INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

SMR/400- 3

WORKSHOP INTERACTION BETWEEN PHYSICS AND ARCHITECTURE IN ENVIRONMENT CONSCIOUS DESIGN
25 - 29 September 1989

"Natural Cooling in Traditional and Modern Architecture"

Giovanni SCUDO
DPPPE - Politecnico di Milano
Milano
Italy

Please note: These are preliminary notes intended for internal distribution only.

International Center for Theoretical Physics
Workshop on Interaction between
Physics and Architecture in Environment-Consciuous Design
Trieste, 25-29 settembre 1989

NATURAL COOLING IN TRADITIONAL AND MODERN ARCHITECTURE

Gianni Scudo
DPPPE Politecnico di Milano - Via Bonardi 3 - 20133 Milano

DRAFT

1. Architecture and Cooling Processes

Architecture is a cultural oriente process aimed at producing built environment appropriate to local needs. One of these needs is comfortable space to live, and, because climate is often adverse, architecture is also a response to climate control need.

Unconscious (or "primitive", "without architect") architecture developed through times subtle and sophisticated solutions for local severe climates:

- at landscape level twin settlements to provide livable conditions in desert areas through seasonal migrations from towns to oasis where hot summer desert climate can be radically modified by vegetation, water and buildings;
- at urban level, continuous low-rise urban tissue to reduce solar gains, promote radial cooling, provide livable public spaces (covered streets, bazars, etc.) during the day;
- at building level, patio and courtyard typologies to cool inside space during the night and provide livable private space during the day.

All these solutions were based on deep "unconscious knowledge" of natural cycles (i.e. water), energy exchanges sun-atmosphere-earth, interactions between forms building, materials, environmental forces and physical comfort.

This traditional unwritten knowledge, often codified in the cosmological and religious views, developed and diffused "cooling solutions" and "specific cooling technologies" (i.e. wind towers) appropriate to particular social behaviours and to locally available resources. Because of the variability of climatic resources traditional cooling systems do not achieve a thermal "steady-state" across time and a thermal equilibrium across space, as modern HVAC systems actually do.

For many decades the uniformity of "standard comfort zone conditions" determined by HVAC systems was the only way to approach climatization:
"a constant temperature is maintained in order to save people from the effort and the distraction of adjusting to different conditions. And yet, in spite of the extraphysiological effort required to adjust to thermal stimuli, people definitely seems to enjoy a range of temperatures. Indeed they frequently seek out an extreme thermal environment for recreation or vacations" (1).

The critical analysis of the pioneers of Bioclimatical Research and Design (2) in the Sixties, and later, the energy cryses in the Seventies, denounced the environmental and social costs of maintaining such uniformity. Modern knowledge of "Climatic Design" considered gain variability of indoor climatic conditions as requirement for the use of variable natural sources of energy to cool built environment.
Traditional cooling systems were revalued and studied. They can be grouped by dominant way of exchange.

- Conductive cooling

In overheated seasons a building loses heat by conduction in the ground. Problems of heat exchange between ground and building are complex, because the temperature of the ground, and, therefore, its potential as heat sink, is altered by the presence of a heated building which loses heat in the ground. An accurate calculation needs simulation; simplified design methods are available in the current litterature along with different techniques to improve potentiality of ground cooling modifying ground temperature (3).

- Radiant Cooling

A building loses it by radiation to the sky, which is the most difficult heat sink to exploit in building design because apparent sky temperature depends from moisture contents of the atmosphere and usually it does not drop more than 6-8°C below ambient earth temperature except in very transparent sky conditions like desert highlands where night is very clear and temperature is very low; radiant power is also influenced by ventilation.
Radiant cooling has architectural constraints derived by the technological difficulties of coupling the interior space of the building to the night's sky avoiding the solar load during the day.
Mass can dissipate in the night heat produced during the day only if envelope is massive enough.
Different radiant technologies and simiplified evaluation methods are described in litterature (4).
Radiant cooling was intensively used in traditional architecture (patio, court, etc.), but relatively undervalued by modern architecture due to the lack of appropriate physical knowledge of the process which is not easily perceived and, therefore, evaluated.

- Convective cooling

Air movement can be used to produce comfort cooling of the body or to cool the structure of the building.
Cooling of the body can be done only when inside and outside air temperatures and vapour pressures are almost the same and mean radiant temperature of the interior of the building is the same of the air. The two assumptions are valid if the interior is ventilated, the exterior is of a light colour and the envelope is not massive.

The limit of convective cooling is air speed which cannot exceed 1.5 m/s.

For cooling strategies for hot humid (light structures) and hot-aired regions (heavy structures), techniques and calculations are described in litterature (5).

- Evaporative Cooling

Space cooling is due to direct evaporation of water into air flowing in the inner space.

Change of phase from liquid to vapour takes place by absorbing sensible heat from the air without any heat gained or lost from water-air system (process at constant enthalpy).

The limits of the cooling strategies are the maximum wet bulb temperature and air velocity acceptable for comfort and the availability of water.

Structure cooling is due to the evaporation of a thin layer of water on structures outside or inside the building.

A number of cooling strategies techniques and simplified methods are described in the litterature (6). (Fig. 1a, 1b)

2. Complexity of Traditional Architecture

We previously defined traditional architecture as an "unconscious and uncodified process" which developed through times settlements, dwellings and cooling solutions appropriate to local climate.

Such solutions have been poorly studied, because of the lack of economic and scientific interest, in climatization by natural, "out of market" resources; therefore to understand why traditional architecture performs relatively well we use more subjective feelings, litterature reports and architectural evaluations than physical data:

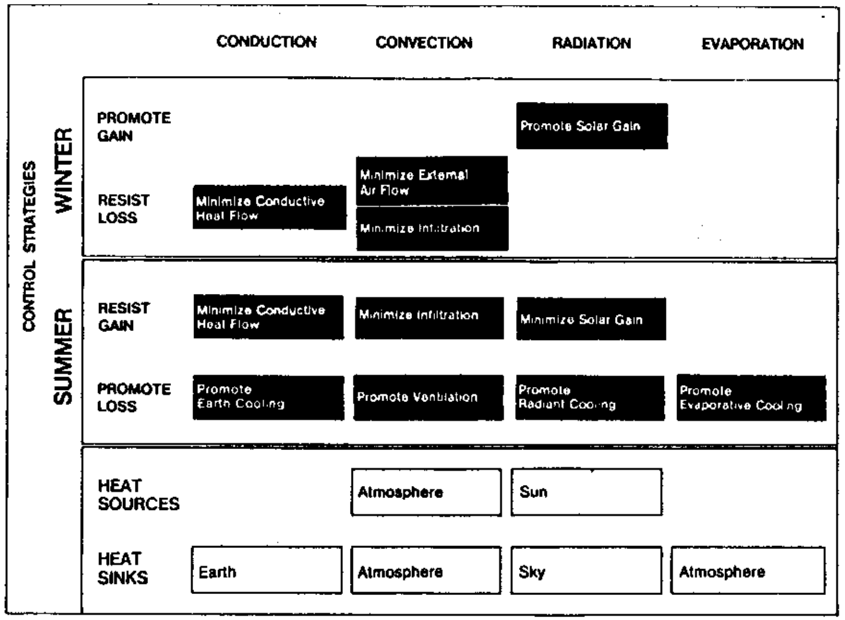


Figure 1a Identification of hypothetical and practicable strategies of climate control.
[WATSON (4)]

Concept 1: **WIND BREAKS** *(winter)*

Two climatic design techniques serve the function of minimizing winter wind exposure:

2 Use neighboring land forms, structures, or vegetation for winter wind protection.

10 Shape and orient the building shell to minimize winter wind turbulence.

Concept 2: **PLANTS AND WATER** *(summer)*

Several techniques provide cooling by the use of plants and water near building surfaces for shading and evaporative cooling.

6 Use ground cover and planting for site cooling.

7 Maximize on-site evaporative cooling.

36 Use planting next to building skin.

38 Use roof spray or roof ponds for evaporative cooling.

Concept 3: **INDOOR / OUTDOOR ROOMS** *(winter and summer)*

Courtyards, covered patios, seasonal screened and glassed-in porches, greenhouses, atriums and sunrooms can be located in the building plan for summer cooling and winter heating benefits, as in these three techniques:

14 Provide outdoor semi-protected areas for year-round climate moderation.

20 Provide solar-oriented interior zone for maximum solar heat gain.

21 Plan specific rooms or functions to coincide with solar orientation.

Concept 4: **EARTH-SHELTERING** *(winter and summer)*

Techniques such as using earth against the walls of a building or on the roof, or building a concrete floor on the ground, have a number of climatic advantages for winter insulation and wind protection and for summer cooling. These techniques are often referred to as earth-contact or earth-sheltering design:

11 Recess structure below grade or raise existing grade for earth-sheltering effect.

24 Use slab-on-grade construction for ground temperature heat exchange.

33 Use sod roofs.

Concept 5: **SOLAR WALLS AND WINDOWS** *(winter)*

Using the winter sun for heating a building through solar-oriented windows and walls is covered by a number of techniques:

1 Maximize reflectivity of ground and building surfaces outside windows facing the winter sun.

9 Shape and orient the building shell to maximize exposure to winter sun.

19 Use high-capacitance materials to store solar heat gain.

29 Use solar wall and roof collectors on south-oriented surfaces.

41 Maximize south-facing glazing.

42 Provide reflective panels outside of glazing to increase winter irradiation.

43 Use skylights for winter solar gain and natural illumination.

Concept 6: **THERMAL ENVELOPE** *(winter)*

Many climatic design techniques to save heating energy are based upon isolating the interior space from the cold winter climate.

