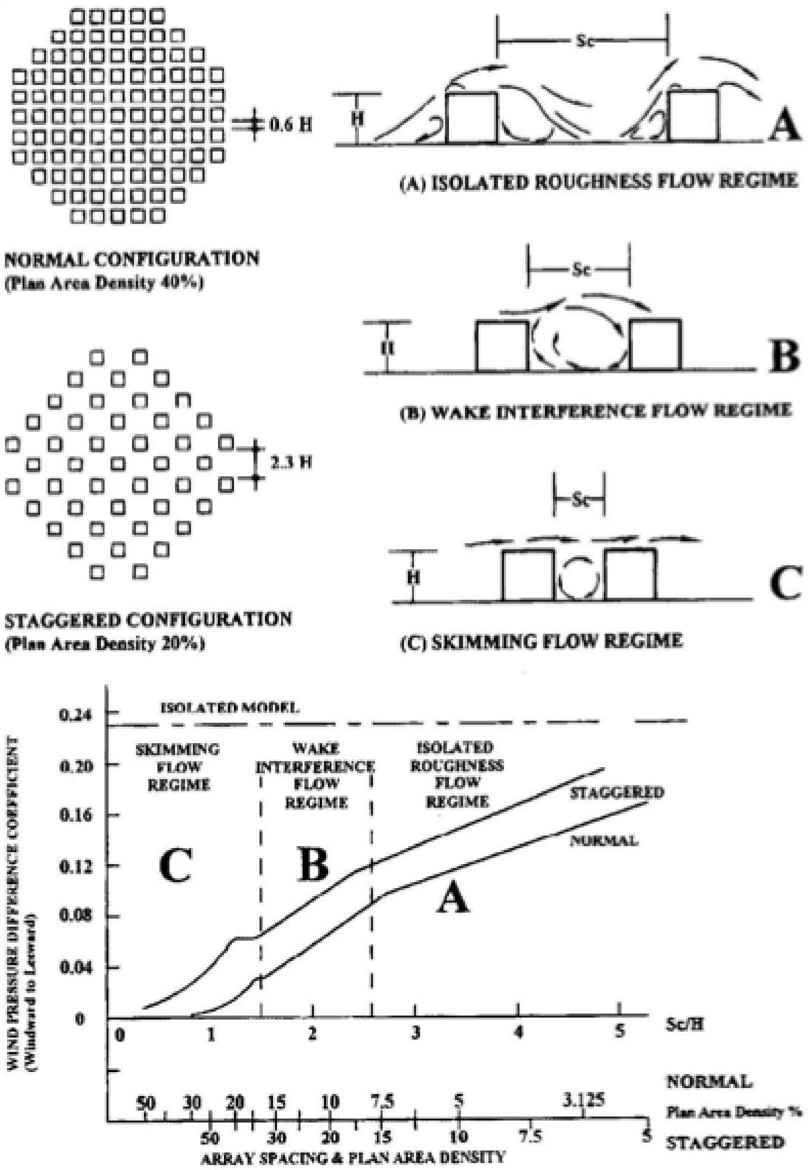
The side setbacks of 1.5 m may not be sufficient to encourage airflow between the houses particularly in the case where there are obstructing timber fences. The spacing would be adequate if the fences are of the chain wire type. Tests by Bin Su (1999) have shown that often air stagnates between buildings when there is no breezepath when there is only a narrow space between buildings.

In the case of build-to-boundary houses, where permitted, it would be advisable to require a 3m side setback on the side not built to the boundary. This would maintain the potential for airflow through the development.

The rear boundary setbacks required by council is currently 1.5m. The resulting back-to-back spacing of houses will result in skimming airflow. The only way large floor area houses can be placed on small lots and retain sufficient back-to-back spacing to avoid skimming is for them to be multi-storey houses. This reduces their footprint and allows for much larger back- to-back spacing that avoids skimming airflow (see Table 6).

In the case of small lots the current 1.5 m rear boundary setback should be reconsidered. In the case of one storey houses with pitched roofs the minimum rear setback should be 6.5m and in the case of 2-storey the minimum setback should be 10.2m.

