Bioclimatic design and energy conservation in buildings

By Despina Kyprianou Serghides
AA Dipt., RIBA II, AA Grad. Dipt. Energy and Environmental Studies

ABSTRACT

This introduction presents the bioclimatic design approach in buildings and outlines the prospects for its adoption in Cyprus.

Bioclimatic design is a climatically interactive building design, which integrates the scope to use the location and the regulatory systems inherent in Architecture, through the choice of orientation, form, fabric and use of natural resources of energy to achieve indoor comfort conditions. This is often succeeded at no extra construction or maintenance cost.

BENEFITS AND SIGNIFICANCE FOR CYPRUS

The benefits for Cyprus from the conservation of energy in buildings are enormous. As a result of the displaced fuel by the free energy systems, is the benefit of financial savings in running costs, reduction of the growth rate of national energy consumption and ultimately reduction of the dependence on the world's finite fossil fuel extending its availability. Moreover the reduction of pollution from the production and consumption of fuel, results to healthier environment as bonus.

Cyprus relies entirely on expensive imported fuel supplies.

The effort of the Government of Cyprus to minimize its deficits while at the same time encouraging industrial development and tourism, the islands' major profit-making commodity, demands serious consideration in the use of imported resources.

Rapid urbanization and the inefficient use of building services technology has had catastrophic consequences on the islands' ecology, culture and tradition.

The trend towards greater standards of comfort in recent years has led to the increasing adoption of air conditioning systems.

The influence of the post war movement for "International", mass production Architecture, has further resulted in climatically rejecting buildings in Cyprus. Buildings which no longer act as climatic moderators to soften the unpleasant climatic extremes, an architectural task the traditional wisdom handled skillfully. On the contrary, adoption of international styles aggravate adverse climatic conditions.

The buildings have become enclosures for our artificial environment and often their shells act as an additional obstacle to the efficient use of their mechanical installations.

The search for identity and styles in Cypriot Architecture, the increasing international awareness in energy and environmental issues spurred on by the energy crisis in 1970s, and stirred up recently with the Gulfwar, focus once more on the challenge of Architecture.

Further more the successful implementation of energy conservation policies in other countries especially the adoption of climatic design measures is a possible model for our island.

BIOCLIMATIC DESIGN APPROACH FOR CYPRUS

Further to these interrelated factors which increase the complexity of the Architecture in Cyprus is the question of the climate itself. The climatic conditions of a location are very rarely combined in nature to give satisfactory indoor thermal environment. The temperate Mediterranean weather pattern of Cyprus, usually lacking in extremes, would appear to present no special problem for bioclimatic design. Yet in Cyprus, buildings must be designed and constructed to cope with the possibility both of uncomfortably hot summers and surprisingly cold winters.

This design challenge is highlighted and all the more complex when the designer uses the architectural design itself to utilize natural renewable energy resources particularly solar energy-rather than the use of auxiliary energy, for the provision of indoor comfort.

In order to assess the energy demands for heating and cooling in Cypriot buildings and evaluate the free energy systems available to contribute to these requirements, the comfort criteria and the local climatic conditions must be carefully considered and analysed.

Cyprus, although a relatively small island necessitates attentive*'bioclimatic analysis; the sea that surrounds it, its morphology, its varied elevation, and its prevailing winds define different topoclimatic zones.

However the lengthy procedure involved do not permit a detailed and extensive bioclimatic analysis for Cyprus to be made during this introduction.

Based however, on the apparent and general demand of the Cypriot climate of cooling in the summer and heating in the winter, some aspects of building design are outlined which incorporate very basic principles of bioclimatic design strategies which are appropriate for the island.

Basically throughout the design process, the aim should be to maximize heat gains in winter, minimize them in summer, encourage heat losses in the summer and limit them in winter.

BIOCLIMATIC DESIGN ASPECTS

A. Sighting the Building *a.*

Solar Access in Winter

The sun path diagram (Fig. 1) in relation to the
i. Site Plan (Fig. 2)
ii. Height of neighbouring buildings (Fig. 3)
iii. Vegetation (Fig. 4, 5)
iv. Land masses (Fig. 4)
determine the spacing distance of the buildings in order to ensure winter sun.

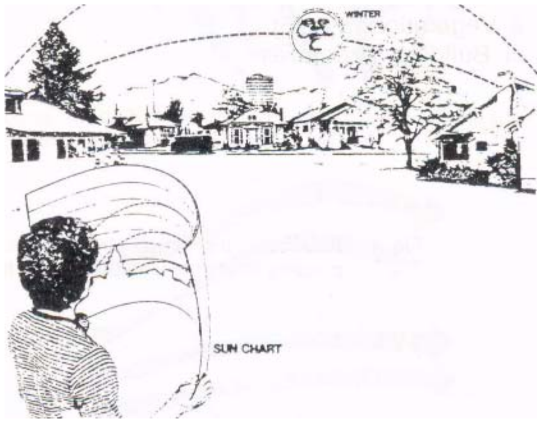
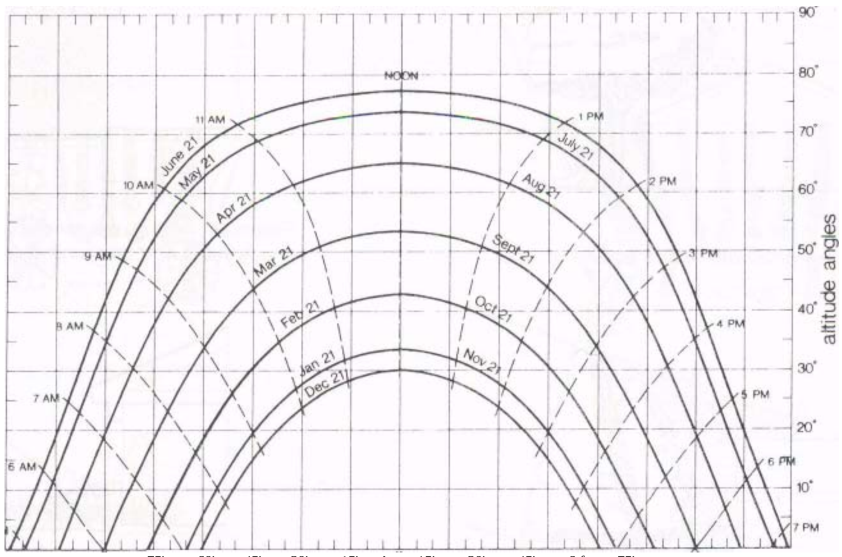