8 Minimize the outside wall and roof areas (ratio of exterior surface to enclosed volume).

15 Use attic space as buffer zone between interior and outside climate.

16 Use basement or crawl space as buffer zone between interior and grounds.

17 Provide air shafts for natural or mechanically assisted house-heat recovery.

18 Centralize heat sources within building interior.

22 Use vestibule or exterior "wind-shield" at entryways.

23 Locate low-use spaces, storage, utility and garage areas to provide climatic buffers.

25 Subdivide interior to create separate heating and cooling zones.

28 Select insulating materials for resistance to heat flow through building envelope.

30 Apply vapor barriers to control moisture migration.

31 Develop construction details to minimize air infiltration and exfiltration.

32 Select high-capacitance materials for controlled heat flow through the building envelope.

39 Provide insulating controls at glazing.

40 Minimize window and door openings on north, east, and/or west walls.

44 Detail window and door construction to prevent undesired air infiltration.

45 Provide ventilation openings for air flow to and from specific spaces and appliances.

Concept 7: **SUN SHADING** *(summer)*

Because the sun angles are different in summer than in winter, it is possible to shade a building from the sun during the overheated summer period while allowing it to reach the building surfaces and spaces in winter. Thus the concept to provide sun shading does not need to conflict with winter solar design concepts, as shown in the following techniques:

3 Minimize reflectivity of ground and building surfaces outside windows facing the summer sun.

4 Use neighboring land forms, structures, or vegetation for summer shading.

12 Shape and orient the building shell to minimize exposure to summer sun.

34 Provide shading for walls exposed to summer sun.

35 Use heat reflective materials on surfaces oriented to summer sun.

46 Provide shading for glazing exposed to summer sun.

Concept 8: **NATURAL VENTILATION** *(summer)*

Natural ventilation is a simple concept by which to cool a house using the following techniques:

5 Use neighboring land forms, structures, or vegetation to increase exposure to summer breezes.

13 Shape and orient the building shell to maximize exposure to summer breezes.

26 Use "open plan" interior to promote air flow.

27 Provide vertical air shafts to promote interior air flow.

37 Use double roof and wall construction for ventilation within the building shell.

47 Orient door and window openings to facilitate natural ventilation from prevailing summer breezes.

48 Use wingwalls, overhangs, and louvers to direct summer wind flow into interior.

49 Use louvered wall for maximum ventilation control.

50 Use roof monitors for "stack effect" ventilation.

Fig. 1b

Fig 1b Practical climatic Design Techniques

"The great fondness of Mediterranean cultures for their streets and plazas is largely thermal. A great deal of social life goes on in the streets and plazas because they offer the greatest thermal comfort. They provide a place to bask in the sun or a shady and airy place to be cool, while the houses are stuffy and either too cool from the night before or overheated by the afternoon sun. In most Mediterranean countries the custom of an evening promenade, or paseo, developed to take full advantage of the pleasant coolness of the streets and square in the summer's evenings. After the sun has set and the heat of the day is broken, peopole emerge from their houses and their work - groups of young men or young women, old people with their grandchildren, whole families together - and take a stroll along the via and the piazza to see whom they may see, to stop and talk, but most simply to enjoy the pleasant air" (7).

Traditional architecture was (and still is) an overall organisation of space at different levels which correlates in a very precise way built environment shapes to their environmental performance through steady and culturally based design patterns.

Traditional architecture was a morphological language which developed rules to adapt common typologies to specific sites and cultural demands at four different levels: landscape, town structure, building, architectural details. The persistence of culturally rooted architectural language gives coherence to all built environment and prevents individual designa and building fallancies.

Morphological languages are very steady and subtle structures; their roots go down to the symbolic and religious meanings.

Taking in example "islamic architecture", we can consider it

as a general morphological language which develops common rools and variations in typology and elements to respond to particularly hard environment and climate. This climate is characterized by dryness, high thermic daily range, fairly high average temperature, strong solar irradiation and finally winds which can often be variable and dusty. The adjustment of such an architecture to climatic conditions has been undoubtedly worked out through a very long process whereby the cultural and religious elements have been fused totechnical knowledge. If we analyse it "a posteriori", we will see that Islamic Architecture presents distinct and varying levels of adjustment.

- Urban level

The urban structure is usually a continuous pattern of courtyard building clustered together and connected by a very diffuse network of "cul de sac" narrow streets departing from the main road system. Urban texture contributes to the thermal protection because the narrow winding streets are aprtially covered and function as the courtyard in the house: they regulate temperature. (Fig. 2)

"In a wide straight street, the cool air deposited during the night is swept away by the first breath of wind. A wide street offers no shade and heats up more rapidly than a narrow one. The difference in comfort is clearly felt in all the street that were widened and straightened during the remodelling of old parts of Cairo. They are extremely hot in summer and are full of dust. In the planning, the planner simply superimposed the new layout on the existing one as if it were non-existent, or as if this plan were made for an underground system" (8).

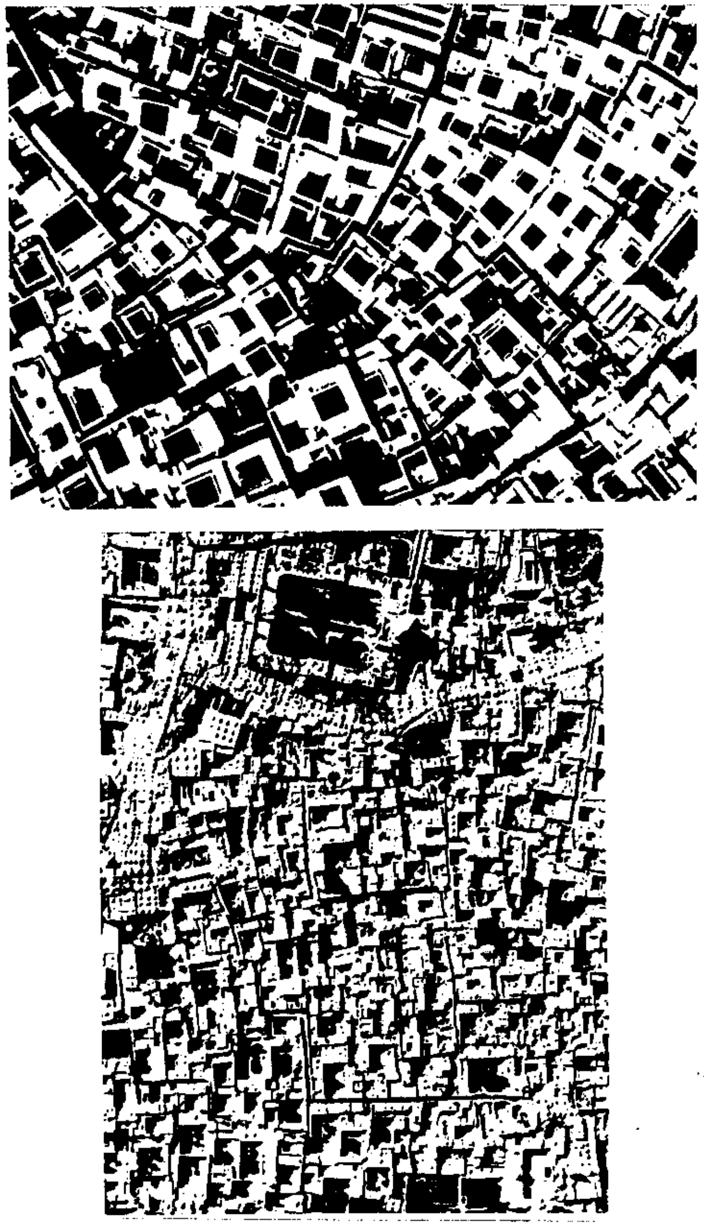


Figure 2
The close-packing, "cul-de-sac" texture of the arab urban structure: a) Marakesh (Marocco),
b Kashan (Iran).

- Dwelling level and internal organisation

The main strategy to resist thermal gains in summer is to reduce walls exposed tosun radiation and hot wind. This leads to three fundamental morphological models: the earth integrated or underground house, the compact isolated courtyard house and the courtyard house grouped in a continuous urban-texture ("casbah").

The underground model is diffused in particular areas like Matmata in South Tunisia, where high cooling load combines with a soft ground which makes possible the underground technology. (Fig. 3)

The compact isolated and "casbah" models are diffused through all arab countries in different variations appropriate to local culture, physical environment and resources. Both models are based on an inner space - the court - surrounded by outer space (House space). Inner and outer envelope have a surface much greater of a close cubic model. Most of the openings are located in the inner envelope. Houses are clustered in a close packing pattern with three main different spaces:

- indoor house space between inner and outer envelope completely covered by roof;
- internal indoor space surrounded by inner envelope and open to the sky (the courtyard space);
- external open space formed by outer envelopes of the houses.

Both compact and isolated models can vary in density (number of stories), courtyard/built ratio, covered/uncovered courtyard ratio, etc. depending on climatic and cultural conditions.

The main element is the courtyard ("shan"). The central

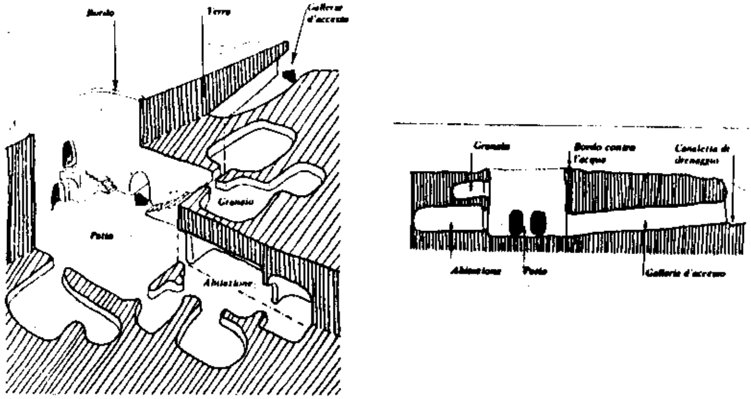


Figure 3a
The underground patio model of Matmata (Tunisia).

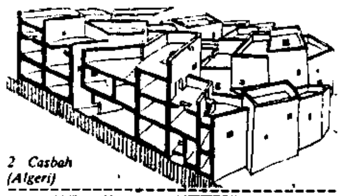


Figure 3b
The continuous Casbah Courtyard model (Algeri).

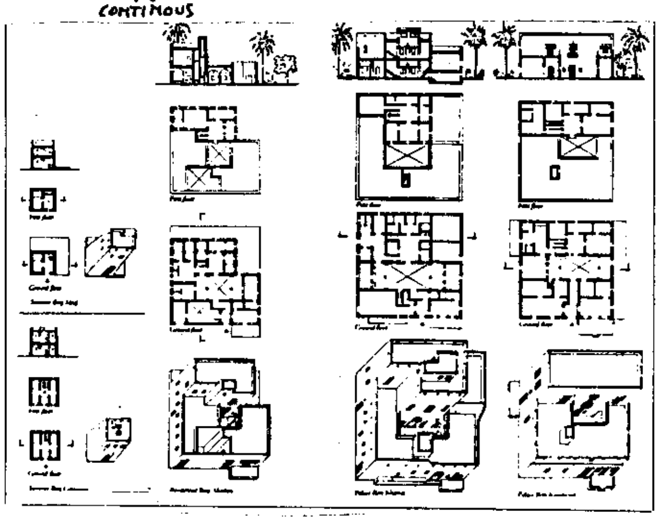


Figure 3c
The compact isolated model (Borij typology, Sfax).

space (called also "patio" when partially covered), protected from solar radiation, has two functions: one of light source and the other of thermic regulation. Indoor space (rooms or "iwan") facing into the courtyard is protected by courtyard and the clustering of houses. The courtyard shadows all day long the indoor space which remains at a lower temperature than the average exterior temperature (F. 4)
Some vegetation may also be grown to increase shading and to provide air dampness and cooling by evaporation. Cooling can provide air dampness and cooling by evaporation. Cooling can be further increased by humidifying devices functioning by water evaporation.
The courtyard may be covered by light and movable shading devices to increase shadow surface of the walls.
The courtyard and loggia are also the distribution system migration which supports inside the house during the day and night for a better utilisation of inner microclimate; also functional distributions are based on inner space.
Daytime shady loggia and rooms near the courtyard are employed to eat, have siesta and work; nighttime people sleeps on the roof terrace taking advantage of the night cooling.
In regions with a marked climatic difference between seasons, also seasonal migration takes place. For this reason the rooms of the upper floors are utilized in winter while those on the ground floor are used in summer (9). (Figg 5,6,7)

- Building technologies (walls, roofs and openings)
The selection and treatment of the materials to control the day and night temperature swing is of the greatest importance.