CASE STUDY 04



Skimming and other flow pattterns for normal and staggered house patterns

HEAT ISLAND EFFECTS AND THEIR MITIGATION

Heat Islands

Solar radiation from the sun cannot directly heat the atmosphere of the Earth due to its wavelength spectrum and the mean free spacing of molecules in the atmosphere. The air at the surface of the Earth is indirectly heated by conduction and convection by surfaces that absorb the suns radiation. The principal surfaces that absorb solar radiation are the earth and paving on the earth. The roofs of buildings, and walls of buildings, also absorb solar radiation. If urban development slows the penetration of air through a development, then the air near the ground becomes hotter and is not carried away by ventilating breezes. This can be very noticeable in narrow spaces between buildings.

The heat absorbed from solar radiation during the day is lost to space by radiation at night. Nocturnal heat loss to space is reduced when there is a cloud covered sky, and nocturnal heat loss to space is at its maximum when skies are cloudless. In Townsville /Thuringowa, the cloudy skies common at night during the wet season, keep air temperature higher than normal.

Heat Island Mitigation

The principle means for mitigating development of urban heat islands are shading sunlit surfaces and reducing the solar absorption by surfaces. The most effective shading elements for ground surfaces are shade trees such as rain trees etc. For those surfaces that cannot easily be shaded then reflective treatments such as light-coloured paints or other durable colouring can be used. Ground surfaces should be planted with appropriate ground cover. This does not necessarily mean grass, other ground cover work just as well. Black bitumen is one of the worst offenders in absorbing solar radiation in urban environments. Consideration should be given to using lighter coloured bitumen for paving, particularly in tropical urban environments. As an experiment a carpark in southern Florida was temporarily covered with white sand. This was shown to significantly reduce the cooling needed in buildings downwind at a relatively low cost.

With regard to buildings, roofs are the most important surface to consider because they are the most difficult to shade. A recent trend in Townsville/Thuringowa of using dark coloured or even black metal roofing for variety is misguided. The surface temperature of these roofs can reach 93°C during calm wind conditions and result in increased heating of the air adjacent to them. The same metal roof painted white, with no wind, would only reach a temperature of about 50°C under the same conditions (Ellen, 1984).

Building's walls should be shaded from direct sunshine. Sunlit brick or block masonry walls will retain the heat for at least 3 hours after the sunlight has gone, leading to hot houses at night when occupants are trying to get to sleep. Lighter weight construction such as fibre-cement clad timber or metal frame walls cannot store as much heat as heavy walls and they cool down more quickly. Lighter coloured walls will absorb less solar radiation. West facing walls are the most difficult to shade and are exposed to solar radiation during the hotter times of the day (Akbari et al, 1990).

When tree species are being considered for the role of ground shading for heat island mitigation, selection should also take into account their suitability for survival and minimal limb-shedding during tropical cyclones.

CASE STUDY 04

DISCUSSION OF CLIMATE-RESPONSIVE DESIGN

Housing shape

The optimum shape of an energy efficient, naturally ventilated house in the hot humid tropics is an elongated building in the ratio of approximately 1:1.7 (Olgyay, 1992). This shape is supported by many others including Townsville architects. There should be plenty of wall openings both windward and leeward. Large leeward openings encourage more air to be drawn through the house.

Duplexes, Town Houses, and Row Houses

Single-Storey duplex and town houses are relatively common in Townsville/Thuringowa residential subdivisions. If these housing types are orientated with their long walls facing N and S they have the advantage of eliminating some W-facing walls.

Currently two-storey row houses are rare in North Queensland residential subdivisions but there are reasons why they should be considered, particularly for achieving lower-cost, climate-responsive housing on small lots.

Roof considerations

Roofs in tropical climates need radiant barriers. Over 80% of the heat transferred downward through the roofs of houses in tropical climates during sunlight hours is by radiation. The simple and effective way to stop 90% of this heat gain into the house is to incorporate a radiant barrier in the roof construction. A radiant barrier in the roof construction consists of an aluminium foil surface facing an air space. An air space with two aluminum foil faces is even better. The best orientation for the foil surfaces in the roof and floor construction is horizontal. More information can be found under the AFIA (Aluminium Foil Insulation Association, Inc.) industry website (www.afia.com.au).