Fig. 2 Using the sun chart to visualize solar obstruction

36° NL



75' 60' 45' 30' 15' ^ 15' 30' 45' 6tf 75'

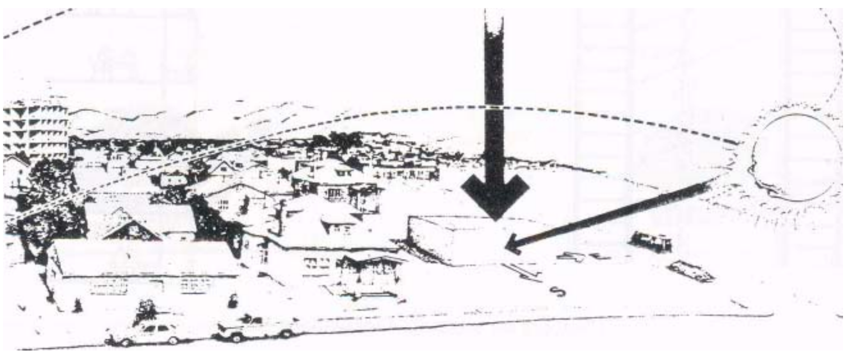
bearing M N* angles

90' U **East** **0* U South** **90' U West**

Fig. 1 Sun path diagram

105' 120'

SUMMER

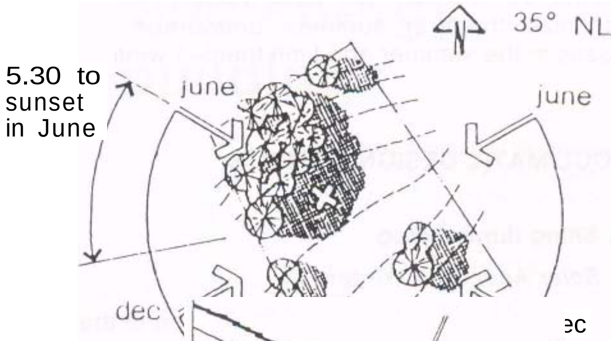


f **Winter**

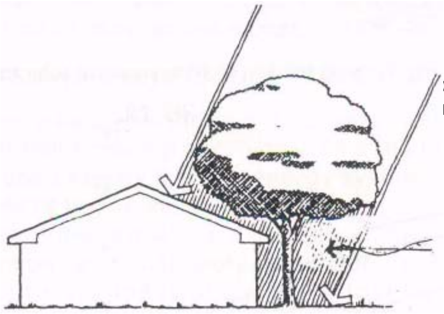
Fig. 3 Existing built conditions Future extensions and development

b. Summer shading

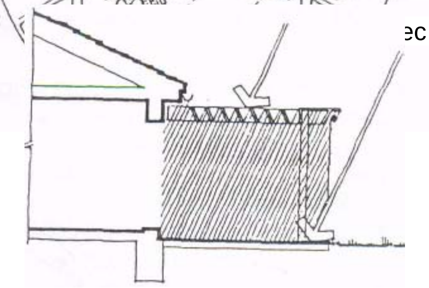
For summer shading one could use i. Neighbouring land forms (Fig. 4) ii. Vegetation (Fig. 5) iii. Building Structures



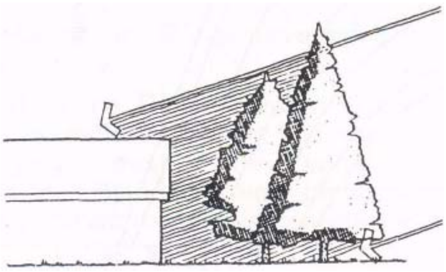
on sun by sighting
nd masses



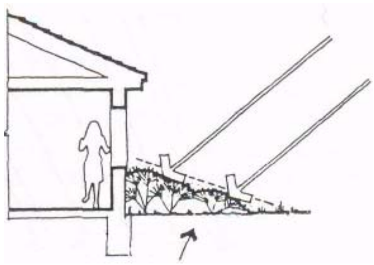
Tall trees on South Shade walls and Roof



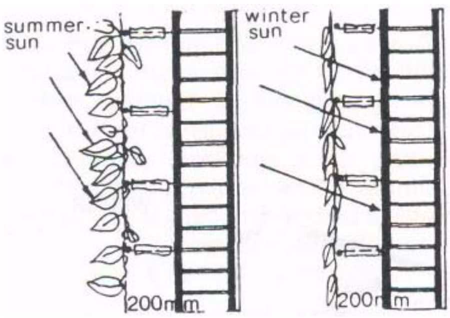
Pergolas or trellises and climbing vegetation to shade walls and fences and reduce reflected gain



Dense trees shrubs hedges, walls on West to intercept afternoon sun



Irregular shrubbery surface intercepts sun for reduction reflectivity



Climbers for shading & Insulation Fig.

5 Vegetation and Shading

c. Summer Breezes

The use of

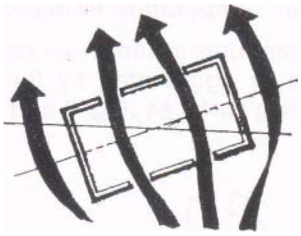
i. Land forms (Fig. 4)

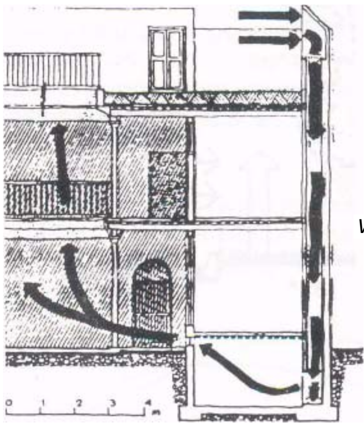
ii. Building structures (Fig. 6)

iii. Vegetation (Fig. 8)

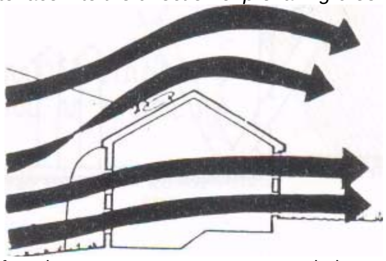
iv. Wind catchers (Fig. 7)

could increase exposure to summer breezes.