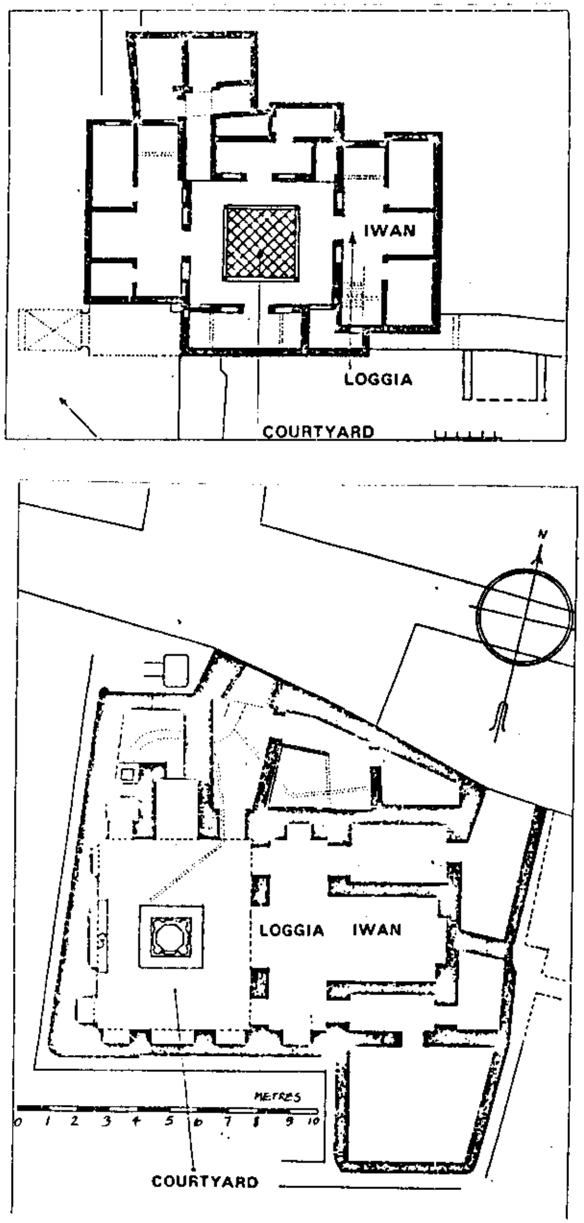


Figure 4
Different examples of court and patio nouse typologies.

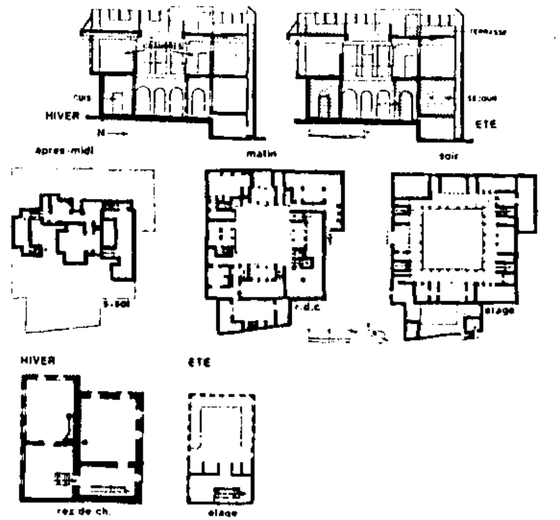


Figure 5
"Daily" and "Seasonal" vertical migrations inside the house follow the best local comfort conditions.

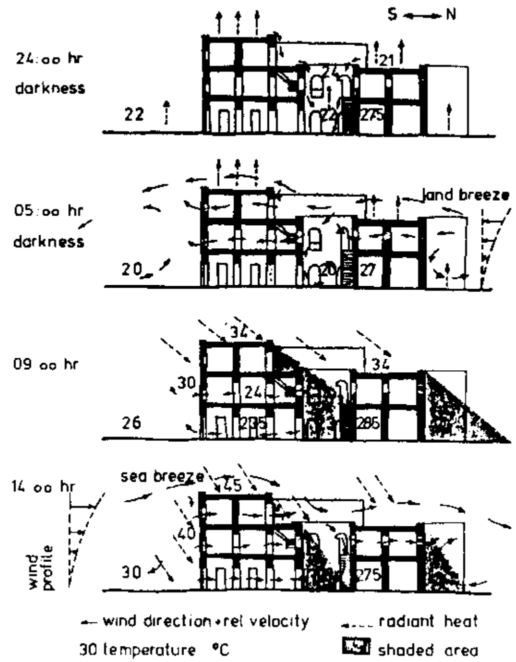


Figure 6
Climatic response of a courtyard house in hot-dry maritime -

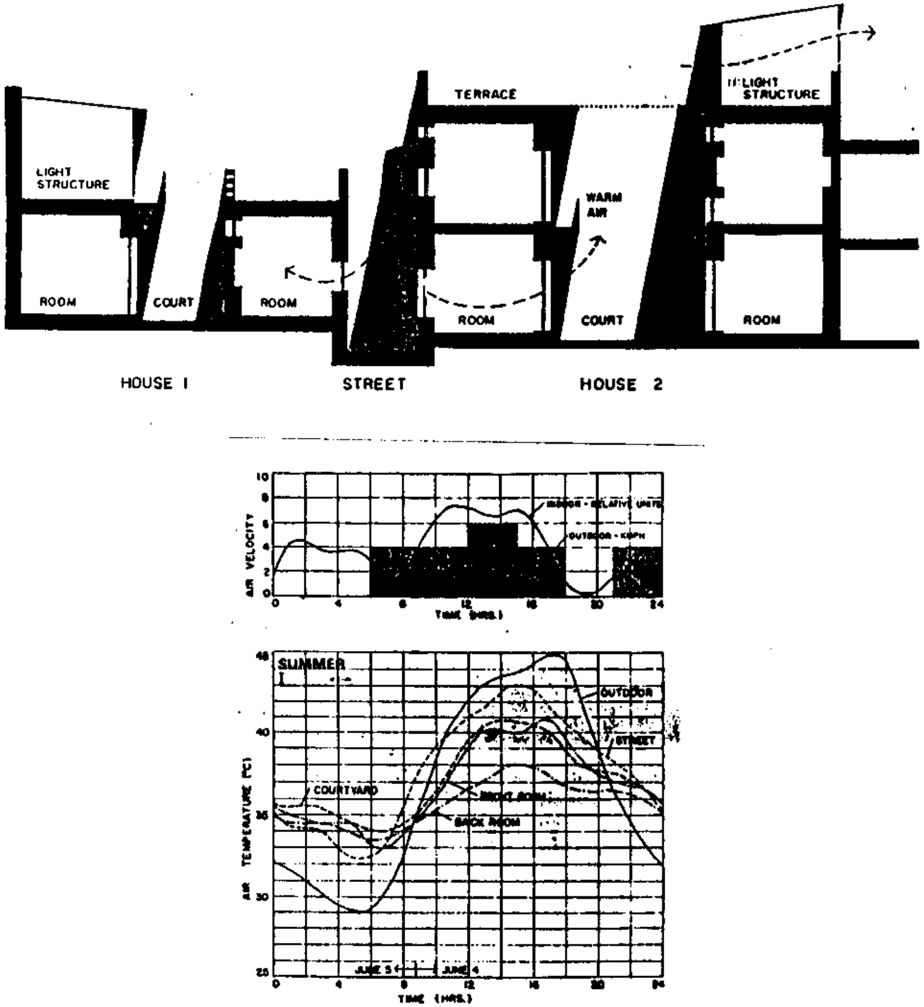


Figure 7
a) The cooling effect of a courtyard house. It regulates air movement, binding on fresh air only when is cooler than the building (Jaisalmar, India).
b) Measured temperature and air flow of the Jaisalmar house.

Heavy weight envelope has a great advantage and is strongly recommended in spaces used during the day because of its high heat storage capacity which attenuates the thermal effect of outside climate.

Thermal resistance and density of materials determine a great variation in thermal behaviour: a dry earth wall has a better thermic performance than a concrete wall because its thermal resistence is very high.

Also the external colour plays a great role: white colour has a high reflectivity which means to diminuish the effect of solar radiation.

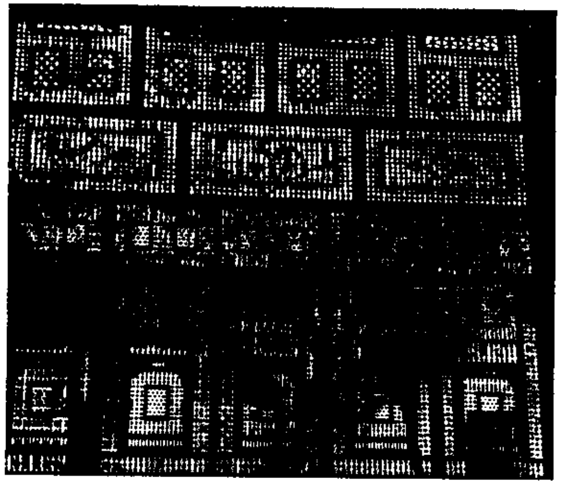
Roof is the most critical component of the whole building: it receives the greates amount of solar radiation during the day and emits the greatest quantity of heat by night radiation to the sky.

The heat loss to the sky is maximum with flat roof (protected from wind by lateral walls) made of building materials (mud-brick i.e.) and painted white.

Outside openings are usually few and provided with shading devices which allow a minimum lighting and outside view maintaining the visual privacy from outside.

The ventilating opening is usually used during the late night, when air temperature is cooler; when used during the day the entering air has to be cooled by evaporation.

"To reduce the glare without reducing the movement of air in those rooms which could not be provided with a "malkaf", the window was fitted with a lattice screen called a "mushrabeya", made of small wooden bars. These bars are circular in section, so that they have the effect of breaking up the light which falls on them; thus, there are no sharp edges visible, nor is there any harsh contrast between the darkness of the lattice and the brightness of the light.



Mashrabiya in the As-Suhaymi house, Cairo.