West Facing Walls

West facing masonry walls need to be shaded by appropriate trees and shrubs. If these walls are left unshaded they will absorb vast amounts of solar energy and release it into the house for 3 hours or more after sunset. Timber or light metal framed west-facing walls should contain a radiant barrier and appropriate thermal insulation to shield the interior surface from heat gain. Glazing, wherever possible, should be avoided in west-facing walls. A shadecloth-covered orchid house or fernery between the house and Western boundary fence should be considered.

Pavement Considerations

Continuous concrete or bitumen should be avoided in favour of mulch and ground covers, light-coloured gravel or block or brick paving. Permeable paving allows evaporative moisture exchange between the ground and the air that minimises surface temperatures of ground exposed to the sun.

Ceiling Fans

In residential applications ceiling fans offer energy-efficiency for both naturally-ventilated as well as air conditioned houses. Ceiling fans are the only form of circulator fans recognised by Home Energy Rating Schemes. The principal reasons for this are that they are widely used in Queensland and that they are hard wired into the house and not moveable plug in fans which are classified as portable appliances.

Cooling Effect of Air Movement in Naturally Ventilated Houses

Khedari et al (2000) conducted studies in Bangkok, Thailand identifying the cooling effects of air speed up to 3.0 m/s incorporating the influence of relative humidity (RH) from 50% to 80%. The writer has extracted from these data temperature offsets up to 9 °C (K) for 3 m/s with 50% RH, Fig. 3.

Saving Air Conditioning Energy with Ceiling Fans

The Florida Solar Energy Research Center has shown that ceiling fans can maintain thermal comfort and save 14.4% to 24.6% of cooling energy in air conditioned houses in warm humid tropical climates (James et al, 1996 http://www.fsec.ucf.edu/BLDG/pubs/pf306/). This saving was achieved by raising the air conditioner thermostat by 1.1ºC and operating the fan to elevate air movement to offset the increase in the thermostat setting. This is a net saving after deducting electricity used by a fan and heat release from the fan motor.

Ceiling Fans and Ceiling Heights

Ceiling fans need at least 0.45m clearance between the blades and the ceiling. Ceiling hugger fans sold for use in houses with 2.44m ceilings are 40% less efficient than fans with 0.45m clearance between blades and ceiling. In humid tropical regions were ceiling fans are most effective 2.74m ceiling heights should be encouraged in all new residential development to enhance sustainability.

CASE STUDY 05

MICRO-CLIMATE - In the South Australian Context

Prelgauskas, E. Climate Responsive Building Design in the South Australian Context. 2008 Viewed March 16, 2011 http://www.emilis.sa.on.net/index.html

This report discuss strategies for climate responsive design in the arid regions of South Australia. It examines various types of micro climate, from naturally occurring to created, and discusses ways in which each can be used to passively cool a home during the summer months. The theories and practises discussed in this article are relevant to the Pilbara areas, in particular Newman, which falls into an 'arid' climate classification. Many of Emilis' ideologies and strategies can be used to inform designs in the Pilbara.

HOUSING STRATEGIES

- Consider which existing features on the land affect the micro-climate, and determine where the building is to be situated on the land for comfort.
- Consider which way the building, its wall faces and openings are to be oriented to maximise comfort.
- Consider the heat, cooling and air flows which are created by the above for comfort(as covered in other information sheets).
- Create heat spaces on the northern side of a building by constructing hard wall and ground surfaces and cool spaces to the south by adding shade in the form of verandah or pergola, this will create thermal convection currents to ventilate houses when no breeze is available.
- Add humidity to the southern side of buildings with vegetation, spray or drip irrigation or water features including fountains.
- Install south facing clerestory windows to allow full daylight inflow without direct sunlight or heat and to provide ventilation, releasing raised hot air from the top of a room.

GENERAL

'South Australia' is a portion of the land area situated on the central southern coastline of the Australian continent. It is situated between the large continental land mass to the north and the large ocean mass and Antarctic to the south.

As a result of solar inflow variation with latitude, in continental terms the large land mass to the north typically is warm, and the water mass to the south is perpetually cool. The interior continental land mass is arid, the summer winds flow over the substantial land area and are also warm. The ocean infiltrates cool air changes across South Australia in the general west to east flow of weather patterns.