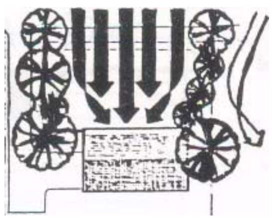
Long facade to face into the direction of prevailing breezes Building as an air flow dam

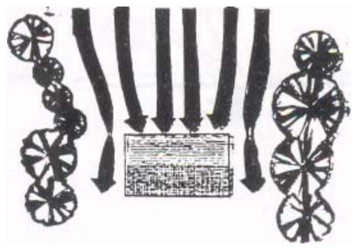


Wind catchers

Fig. 6 Higher facades mean greater pressure and air movement
Windward roof plane experiences sunction Stacking rooms vertically facilitates good ventilation

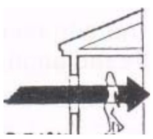
Fig. 7 Inlets enough to the streamline flow zone Uni-directional orientated to favorable breezes Multi-directional utilize winds from any direction





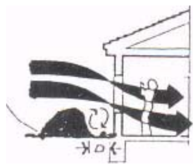
Trees *to guide wind into the building*

Rear venting
Funnel at front
Narrow corridors for air jets

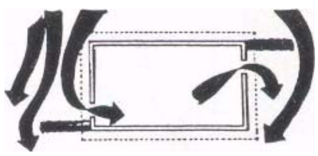


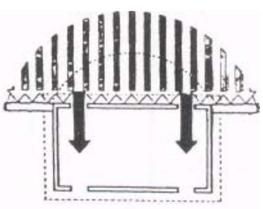
LT

Unwanted wind pressure

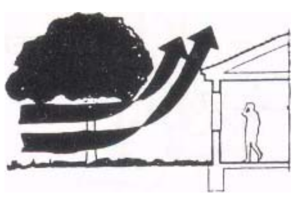


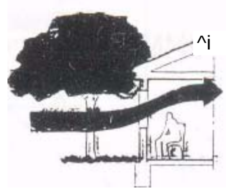
Relieved by Hedge and shrub
Fostering downward deflection of air stream





Hedges or walls to the side of the window increases air pressure through the building





^i *Ceiling wash flow*

Air stream misses the house

Influence of tree canopy outside the window is to lift or warp the air steam upwards

Fig. 8 Summer breezes & vegetation

d. Summer Temperature Reduction

The temperatures in and around buildings can be tempered or aggravated by the nature of the surrounding surfaces (Fig. 9 and Fig. 10)

Temperatures shown here were recorded in a hot-dry climate when the air temperature was 42 degrees Celsius. (Fig. 9)

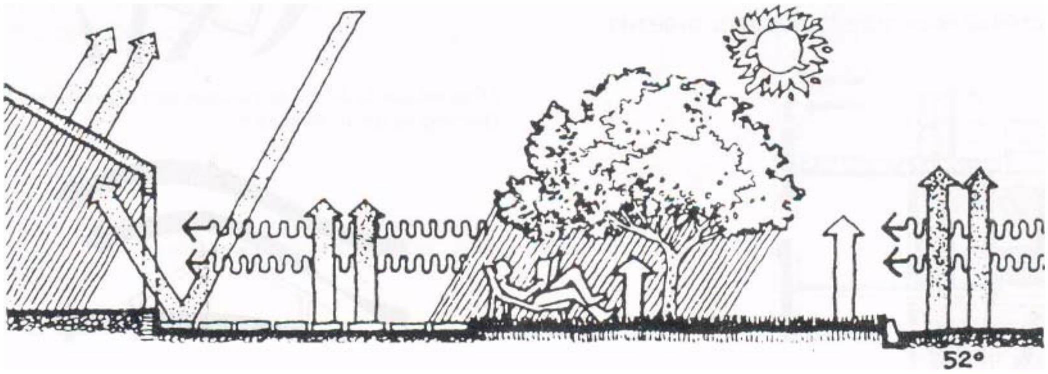


Fig. 9..Summer temperature reduction

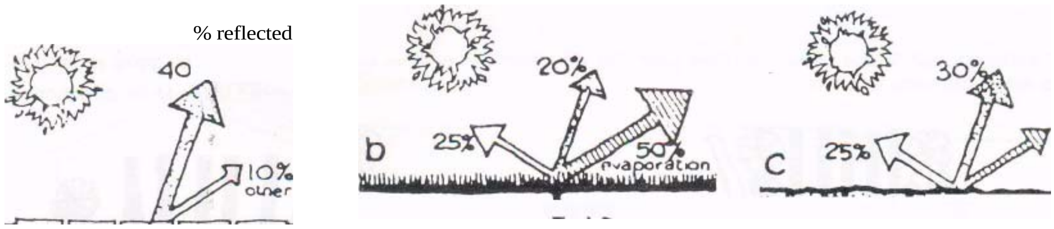


Fig. 10 Absorption of heat by different surface materials; (a) paving, (b) grass, (c) bare ground

B. Orientation and Shape of the Building

Elongated building shape maximizes heat gains in winter and minimizes heat gains in the summer. (Fig. 11)

In winter the South side receives three times more solar radiation than the East and West sides. In the summer the situation is reversed; North side receives little radiation. (Fig. 12)