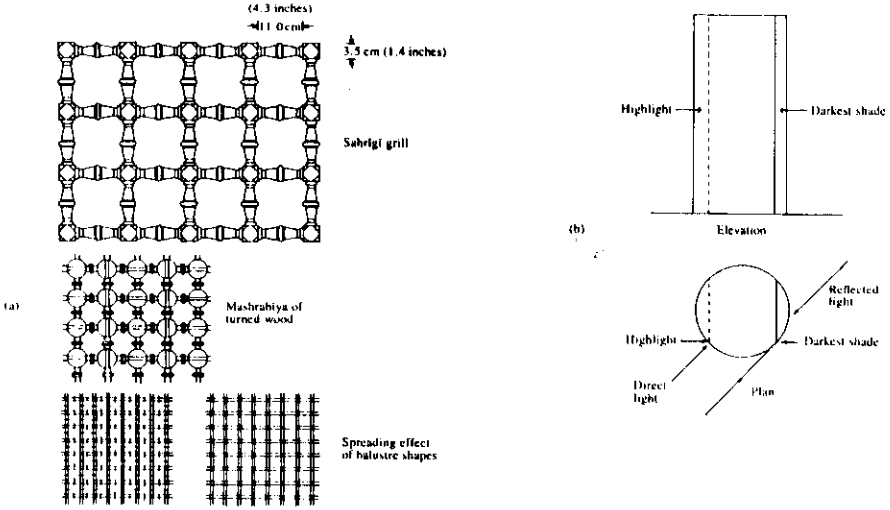


Fig 8

Analysis of light falling on a *mashrabiya*: *(a)* examples of lattice arrangements; and *(b)* the effect of light falling on a cylinder. The graduated light and shade of the cylinder subdue the dazzling effect of dark-light contrast which occurs when looking from the inside toward the light outside.

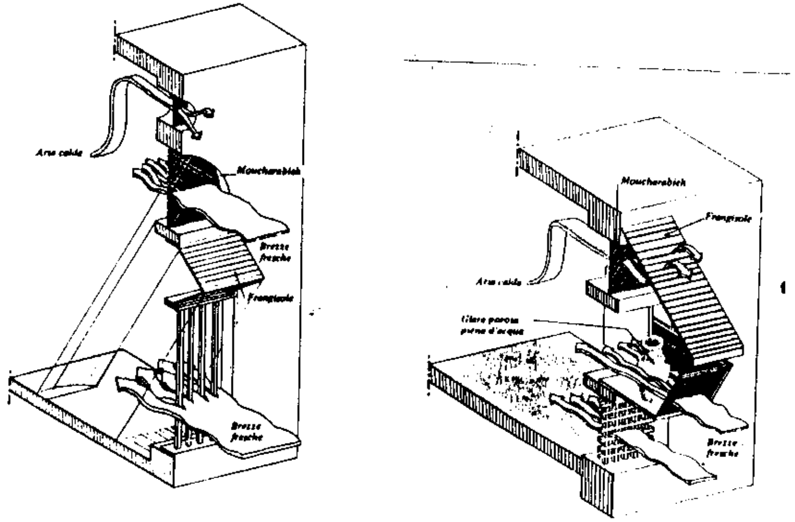


Figure 9

a) The "musharabeya" is a special device filtering light, insect ecc. and allowing convective exchange inside-outside and outside-inside.

b) The "musharabeya" combining convective and evaporative processes.

The glare is softened and the eye is not dazzled" (10).
(Figg. 8,9)

- Cooling devices

Air movement inside the building can be used either to cool structure either for physiological cooling.

Air movement can be generated by wind effect or by "stuck" effect (temperature difference).

When wind iw warm it is better to generate ventilation by stuck effect; when wind is cool the natural convenction can be activated with a device able to catch winds and drive them into the rooms.

The "Wind catchers" are very frequent in Iran, Iraq and Egypt; they project on roofs to intercept coolerm fasterm less dusty air flows. During the day (when inside temperature is lower than outside one) bhot inside aire flows down the walls of the wind tower, loses heat and enters fresher than outside air into the room; it absorbs heat (refreshing ambient air) and then is evacuated through windows. During the night if wind is not blowing, wind tower functions as a chimney suching exhausted hot air from rooms and replacing it, with outside fresh air entering through openings.(Figg. 10,11)

Natural convenction and ventilation can be improved by adding a device for the evaporation of water in order to lower the temperature by means of latent heat loss by evaporation. "Wind catchers" are often combined with fountain and humid underground tunnels.

Water, which is quite rare in dry countries, is to be found in the habitation and its usage is well defined and efficient in witness to its scarcity. It may be utilized in "patios" with basins, water-sputs, and fountains or little streams which sometimes allow also the watering of the

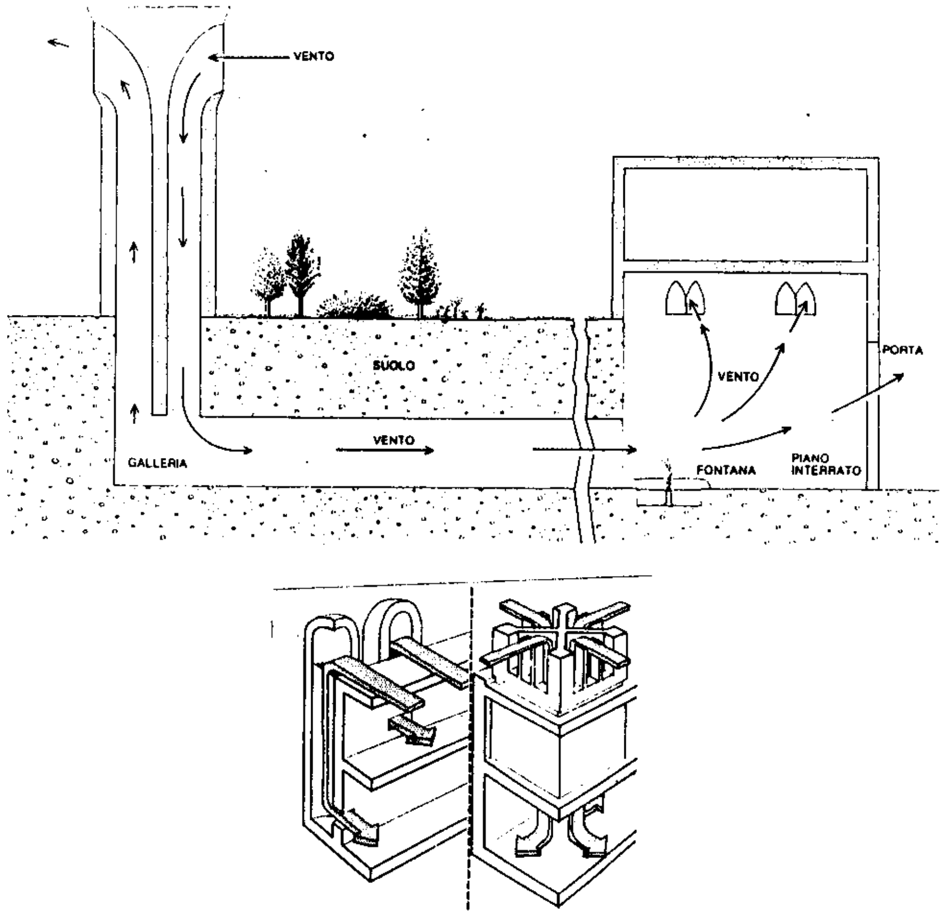


Figure 10
a) Wind catchers at work in the day (Wind entering on the right) and in the night (hot air extracted on the left).

b) Mono and multidirectional wind catchers.

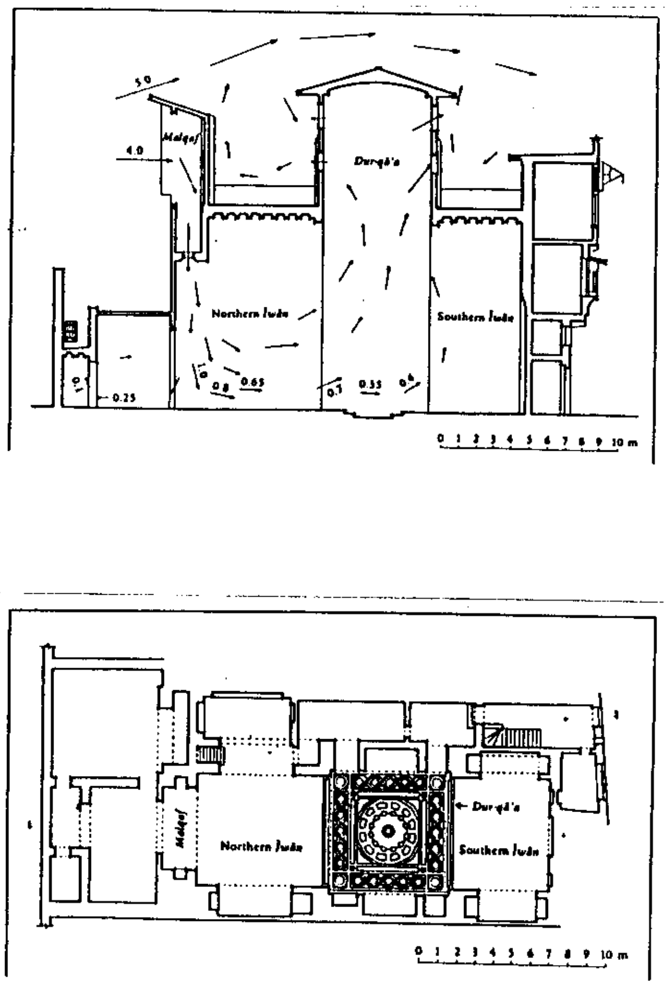


Figure 11
a) Air flow measured in a "Qa'a" in Cairo (arrows indicate direction and velocity in m/sec). The air flows in through the "Malkaf", ventilates the "Qa'a" and is evacuated through the vents of the "Dur-qa'a". Ref. (17).
b) The plan of the "Qa'a" in Cairo.

ground. It may flow on "silsabils" (which are decorated inclined surfaces where a fine stream of water flows emphasizing the evaporation process) or it may make the air cooler thanks to a porous jar which catches the air through a "wind tower" or a "moucharabieh" window (11).

3. Simplicity of Modern Architecture

The Modern Movement in architecture was an attempt to design the overall organisation of space at different levels in a "scientific way"; this means extending modern science and technology to space control with designed patterns based on "general and clearly stated rules", which tended to generate simplification, lack of "sense of place", uncontrolled environmental performance.

Steel, reinforced concrete structure, glass, heating, ventilating and air-conditioning (HVAC) installations and other new technologies gave modern architects the opportunity to build without the constraints of local physical environment, rejecting one of the basic historic lesson of the past.

HVAC installations eliminated the need of accurate definition of building shapes/environmental performances and this quickly brought to a new "international style and language" which can be roughly synthetized by the Le Corbusier statement:

"The buildings of Russia, Paris, Suez or Buenos Aires, the steamer crossing the Equator, will be hermetically closed. In winter warmed, in summer cooled, which means that pure controlled air at 18°C circulates within for ever" (12).