As a result the general weather patterns in South Australia are typified by cool winters with southwest winds and moisture, and hot summers with northerly winds, either dry and dusty, or tropical.

The climate is characterised as `temperate', with temperatures outside the normal human comfort range principally in summer. This is an arid fringe climate.

PASSIVE SOLAR BUILDING DESIGN

Passive solar building design suits cool climates where inflow of solar heat gain creates comfortable interior space with limited additional interior space heating.

This design approach has some applicability in the limited number of cool climate locations in South Australia.

THEORY DEVELOPMENT

Investigations about climate responsive building design in the South Australian context are the synthesis of theoretical hypotheses, backed by empirical evidence and applied to building designs both in concept and real life applications.

The hypotheses used have been developed from basic meteorology and physics theory.

Empirical evidence is available from human use of weather forces in other activities. In Australia about 1000 sailplanes achieve 150,000 flying hours in convection weather conditions annually. Convection weather conditions typify the forces available in the climate and are applicable to building design. This is one of the substantial empirical data bases available to the formulation of climate responsive building design principles.

Buildings designed to these climate responsive principles are in operation and are achieving the low energy comfort environments originally postulated.

MICRO-CLIMATE FOR BUILDING COMFORT

In arid fringe climate areas the design of buildings for comfort must address:-resisting summer heat inflow from outside, and ejecting the heat build up emanating from occupants and appliances inside the building.

This approach is appropriate for comfort design for the majority of South Australia.

The Weather

Weather occurs everyday. Even though it varies in detail from day to day, it is nevertheless uniformly composed of three contributing influences sun heating, wind, moisture mixed to varying degrees.

These forces are the components pieces of micro-climate.

CASE STUDY 05

Creating Micro-Climate

A standard vacant house block can be envisaged as consisting of flat and open ground, unfenced, and with neither structures nor vegetation on it. The climate on such featureless land is the same as that of the surrounding general area weather in which the site is located; that is macro-climate and micro-climate are the same.

By erecting a building on that land, this changes the climate on the land. This occurs with every building constructed on every site. Now there is shade cast by the building onto the ground to the south of that building, and the portion of the site north of the building receives additional reflected heat load from the building's walls.

By constructing a building on the land, the site is now segmented into a sun side hot zone and a shade side cool zone. This occurs as part of locating the building on the land. This is a simple example of the creation of micro-climate.

Naturally Occurring Micro-Climate

Very seldom is land as featureless as is described above. Existing features on vacant land contribute to modifying the climate on the site from the general area weather. Existing vegetation and structures on the land create shade and moisture variations; land slope and soils change the heating load on areas of the land.

On land with a north facing slope, compared with another with a south facing slope, quite different house designs will be required for comfort. Even where this land is on adjoining allotments. The local micro-climate on these sites is so different that on the south slope high solar inflow is required to achieve comfort, on the north slope solar shading is needed.

Using Micro-Climate Forces For Comfort

Micro-climate can be used to advantage. Warm external spaces are pleasant places to live in winter, cool outside spaces are comfortable in summer.

But these changes to the home site's micro-climate also affect the interior comfort of the building. By creating variations in heat load, wind pressure and moisture on different faces of the home, the interior can be kept comfortably warm in winter and ventilated in summer.

Micro-climate occurs on every home site, with the combination of the land's existing features, and by placing the building appropriately on the site.

The first considerations in planning a home are:-

- which existing features on the land affect the micro-climate, and determine where the building is to be situated on the land for comfort,
- which way the building, its wall faces and openings are to be oriented to maximise comfort; and
- the heat, cooling and air flows which are created by the above for comfort(as covered in other information sheets).

The Benefits

Buildings designed to use micro-climate are achieving substantially lower energy consumption to achieve the same comfort as conventional buildings; anything between a half and a sixth of normal energy use. That is a lot of money saved on annual operating costs.

ECOLOGICAL DEVELOPMENT

Micro-climate is consistent with ecological development principles because the existing features and ecology of the land gives a sound guide to the micro-climate potential and features which should be incorporated in buildings for comfort on each site.