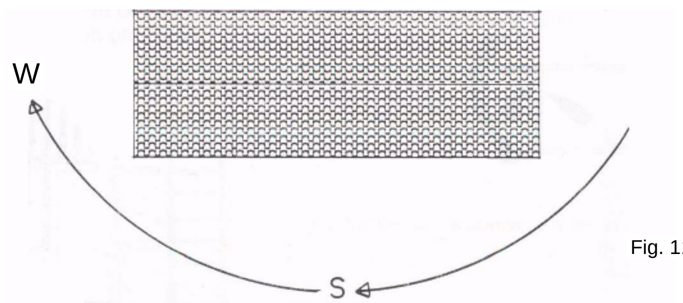


Fig. 11 Orientation and shape

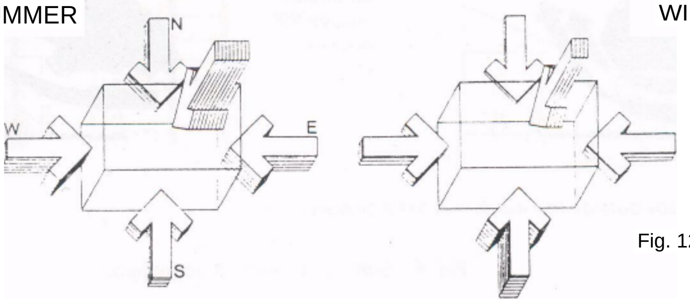


Fig. 12 Solar radiation

C. Building Layout

Generally the rooms according to their sunlight requirement, and the sequence of the activities housed in them, should follow the Sun-Path, located South-East, South, South-West. Placing spaces with minimal heating and lighting requirements, along the North face as buffer.

Internally heat gains generated in certain spaces (by people and equipment) should be either utilized to supply heat, or isolated according to the demands of the spaces.

Long thin buildings with rooms stacked high, offer good cross ventilation opportunities. (Fig. 14)

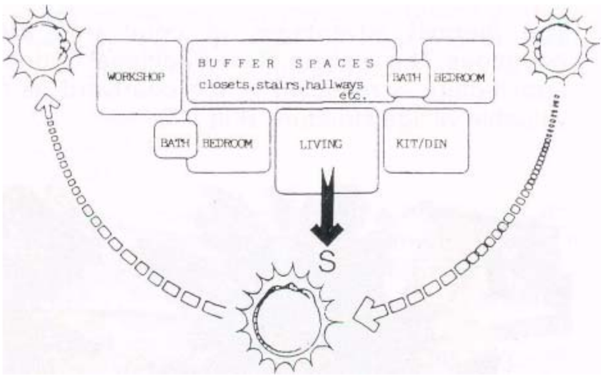


Fig. 13 Building layout to follow sun path.

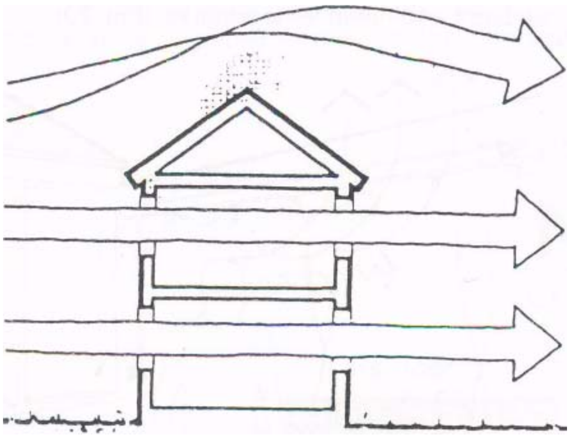


Fig. 14 Long thin buildings

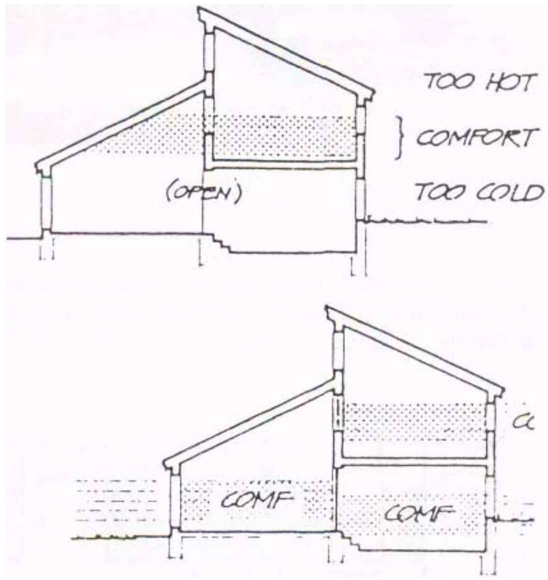


Fig. 15 Open Interior

Although an open interior is useful for natural ventilation during the heating season, it is a liability during winter. It must be ensured that all openings can be closed to control stratification and to maintain separate zones. (Fig. 15, 16).

If the entry is large and supports other activities, provide a way to passively heat the space in winter

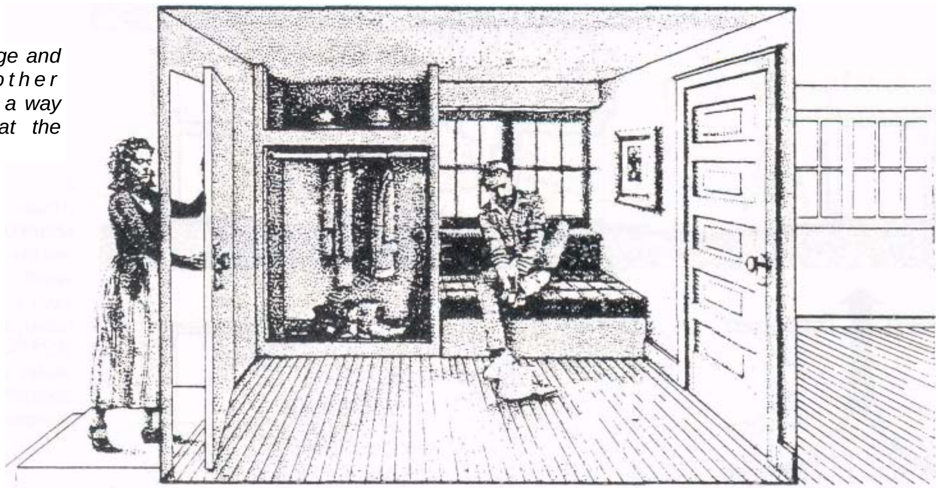


Fig. 16 Protected entrance

D. Courtyards

The thermal advantages of courtyards are enormous. The wisdom of the traditional Cypriot architecture is reflected in the courtyard as a valuable village structure. (Fig. 17)