Poor building physics knowledge and understanding of thermal comfort-building-microclimate relationships brought often Le

Corbusier to apply modern techniques in a very disastrous way: an example the attempt to apply the double glass cladding technology to the famous building "Cité de Refuge". "We had been looking for an opportunity - it came: the Salvation Army hostel Cité de Refuge. Six hundred poor souls, men and women, live there. We gave them freely the ineffable joy of full sunlight. A thousand square metres of glass wall lit every room, from floor to ceiling, from wall to wall ... the glass was hermetically sealed, because warmed and filtered air circulates constantly inside, controlled by the heaters and fans" (13).

This experience came from the M.M. principles of dematerialisation of architecture:

"In that epoch when 'mince' must have been one of his highest terms of praise, all other materials seem to have been in his eyes poor substitutes for glass, his ideal of the dematerialised building skin, the minimum membrane between indoors and out"

"This sealed box of controlled ventilation and ineffable sunlight opened triumphantly, because comfortably warm, in the bitter December of 1933, as Le Corbusier proudly claims. And as he also frankly admitted, it ran into serious trouble at the other solstice *au gros de l'été, à la pointe de chaleur*. The sealed glass wall with its southerly aspect made the interior an intolerable glasshouse; for reasons of economy it was a single skin, and not a *mur neutralisant*, and even if it had been, it would have made much difference, by Le Corbusier's reckoning, because the same budgetary restrictions meant that there was no cooling equipment in the ventilating system. In the upshot, the town planning authorities insisted on the fitting of openable *fenêtres d'illusion* whose environmental performance seems to have been less illusory than Le Corbusier liked to pretend, while he himself was driven, shortly after, to invent the external sunshade or *brise-soleil*. He did not, however, fit such a sunshade to the Cité de Refuge—that had to wait for another hand and a much later date." (14) (Fig. 12)

Later in the Thirties:

"he was becoming conscious of what he had done, what environmental qualities had been mislaid in his attempts to abolish the load-bearing wall. He was to discover, now, any number of good reasons 'to fill this space up again when it has been given to me empty'. To fil it up with suspended lead sheets for sound insulation, to fill it up with

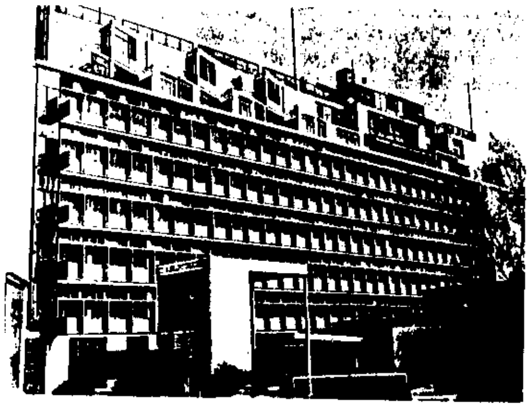


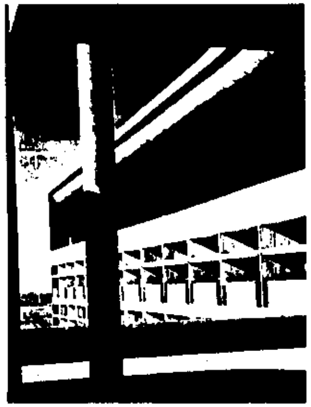
Fig. 12. Cité de Refuge, Paris, France 1932 by Le Corbusier - above: the original glass fasade
Below: with brise-soleil added

curtains to exclude sun and staring eyes, to fill it up with glass bricks for related reasons, to fill it up with solid masonry and other 'materials friendly to man', or to start thickening up the glass membrane with sun-breakers in the exterior, further layers of glass containing warmed air on the interior. In short, to replace additively, elemtn by clip-on-element, the performance factors that a massive wall had contained homogeneously and organically" (15).

I spent some times in dealing with Le Corbusier "environmental misapprehensions", because they reflect the basic conflict of the M.M. design pattern: the symbolic strength of M.M. architecture has to be against local culture, climate and ... definitely man.
I am not making a radical critique to Le Corbusier, who was a great master of the M.M., but we have to start from the above mentioned "misapprehensions" (extended to a large number of architects of the M.M.) to understand how design and architectural patterns worked in hot climate context.
It worked apparently better in hot humid regions, where light structures and "free space" made possible by reinforced concrete and steel, were more fitted for freedom to adjustment to climate. International style (which is the quantitative diffusion of the M.M.) broke with "colonial architecture" losing an important lesson of the past.
Colonial architecture is a loose definition of the built environment developed by European in their colonies in the last four centuries. The first approach to adapt to the new climatic conditions consisted in "tropicalising" current European architecture (Palladian, baroque, neo-classical, etc.). Tropicalising processes have different patterns depending from dominant European cultures: not Europeans had to radically modify their traditional building habits and therefore the connection with local architecture and culture is very loose. Portoguese and Spanish, whose architecture was more adaptable to tropical climate, developed hybrid architectures (American-Spanish, Brazilianm etc.) which were very well fitted to local climate at different levels from town plannings to architectural details.

Simplicity of international style was fitting only to the necessity of uniform colonial market, which made a strong effort to diffuse industrialized building and HVAC technologies.

The design of Chandigar by Le Corbusier in the Fifties is considered a "starting point" in the development of modern architecture in tropical areas (16).
But if we analyze cooling performance of single buildings, we realize that generally it is not very high, because Le Corbusier developed simple environmental control devices (breeze-soleil for the sun and roof for rain protection) without taking into consideration the complex interaction between local microclimate and building thermal performance.
The High Court Building, i.e. Fig.13, is shaded by concrete vertical "breeze-soleil", but their efficiency is very low because of the high heat storage capacity. Breeze-soleil are heated by sun in the day and in the night warm cool air entering into the building, making impossible the convective night cooling for daytime comfort (17).
Environmental misapprehensions of the masters of modern architecture are partially due to the lack of technical knowledge, but mainly to the strong will to impose over people and environment "personal languages" without social rules and this is possible only when architects design for the "Prince" and not for the people.
This "teocratic attitude" of M.M. architects originated from the breech they made with the past historical architecture in the faith that European progress and technological achievements could solve the housing and urban problem of the underdeveloped countries.



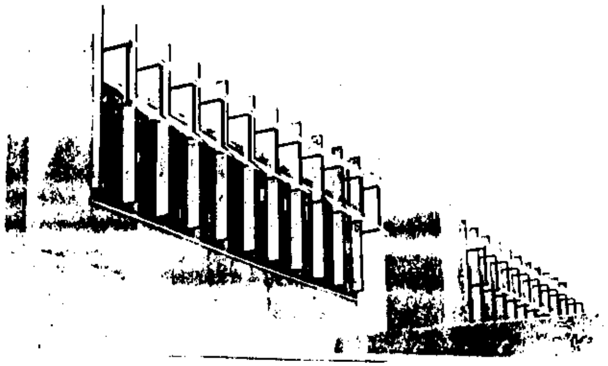


Fig 13

. *Efficiency of these fixed concrete louvres in the High Court building in Chandigarh, India, is considerably reduced because of their high heat-storage capacity. After sunset the louvres steadily warm the cool night air on its way into the building, thus making it difficult for interiors to sufficiently cool down for daytime comfort.*

. *For conditions where buildings rely chiefly on night cooling, louvres of thin light-weight materials were used by architects D. and I. Alrod in this primary school building in Beersheba, Israel (right).*

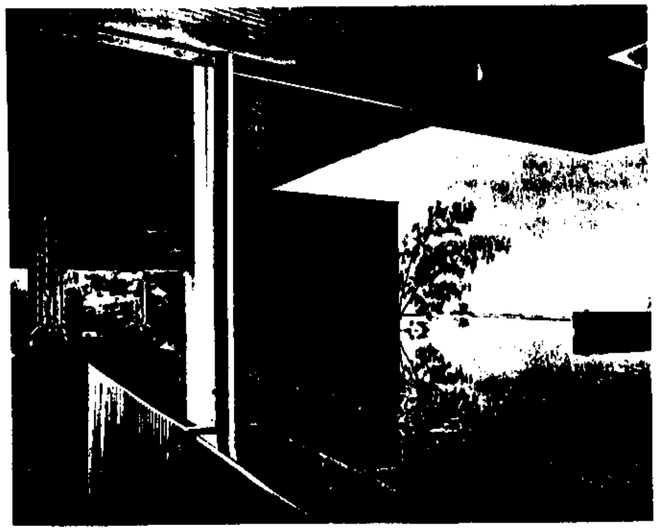


Fig. 15

The roof of the sleeping quarters of a small house Sierra Madre, California, is permanently covered with water which, according to its architect Richard Neutra, makes the interior 6 to 8 degrees cooler. Roof pond viewed from the living room.

New independent countries called famous architects to design and build new cities and public buildings. Le Corbusier in Chandigar (India), Louis Khan in Islamabad (Pakistan) (Fig. 14) and Dacca (Bangladesh) and Walther Gropius in Baghdad (Iraq), etc.

Most of these architects and those who followed the works there, tried seriously to understand local culture, values and physical environment, so different from their original culture, but often their effort was more "an intellectual process" than a deep understanding which often requires living, working and studying in the area for many years. Architectural forms were the result of personal languages, more often without any link with local culture, which in many cases was vary strong (18).

4. <u>Tropical Architecture</u>

The term "tropical architecture" was conied at the beginning of the Fourties (19) to indicate architecture designed to fit tropical conditions by means of environmental control techniques, or practical means developed in the region.

Modern tropical architecture was developed at the beginning in English and French colonies starting from the Thirties.

The need to adapt military forces to tropical climates during the war, influenced the interest to develop tropical architecture.

After the war, for the first time "natural cooling" is advocated, guidelines on tropical buildings are published (26) and some European architects began to design tropical shapes appropriate to hot climate and to use cooling technologies.

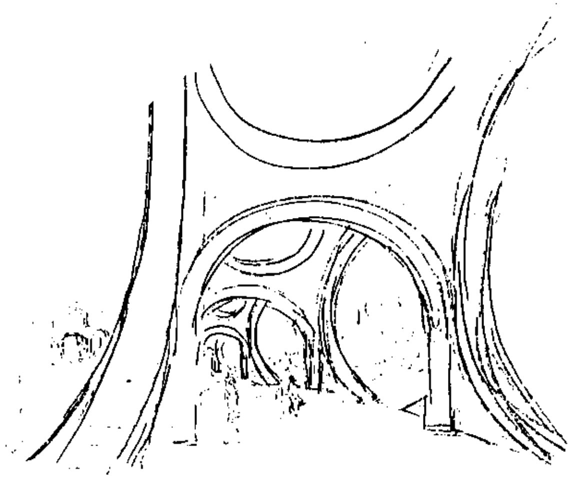


Fig. 14 Ayub National Hospital in Dacca, Bangladesh by Arch. L. Kahn

In particular solar control and ventilation devices diffused very much

M.M. forms are still dominant with some change in external cladding and interior arrangement.