SUMMER COMFORT WITH CROSS VENTILATION

Every day the sun tracks through the northern sky over Australia. Each building casts its shadow on its southern side, and reflects the sun's heat from its northern wall and adjacent ground.

South Australia is situated in an arid fringe zone, with a substantial summer heat load where building cooling can be a major energy user.

The naturally occurring heat imbalance around buildings described above can be used to improve comfort in buildings in South Australia in summer. Several complementary actions are involved.

As air temperature increases locally, that air parcel expands and reduces in density. Such a low density air parcel has a higher temperature than ambient, and is forced upward by the surrounding ambient air temperature and pressure.

This takes the form of thermal convection. This is a common meteorological phenomenon.

On the northern side of a building, this temperature imbalance can be accentuated by constructing hard wall and ground surfaces which reflect solar heat, and these can be formed into a sunken or walled courtyard configuration to maximise the temperature imbalance created.

As air humidity increases, the density of that air parcel increases and the temperature decreases because the latent heat capacity of the air also increases.

Buildings cast shadows to their south. The air in this external area abutting the building is cooler than ambient. This air temperature can be further contained by adding more shade in the form of verandah or pergola, and adding humidity with vegetation, spray or drip irrigation or water features including fountains.

Buildings designed with both these micro-climate features are suited to summer cross ventilation.

Opening of windows on north and south sides allows cool and humidified external air from the southern side to infiltrate the building while the building air volume is drawn out to the north by the thermal convection.

The calculated effect of this mechanism in an effective installation is up to 9 air changes per hour. The effect is to create air changes within the building with cooler than ambient air suitable for comfort in summer conditions. The pre-cooled low volume cross ventilation is created with little on-going or recurrent operating costs.

Micro-climate generated cross ventilation is based on simple and well understood meteorological phenomena.

Their application to individual buildings should however be undertaken with care. Poor building and landscape design in relation to the building's unique site and location can negate the effects being sought.

For a new building, the site should be assessed with a view to the naturally occurring hot and cool spaces. North facing slopes, depressions created by both landform and vegetation, soils, rock outcrops; all form favourable hot spaces.

In existing developments, adjacent overshadowing by other development, and heat absorbing building facades reduces adjacent hot space potential.

Surfaces suitable for heat reflection should be selected and sited to reflect heat into the external space, not to the building. Light colour matt surfaces are more effective than dark colours. Both high thermal mass and heat reflectance materials are suitable.

Sunken paving with retaining walls or walled courtyard accentuate heating by avoiding wind chill cooling of the space, and minimising air inflow directions, a wall of vegetation can be also be suitable.

CASE STUDY 05

For cool spaces, shading by both built enclosure and vegetation are suitable. Pergolas, trellis, and vine. Verandah materials should resist heat transfer through the roof. Light colour and insulation or proprietary reflectance surfaces are suitable.

External ground level raised in relation to the building allows the cooled air to descend, accentuating through flow. Walls and vegetation barriers are not beneficial.

To maximise cross ventilation, large opening areas in the building faces to both spaces should be possible. Written operating directions for occupants assist in maximising the effectiveness of the installation.

SUMMER COMFORT WITH CLERESTORY VENTILATION

A clerestory is high level openable glazing, resulting in the room having a high or sloping ceiling, and associated with it a high, sloping or curved roof on the building.

This high level glazing can be situated over the centre of a room or building to introduce natural daylight into the house in addition to daylight through windows on the perimeter walls.

The result is a greater amount of and more uniform distribution of natural daylight within the room or building, reducing the need for daytime artificial lighting and thereby reducing energy use.

The clerestory lighting offers privacy, and daylight clear of vegetation as a result of its elevated situation.

In cold climates, clerestory windows can face the sun with a northern aspect, reducing winter heating costs.

The majority of South Australia is situated in an arid fringe climate where summer cooling is the major energy use. In this climate clerestory faces south, allowing full daylight inflow without direct sunlight or heat.

The clerestory also can contribute to ventilation and cooling of the home in summer. Because clerestories can generate airflow, their use in bushfire prone areas must be considered carefully. In situations where they can encourage fire ingress to the home they should not be used; where fire ingress potential is less extreme their use is conditional on other fire resistant features including wired glazing, metal mesh screens, shutters and frames being incorporated.