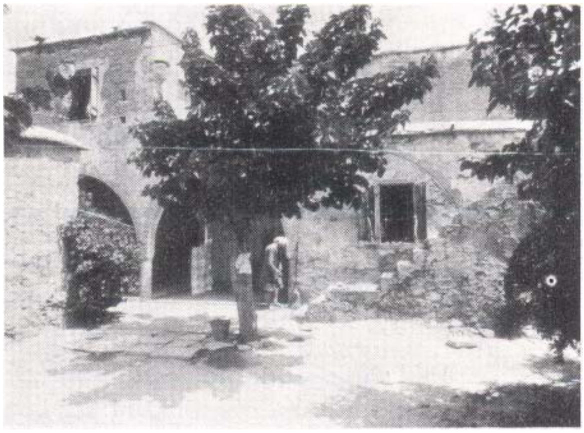


Fig. 17 Traditional Cypriot Courtyard

The courtyards can be used as cold air 'sinks' in the summer and wind protected exterior spaces in winter. (Fig. 18)

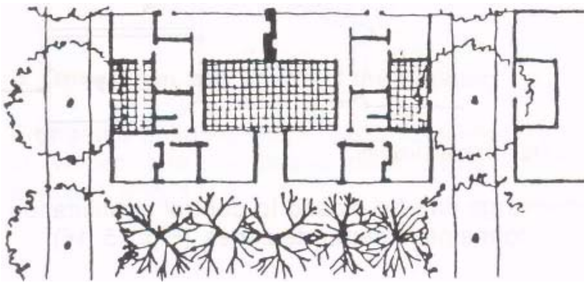


Fig. 18 Courtyards as exterior/spaces in winter

Shading can be provided with the introduction of trees and vegetation. (Fig. 19)

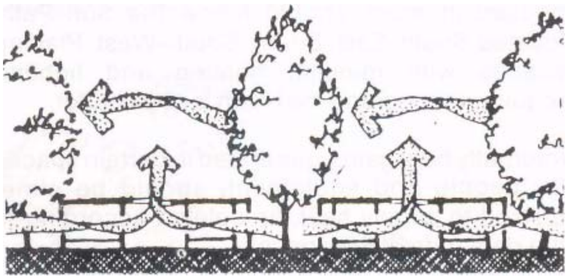


Fig. 19 Provision of shading in Courtyards.

Spray-pipes on courtyard wall is an excellent and inexpensive way of providing evaporative cooling in a courtyard. Moreover, spray cools air as well as wall surface, thereby reducing both ambient and mean temperatures. (Fig. 20)

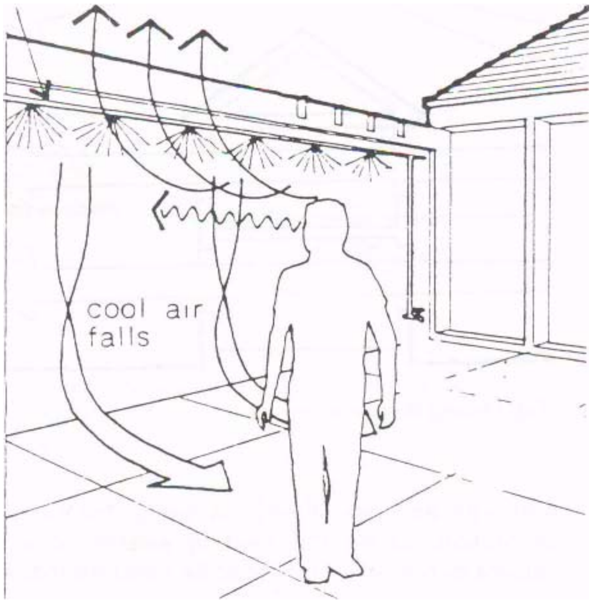
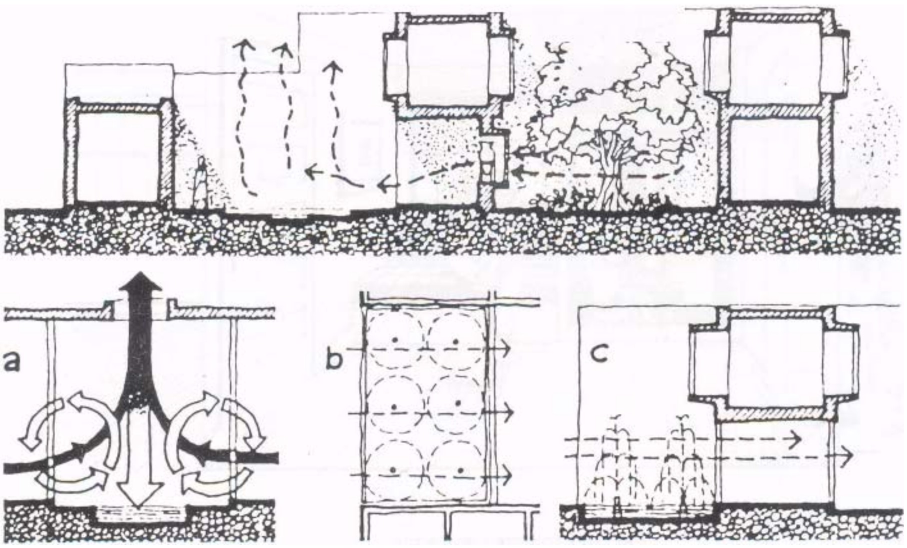


Fig. 20 Evaporative shading in Courtyards.



TOP: In the two-courtyard house, the air from the shaded courtyard flows over evaporative coolers to larger warm courtyard. The coolest space lies between the courtyards.