M. Frey and J. Drew, British architects, began to write on their experience on "colonial" design and building, Research Centres (BRE in Great Britain, CSTB in France, etc.) began to investigate material behaviour and building problems in tropical areas (19).

During the Fifties, the late years of colonial Domaine, the interest in tropical architecture extended to the USA, Africa, Australia and India, but it is still the work of small groups and individual architects as documented in periodical publications.

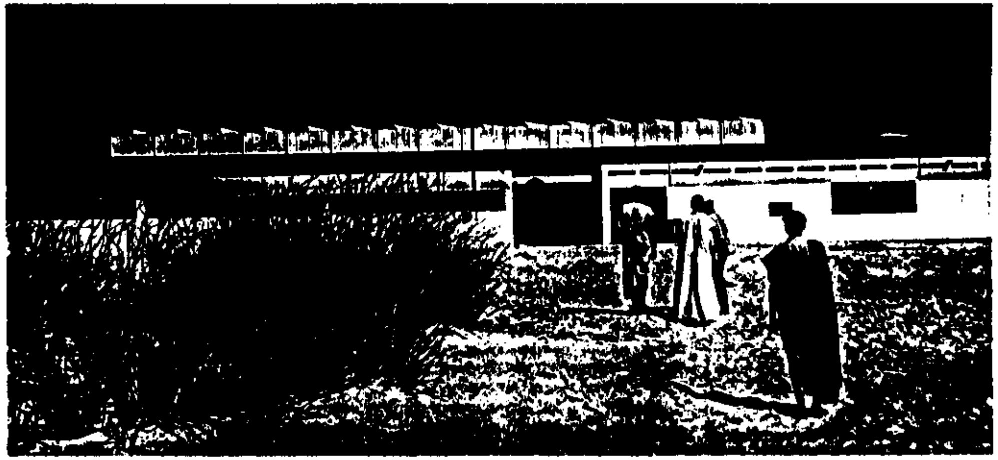
Interesting radiant-evaporating cooling solutions developed by Hay and Yellot in the States and, in general, solar energy research influenced hot-arid USA regions and Australian architecture (Fig. 15); French architects designed interesting natural cooled buildings supported by research development on cooling technologies (sun control and ventilation) (20).

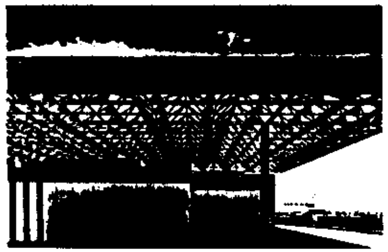
The colonization processes in the Sixties supported a new flourishing of studies in thermal comfort, cooling process and techniques, use of solar energy, simplified calculation methods, etc., which brought to the publication of well-known guidelines and manuals, among which we mention V. and A. Olgyay's, Design with Climate, 1963, D. Danby, Grammar of Architectural Design, 1963, F. E. Maxwell and J. Drew's Tropical Architecture in Dry and Humid Zones, 1964, G. Lippsmaier, Tropenbau - Building in the Tropics, 1967 and B. Givoni, Man, Climate, Architecture, 1969 and O. Koenisberger

et al., Manual of Tropical Housing and Building, 1974.
These methodological supports helped to diffuse among students and architects an environmental conscious design approach, which, anyway, did not produce much effects in the built environment because of the world dominant HVAC approach based on the very low oil cost.
Nevertheless also in these years some remarkable international style tropical architectures were built (Fig. 16).

5. Cultural Continuity and Innovation in Contemporary Regional Architecture

Underdeveloped countries agricultural and housing crises, environmental and oil crises in developed countries, consciousness of the limit of material resources underlined at the beginning of the Seventies the necessity to approach settlement and housing design with appropriate technology, based on local cultural tradition, production and renewable energy sources.
One of the limiting factors in the development of International Style in the arid zones was the availability of industrially produced buildling materials, HVAC equipments and skilled craftmanship, which usually were imported (with the architects) from developed countries.
The high economical and social costs of international style architecture limited the use to few important public buildings and upper classes dwellings leaving all other housing demand to "informal sectors" because generally many of the public supported programs for low cost housing failed.





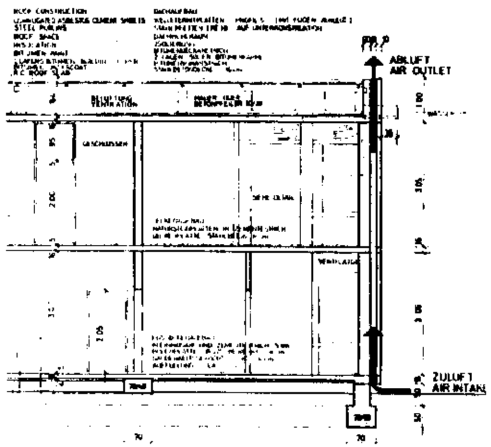


Fig. 16
National Printing Work in Monakchott, Mauritania by Arch. G. Lippsmeier - Parasol roof covering the Factory in hot-arid climate.

Failure was (and still is) partially due to the design and building paradigms of the International Style which usually was unable to consider existing urban and dwelling cultures as a resource to develop along with the other local resources (building materials, climate, etc.).
In fact, International Style diffused quickly in humid tropics because of the lack of the architectural local tradition, since adverse climate (high humidity and temperature) creates unhealthy environment which tends to handicap population and urban growth.
On the contrary International Style did not diffuse very much in hot arid climate regions, because of their very rich and precise architectural traditions which influenced modern western architecture.

The lesson of cultural continuity comes from the pioneers of the new Arab architecture: Hassan Fathy in Egypt, Mohamed Salah Makiya in Iraq and Saba George Shiber in Kuwait (21).

H. Fathy, the most famous in the world, also for his book "Architecture for the poor", combined the use of local available resources - mud and climate - with the traditional features of islamic architecture and opened a way to solve urgent housing problems in the underdeveloped countries without importing unnecessary, culturally and climatically inappropriate western technology.
H. Fathy's "natural cooled architecture" is essentially based on the deep, culturally rooted knowledge of the thermal behaviour of traditional architecture: urban courtyard pattern, covered streets, domes, vaults, cooling technologies (wind catchers, selective openings, etc.) (Fig.17
18) mean continuity with tradition which is the opposite of

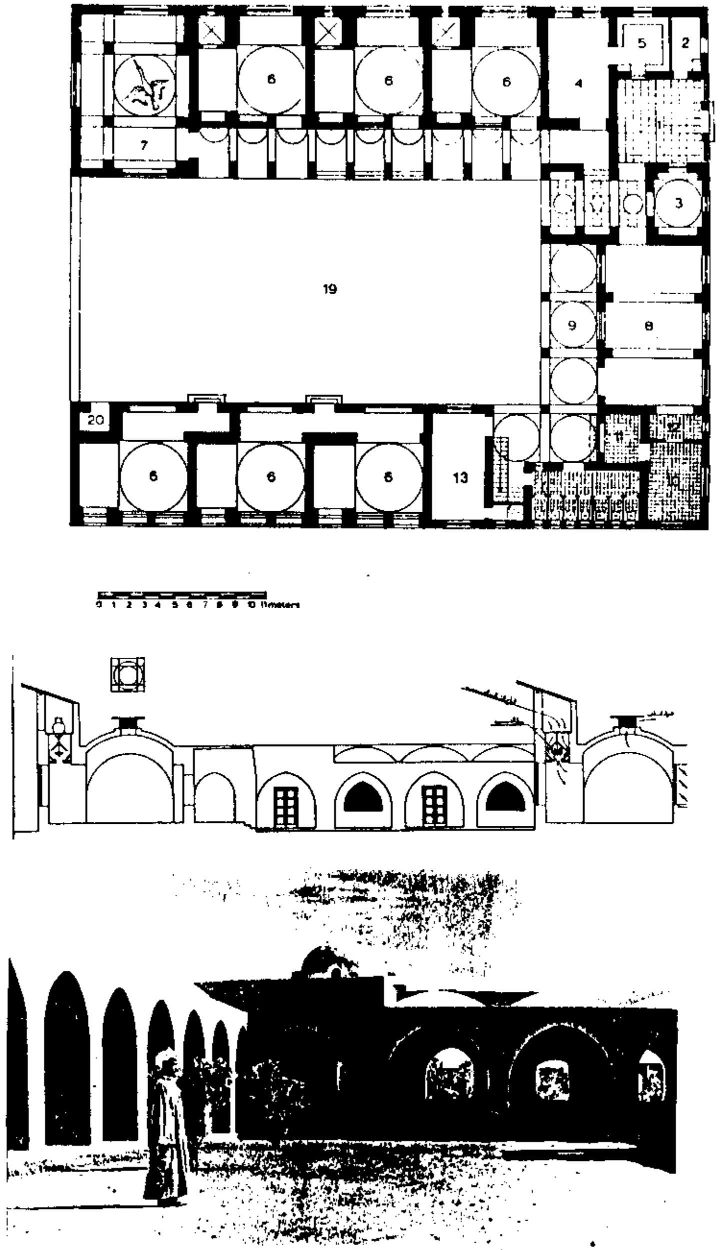
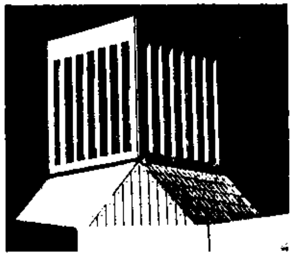
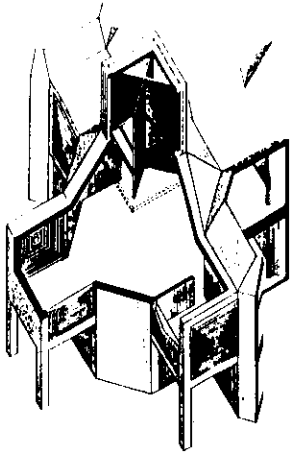
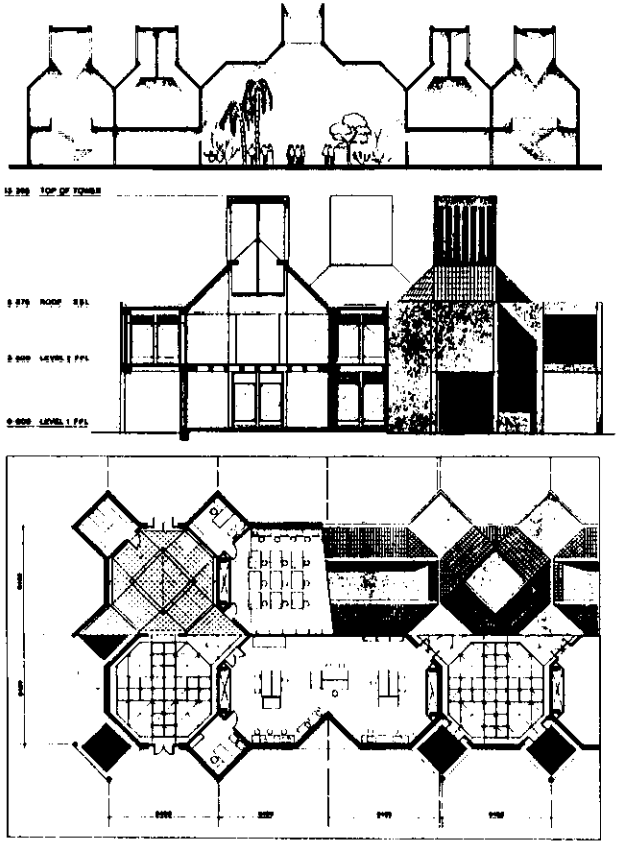