Ventilation through clerestory windows is generated by the variations in air pressure from wind flow around the home and can also operate in concert with thermal venting.

As air flows around the building, upwind surfaces dam air to higher than atmospheric pressure. Downwind and sheltered areas contain air at atmospheric or lesser pressure. South facing clerestory is situated in a sheltered area relative to South Australia's prominent northern summer winds. The combination of sheltered area between high and low roof, the reducing air pressure over the sloping or curved roof results in air outflow from the building when clerestory windows are opened.

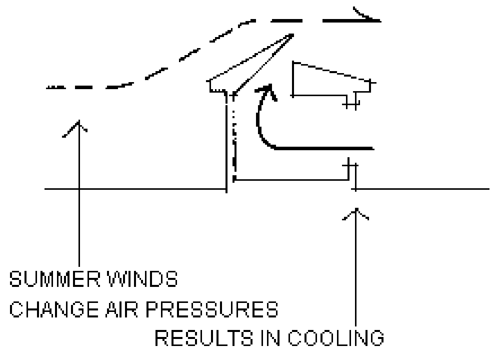
Effective ventilation depends on replacement air being drawn from elsewhere around the building. In summer the north winds are hot, dry and dusty, and direct ventilation is undesirable.

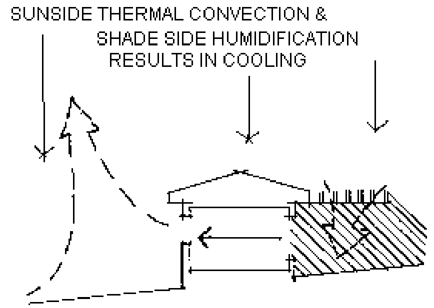
The south downwind side of the home encompasses shaded air which can be cooler than ambient temperature as well as at dust free atmospheric pressure.

This is suitable replacement air by opening south windows in concert with the clerestory.

During summer weather changes characterised by south-west `cool change' conditions, opening the clerestory to act as an air-in ram bringing cool air into the home to rapidly cool the structure.

The effectiveness of this action depends on opening a north window laterally in the home to encourage air through flow.





CASE STUDY 06

USING MASS AND SHADE TO KEEP SPACES COOL

The South Hedland Campus of Pilbara TAFE was built in 1982. Today, the passive climate control elements which were included in the original design are still valid and effective, providing comfortable thermal comfort in the interior rooms and central courtyard.

The building is still functioning as an education facility and it an excellent opportunity for us to experience passive climate control strategies in local Pilbara conditions. Its age and ongoing use are also a good example of the durability and longer term efficiency of the strategies.

Many of the strategies were implemented because there were not sufficient funds for mechanical air conditioning in the large workshop classrooms. Without the mechanical air conditioning, there has been a considerable saving in annual energy costs.

The building was for many years the main shelter for the community during cyclones. The heavy mass of its perimeter construction provides a stable strong protection during cyclonic winds. The concrete and masonry mass is shaded by trees, verandahs, awnings and the courtyard screen roof, and is generally not exposed to direct sun. Therefore, the surfaces remain cool to touch, as are the internal concrete floors.

The choice of colours for external walls and roofs is also appropriate to the Pilbara because dust and dirt from the red Pindan soil is less obvious.

The building demonstrates strategies for:

- keeping spaces cooler
- providing shade
- enabling air flow and heat exchange
- allowing natural light inside without heat radiation from direct sun reaching walls and ground surfaces.
- using vegetation to shade buildings and providing shaded outdoor spaces
- using natural contours to protect the building

DESIGN STRATEGIES

- The introverted, inward looking, layout uses the building to protect the inner campus from harsh sunlight and strong winds.
- Deep narrow entries into the courtyard act as a bottle neck to mediate between hotter carpark and cool courtyard. The entrances create a draft effect which enables an exchange of hot and cool air to refresh the adjoining workshop rooms.
- The passageways through the building remain cool because they are not exposed to direct sun.
- The courtyard is on an east-west axis with workshops and class rooms to the north and south. This gives the greatest control of shading of the rooms and minimises the exposure to early morning and late afternoon sun.
- The courtyard screen roof allows air flow as well as shading the surrounding workshops and classrooms. The classrooms can have large glazed openings because they are always shaded.
- Permeable screen walls and overhangs filter sunlight and keep spaces feeling bright and airy whilst protecting them from the full exposure to the sun.
- Permeable screen walls at each end of courtyard enable cross ventilation and expulsion of hot air.