BOTTOM: Air passing over water sprays is cooled and cleaned before entering the building.

Fig. 21 Evaporative Cooling in Courtyards.

E. Building component design

For the windows, floors, walls, roofs and balconies one must carefully consider:

- Insulation: Levels of insulation, location, and order of assembly to prevent heating in the summer and heat losses in the winter.

- Thermal mass: To act as heat and cold storage. For Cyprus where diurnal temperature differences are large, thermal mass is ideal.

- Heat reflective materials: For surfaces exposed to the summer sun.

- Absorbing materials: For surface exposed to the winter sun.

a. Windows

The openings whether glazed or not, open able or not, play a significant role in the thermal performance of a building, due to their great effect on the heat transfer of the building fabric. Through the openings the heat transfer may occur in any or in all of the three modes of:

- Conduction
- Convection
- Radiation

Therefore, their contribution to heat gains and losses is considerable and their design is significant for the thermal performance of the building.

The best orientation of the major glass area of a building is one which receives maximum solar radiation in winter and minimum in the summer. (Fig. 22)

Use windows for ventilation according to the desired pattern of air flow (Fig. 23) and shade when necessary (Fig. 24, Fig. 25).

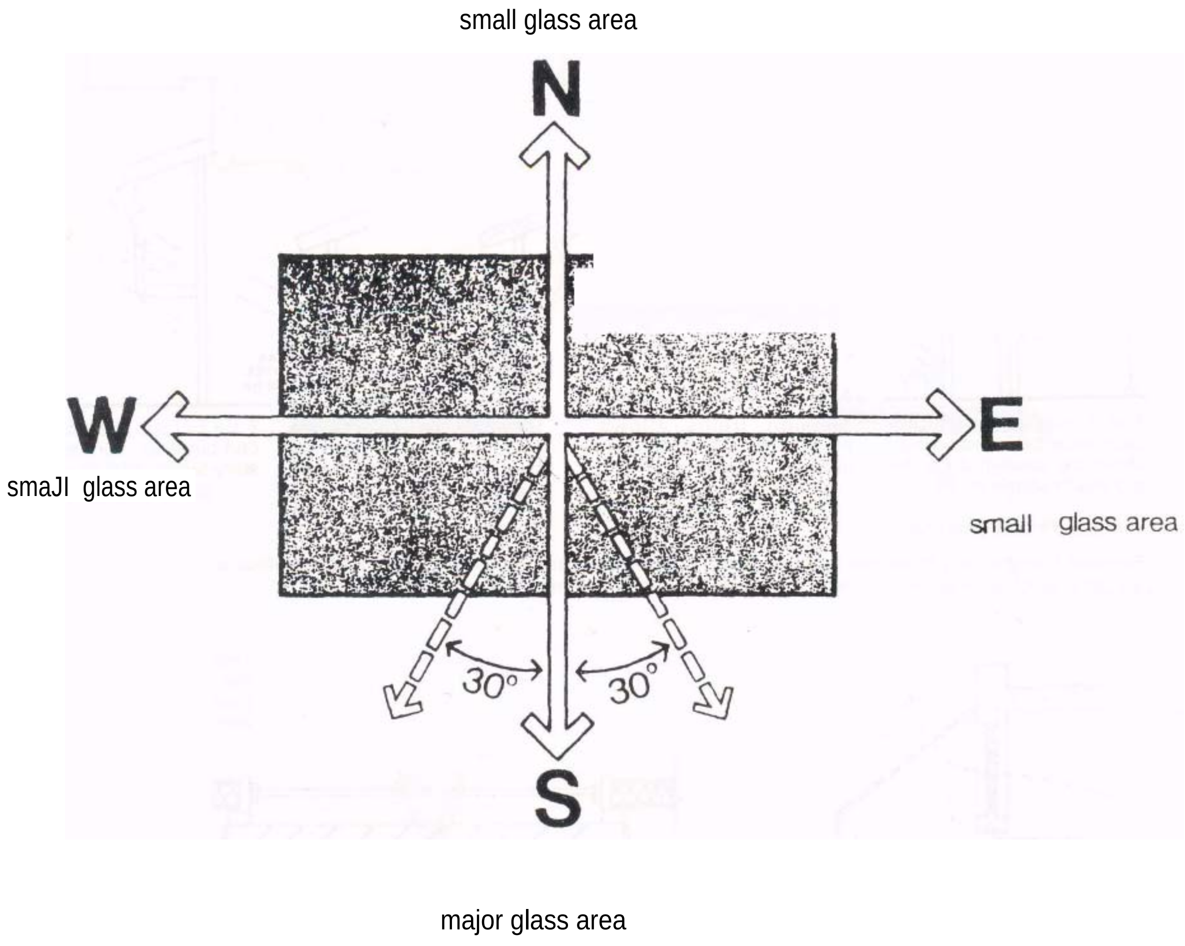
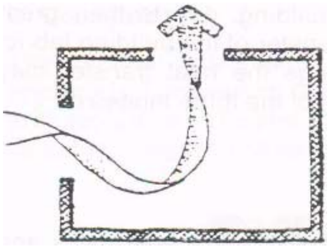
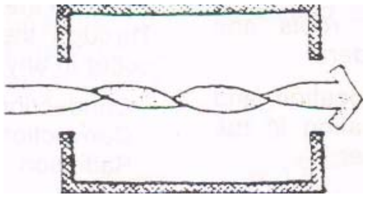


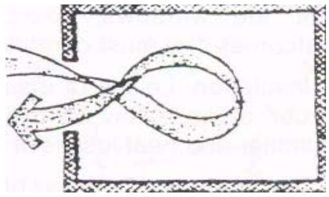
Fig. 22 . Orientation of windows.