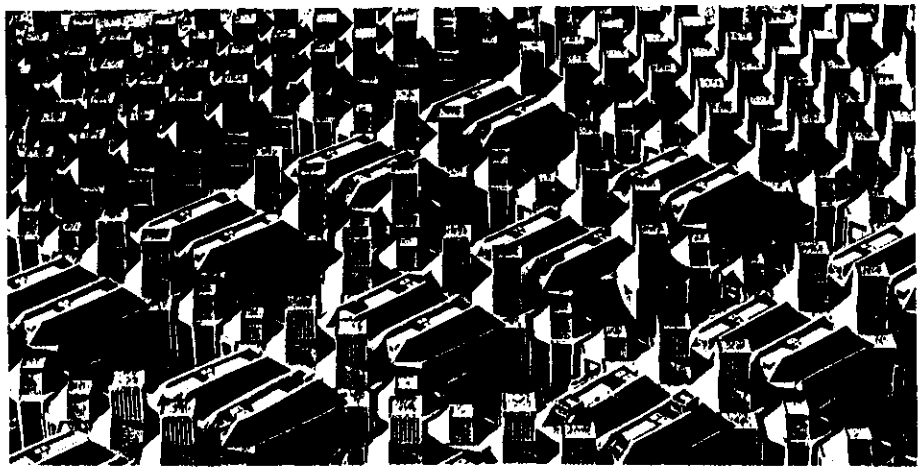
Fig. 17 Plan, ventilation system and view of the courtyard of the girl's primary school in New Gourna, Egypt, arch. Hassan Fathy







Top: The architect-designed square tower over a typical modular unit forming the basis of the University's plan.
Above: Axonometric drawing of the basic octogonal unit with its extensions, capped by a square cupola allowing light and, on occasion, air to penetrate below.

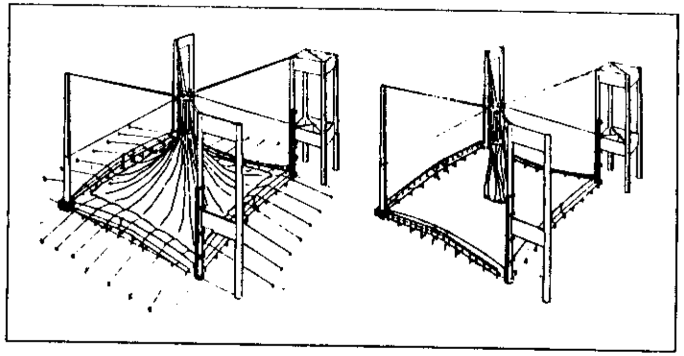


Ill. Fig. 18 - Basic units and view of the Qatar University, Arch. Kamal El Kafrawi -

the international style concept of design emancipated from precedents.

The architectural and theoretical work of the pioneers of the new arab architecture educated a new generation of Arab architects and recently influenced very much also the work of European architects (Mokkah University, near Mecca by Skidmore, Owings and Merrill, Brooklyn Museum in Karnak by Esherick and partners) and some large buildings (The Congress Centre in Mecca by F. Otto and R. Guthbrod, the Airport in Jeddah by Skitmore, Owings and Merrills), which mediated high-tech with a tradition of Arab architectural language (22). (19)

I spent some time in dealing with Arab Architecture to point out the general regionalisation of architecture, which is a continuous process to approach built environment design through local cultural values and resources (climate included).
In example we can speak of Australian regional architecture only in a very broad sense; if we analyze the work of a single Australian architect we have to better define the region in which he is working (Fig.20a,b).
And along with Australian architecture I can mention USA West Coast Architecture, hot arid areas Indian architecture, South East British Architecture, and .... a long list of environmental-conscious local architectures. It is my opinion that a contribution of "climatic design" to the diffusion of cooling strategies and technologies in built environment has to move from the knowledge and the physical performance analysis of such local architectures.



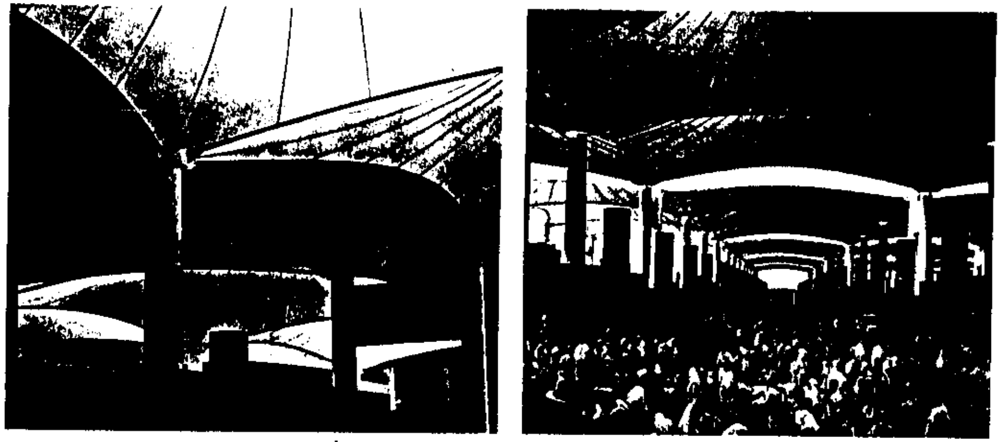


Fig. 19 · International Airport King Abdul Aziz, Jeddah, Saudi Arabia by F. Otto / Rolf R. Gutbrod.

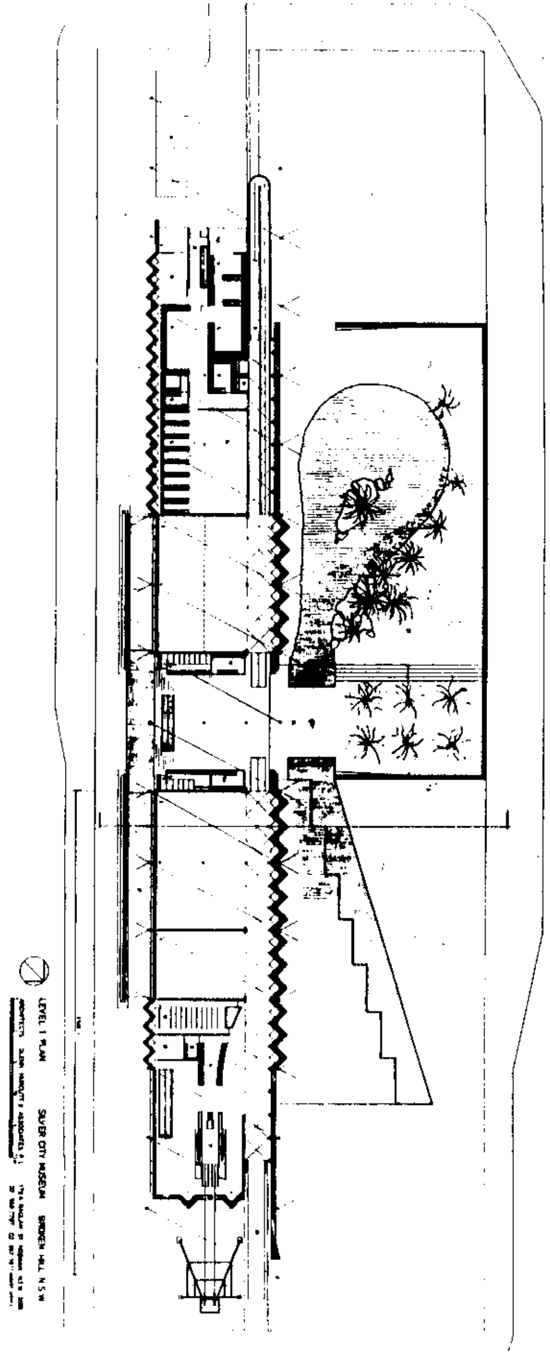
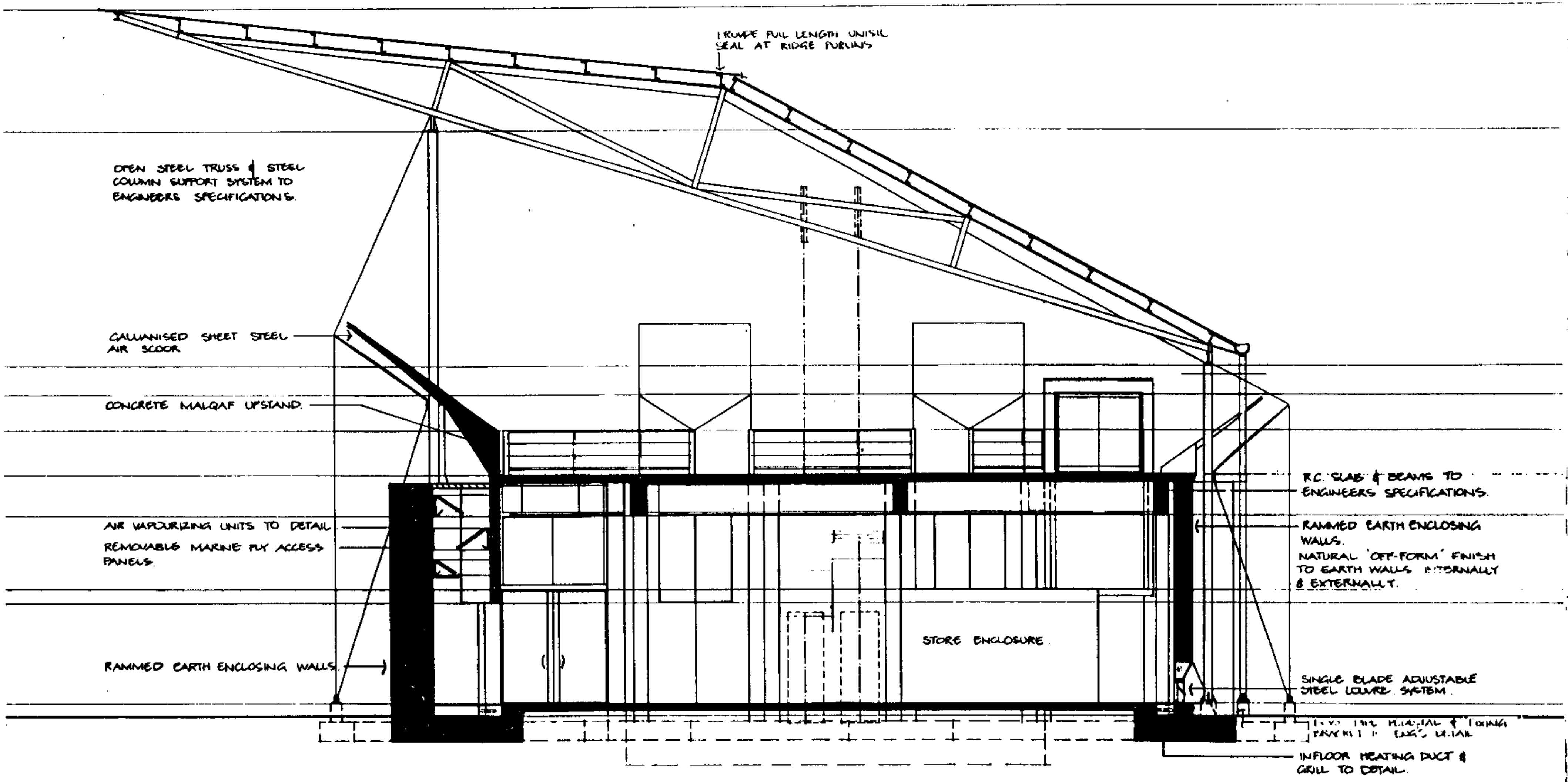
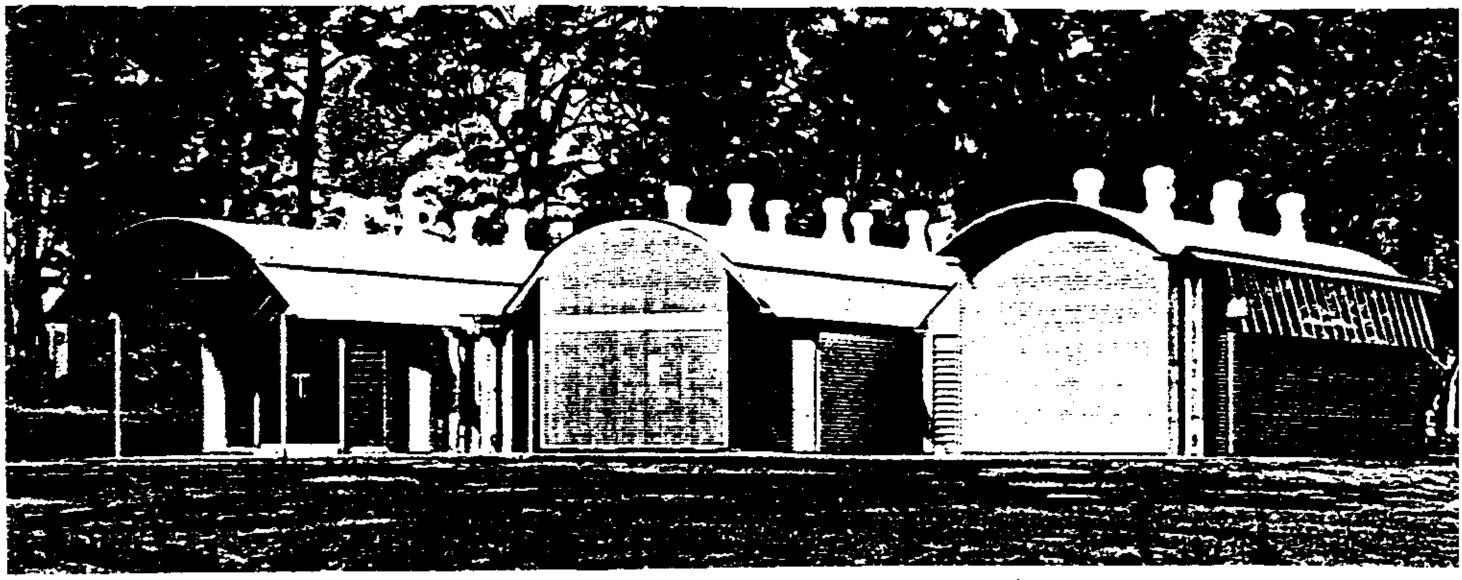