SOUTH HEDLAND CAMPUS, PILBARA TAFE, WESTERN AUSTRALIA

Architect: Tony Brand, Forbes and Fitzhardinge, Perth. Constructed 1982

Inward looking plan protect classrooms, workshops and the central courtyard from the harsh climate.

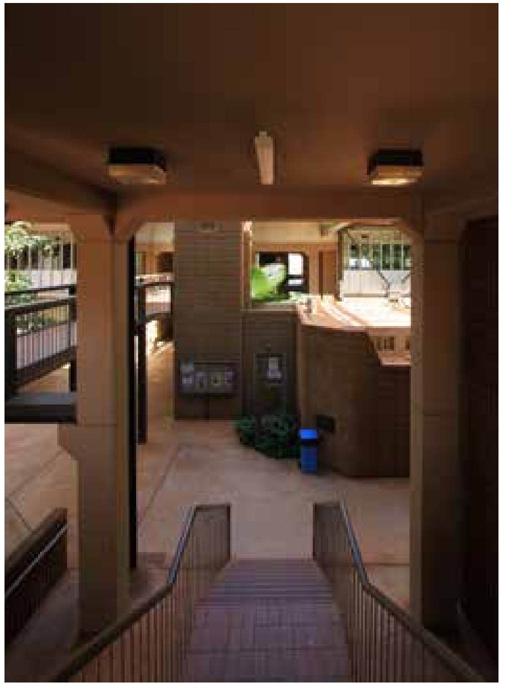
- The double volume perimeter building encloses the courtyard and shades the central outdoor space from direct sun, especially in early morning and late afternoon.
- Classrooms and workshops open onto a roofed colonnade around the courtyard which provides a second layer of protection from direct sun as well as providing protected circulation in wet weather.
- Concrete frame construction provides mass for thermal control as well as strength against cyclonic winds.
- Toilet pods in courtyard are concrete providing a coolth mass which is never exposed to direct sun.
- Brickwork walls have alternate courses sitting proud to provide self-shading to the wall face.

CASE STUDY 06

- Deep eaves and awnings around the exterior of the building keep sun off windows and provide wide, shaded circulation spaces.
- Deep recessed windows enable natural light into rooms but reduce direct sun onto glazing, thus reducing heat transfer to the interior and reducing glare.
- Huge roof vents enable cross ventilation in classrooms but avoid direct sun to lower levels.
- Interior concrete floors are not exposed to direct sun and remain cool to touch. The concrete is either exposed or overlaid with quarry tiles.
- Barbecue areas at both ends of courtyard are for external cooking, rather than heating internal kitchen spaces. The screen walls at each end of the courtyard enable smoke and heat to escape.
- Storm water is directed into concrete gutters around the perimeter of the building.
- Earth berms and local stone retaining walls around the perimeter of the building protect against hot winds and work with the in-ground gutters to keep storm water away from the building.
- Trees and shrubs around the external perimeter of the building protect the facades from sun and win.

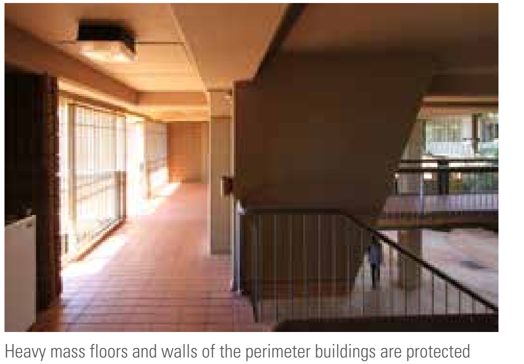
The central double volume courtyard with its permeable screen walls and roof protects classrooms and workshops from direct sun

Permeable screen walls for cross-ventilation and shade



Deep verandahs around the external perimeter of the building provide protected circulation

Storm water is directed into concrete gutters around the perimeter of the building



Heavy mass floors and walls of the perimeter buildings are protected from direct sun