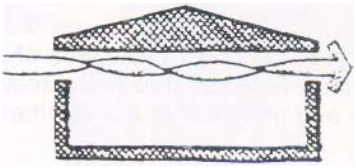
Two openings-Adjacent Walls



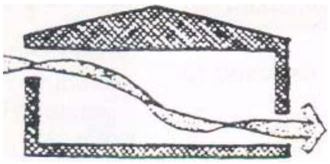
Two Openings-Opposite Walls



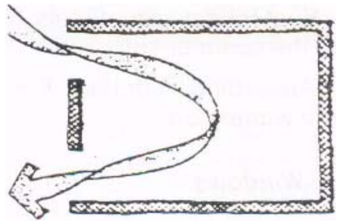
Single opening



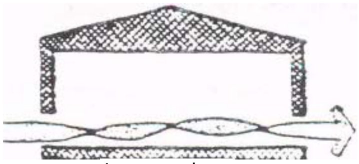
High openings



High and Low Openings

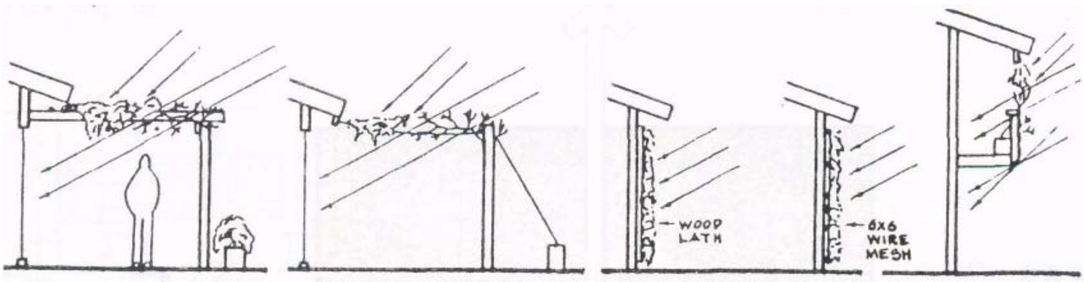


Two openings-Same Wall



Low openings

Fig. 23 Use windows for ventilation



Trellis over south glazing caps must be taken so that structure does not cause too much shape in winter

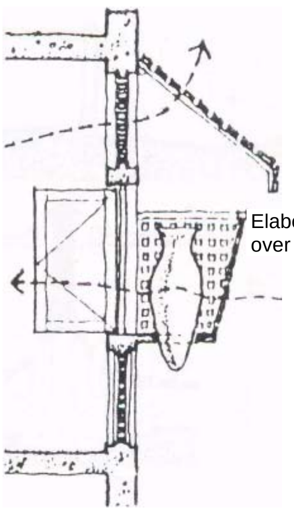
Tension trellis allows minimum structural shading of south glazing

Vertical trellis provides good shading to prevent heat gain in east and west walls

Trellis/Balcony combination for second story facing east or west

Fig. 24 Window shading

Besides being a very attractive method of sun control, deciduous plants on pergolas or trellises will automatically adjust to cool springs or hot autumns provided that the plant material is carefully chosen.



Elaborate window. Air is cooled by evaporation as it passes over surface of water-filled porous pot.

Vertical louvers are most effective for controlling sun on east and west walls

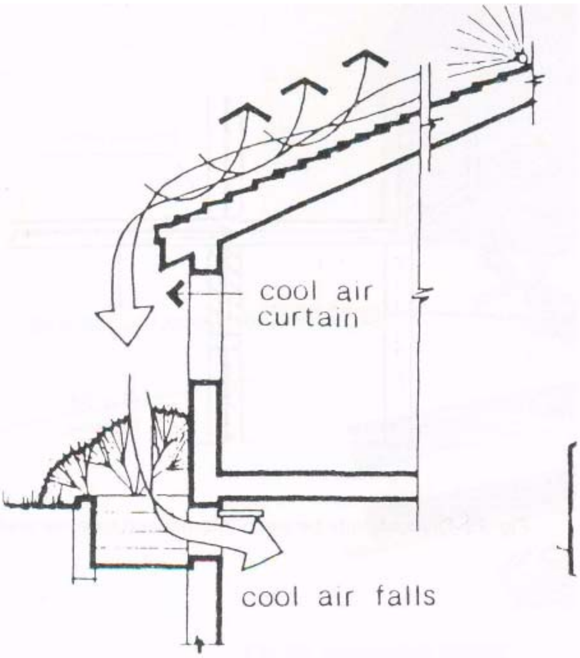
Angle louvers appropriately to prevent low summer sun from entering while allowing access to low winter sun

Fig. **25** Shading and other window considerations

b. Roofs

Roofs are the most vulnerable envelope component to solar gains. Improved design can be achieved:

(a) with application of thermal insulation and introduction of mass.



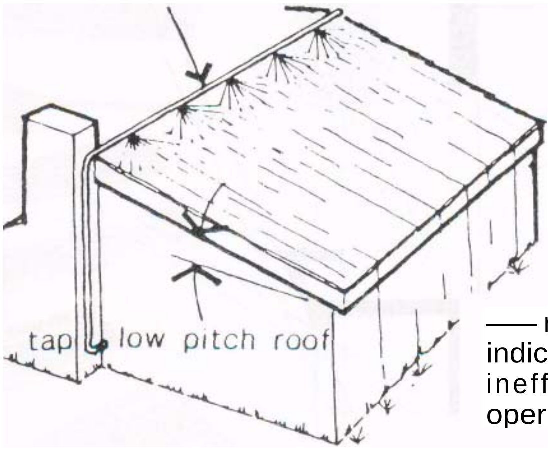
(b) by using roofs as reflective surfaces and for evaporative cooling. (Fig. 26)

Spraying roof keeps surface temperature constant, and prevents rapid expansion and contraction that ages roofs quickly. Roof spray has advantage of being operable only when needed.

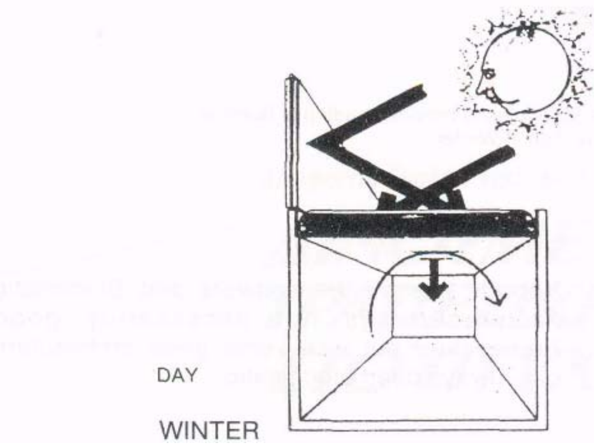
perforated pipe, hose, or lawn sprinkler can be used for spray source.