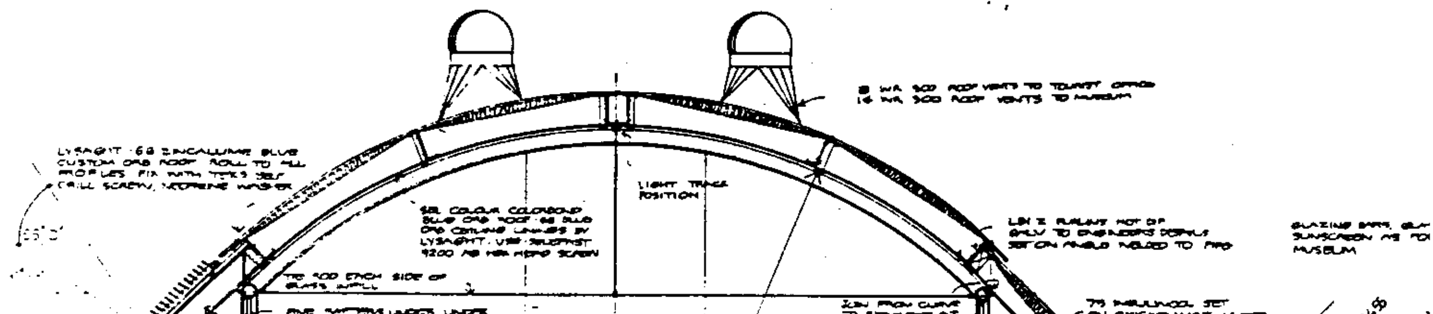
Fig. 20 b. Plan and Sections of the Museum of Mineral and Mining. Broken Hill, N.S.W, Australia, [illegible]



SECTION B B

1:100





"Murcutt added two lines of Western rotary ventilators on either side of the ridge which spring to life and whizz around in the lightest airs. The vents are simple and extremely effective, their purpose is to clear the air from below the arched ceiling and ventilate the museum hall. But they do something else that is equally important, they keep the building alive by their movement, and they tell us what kind of day it is, whether it is windy or still."

Fig. 20a The new Museum, Kempsey, NSW, Australia, by "Arch." Glen Murcutt.

" The roof of the typical Murcutt house has a similar rounded ridge which the architect has explained as responding to the wind in much the same manner as the aerofoil section of an aeroplane. The wind influenced the house in several ways: the long rectangular plan shape is well suited to take advantage of cooling breezes in the summer, and the walls are constructed as diaphragms so they can be opened up to allow the wind to percolate through the interior. The ridge profile is rounded like the roof of the Turkic trellis tent so it does not catch the wind, and a continuous gap is left on either side below the ridge running the entire length of the roof to draw air through the enclosed roof space and keep it cool in summer. This is rather like a "parasol" in its achievement of a cooling effect by moving air under shaded conditions, a principle which Maxwell Fry had noted in West Africa, and which Le Corbusier incorporated in the High Court at Chandigarh. "

NOTES AND REFERENCES

(1) Lisa Heschang, Thermal Delight in Architecture, MIT Press, Boston, 1979, p. 21.

(2) V. and A. Olyay, B. Givoni, G. Lippsmaier and others mentioned in par. 4.

(3) K. Labs, Direct Coupled Ground Cooling: issues and opportunities, Passive Cooling '81 AS/ISES, 1981.

D. Watson, K. Labs, Climatic Design, Mc Grow-Hill Book Co, N.Y., 1983

(4) D Bartoli, V. Silvestrini, Raffreddamento naturale per irraggiamento, Le Scienze, 139, marzo 1968.

J.I. Yellot, Solar Energy Utilization for Heating and Cooling, Chapter 58, Application Book, ASHRAE, 1978.

B. Givoni, Man, Climate and Architecture, Applied Science Publ., London, 1976.

D. Watson and K. Laps, op. cit.

(5) J.F. Von Straaten, Natural ventilation, Chapter 14, Thermal Performance of Building, American Elzevier Publ. Co., N.Y., 1967.

B. Givoni, op. cit.

D. Watson and K. Laps, op. cit.

(6) J. Peube, Evaporative Cooling, International Expert Group Meeting on Passive and Low Energy Cooling, Heating and Dehumidification, Miami, May 1980.

J.I. Yellot, op. cit.

D. Watson and K. Laps, op. cit.

(7) L. Heschong, op. cit., p. 43.

(8) Hassan Fathy, The Arab House in Urban Setting: past, present, future, Longman for the University of Essex, 1972, p. 8.

(9) Hassan Fathy, Architecture for the poor, The University of Chicago Press, Chicago and London, 1973.

Hassan Fathy, Natural Energy and Vernacular Architecture, Published for the United Nations University by The University of Chicago Press, Chicago and London, 1986.

(10) J. L. Izard, Archibio, Ed. Parenthèses, Roquevaix, 1979.

(11) M.N. Bahadori, Passive Cooling Systems in Iranian Architecture, Scientific American, vol. 238, n. 2, February 1978.

(12) R. Banham, The Architecture of the Well-Tempered Environment, The Architectural Press, second Edition, 1984, p. 160.

(13) R. Banham, op. cit., p. 157.

(14) R. Banham, op. cit., pp. 154, 156

(15) R. Banham, op. cit., p. 155.

(16) F. Atkinson, The Genesis of Modern Tropical Building, Royal Society of Arts Journal, July, 1969.

(17) B.S. Siani, Building in Hot Dry Climates, John Wiley & Sons Ltd., 1980.

(18) Indian classical Mogul Architecture developed interesting cooling strategies (evaporative cooling, shadings, etc.); see:

F. Atkinson, op. cit.

A. Petruccioli, La città del sole e delle acque, Fathpur Sikri, Carucci Ed., Roma, 1988.

(19) C.A. Rivera De Figuera, Architecture for the Tropics, a bibliographical Synthesis (from the beginnings to 1972), UPRED, Ed. Universitaria, Univ. de Puerto Rico, 1980.

(20) Techniques et Architecture, special issue on "Architecture intertropicale", N. 5-6, April 52.

(21) U. Kulterman, Verso una identità araba, l'architettura araba contemporanea; in: Architettura nei paesi islamici, 2.a Mostra Internazionale di Architettura, Ed. La Biennale di Venezia, Venezia, 1982.

(22) Architettura nei paesi islamici, op. cit.

(23) Ph. DREW, LEAVES OF IRON, GLENN MURCUTT: PIONEER OF AN AUSTRALIAN ARCHITECTURAL FORM, THE LAW BOOK CO. LIMITED, MELBOURNE, 1985, p. 68