(c) By using roof ponds to act as combined system: (Fig. 27)

- solar collectors in winter
- heat dissipaters in the summer to achieve cooling.



—— runoff indicates inefficient operation



NIGHT

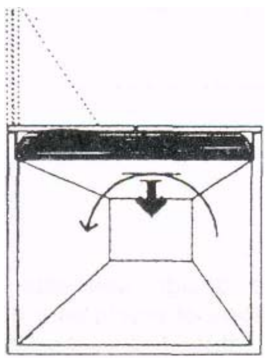
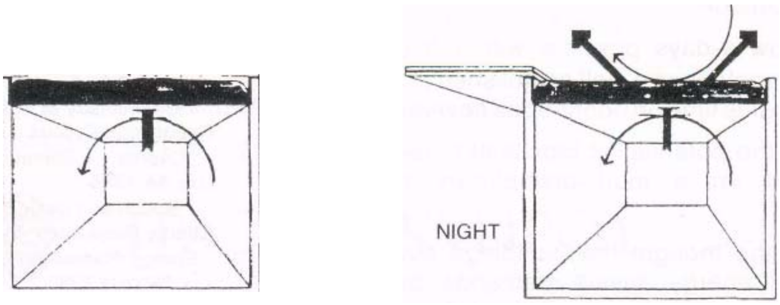


Fig 27 Roof ponds - mild climates

DAY

SUMMER



c. Balconies

Balconies, when well designed, are offered as pleasant sitting areas for the sunny winter days and the cool summer nights.

Balconies can be designed to admit the winter sun, but prevent it entering the glazed facade in the summer. (Fig. 29)

Construction provision of the balconies must ensure discontinuity of their extended, exposed structure to the air, which is liable to act as a thermal bridge to the internal slab. (Fig. 28)

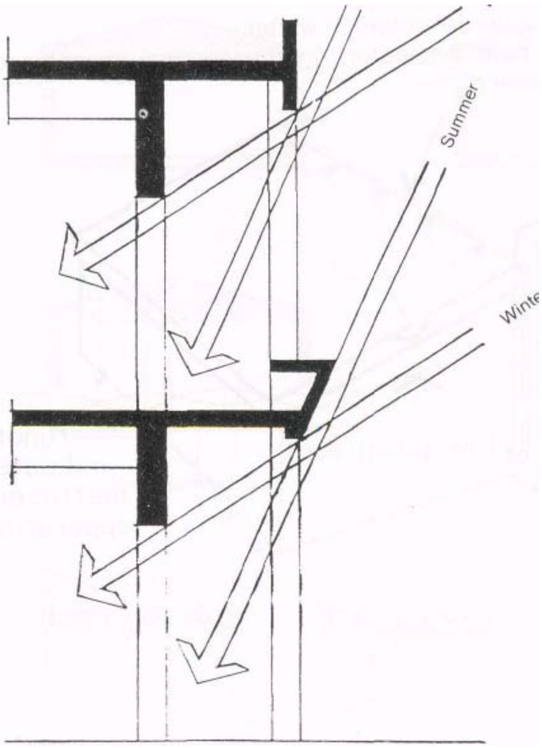


Fig. 29 Use Balconies to provide shading in Summer
Allow Sun in Winter

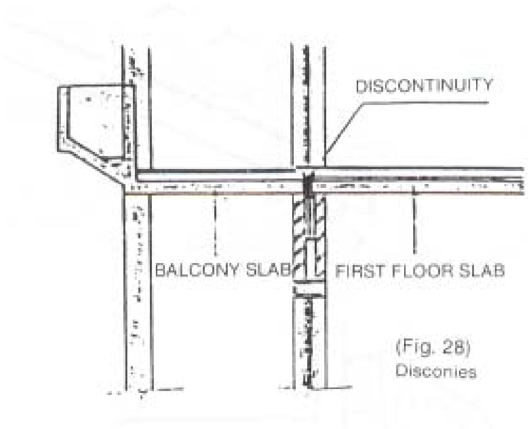


Fig. 28 Discontinuity between internal and external slab

Epiloque

The above design concepts are only basic considerations of bioclimatic design approach. However, detailed bioclimatic analysis, optimization of the regulatory building systems in order to achieve its fine tuning and become successful climatic moderator, evaluation of the building performance, and ultimately analysis of cost-effectiveness, necessitate detailed and at the same time robust, dynamic and interactive design approach.

This is now-a-days possible with the use of computer analogues a well established practice, but at the same time on continuous development.

No doubt the potential of bioclimatic design is dependent on a multi-disciplinary design approach.

However, the thought that building could be permanent energy savers demands building designers to consider carefully the practical options available to them.

Nobody has all the answers and Bioclimatic Architecture is not necessarily good Architecture but vice versa good architecture has always been bioclimatic.

REFERENCES

1. "The Passive Solar Energy Book" by E. Mazria.
2. "Passive Solar Energy Efficient House Design" by S. Yannas AA.
3. "Anadromi tis Kypriakis Architectonikis" by Stefanos Sinos.
4. "Passive Solar Energy in Buildings" by P. O'Sullivan.
5. "Man Climate and Architecture" byGivoni B. Elserier 1969.
6. "Local Climates of Cyprus" Meteorological Services 1984, Ministry of Agriculture and Natural Resources Republic of Cyprus.
7. "Cyprus - A Climatic Design Primer" by M. Eugene Uys AA 1986.
8. "Bioclimatic Design - Architecture and Renewable Energy Resources" by Simos Yannas SADAS Greece.
9. "Energy Planning" Planning Bureau Republic of Cyprus, Nicosia 1986.
10. "Design with Climate" by V. Olgyay Princeton 1973.