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Passive solar systems for domestic architecture in Southern Africa

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Fig.6.

In their buildings men left special openings for the divine gift of sunlight to enter.

Thus the windows are the eyes of a house but they are also the openings through which the Gods may look in and allow some higher power to come in.

The opening in the dome of the Pantheon represents the eye of God. Fig.5.



Fig.7. Tut-ankh-Ammon and Queen Ankhenpaaten under the Sun's protection.

"The sun", in many representations,

figures in the lore of many nations. It is either itself a God, or a symbol of God. Fig.6.

In various ways it is linked with Kings and Rulers.

For pagan tribes the sun itself thus becomes a ruler, watching over the lives of men.

As a ruler, the sun has the great merit of making its existence vital for mankind, and for its vital influence and beauty the sun is held in great awe and esteem." Fig.7.[1]

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Vernacular

Architecture



The interest by architects and historians in the primitive and vernacular form is, according to Rykwert, a universal manifestation of search for roots.

It is a validation of what we do in terms both of what has gone before and of where we are going ... "Paradise is a promise as well as a memory".[1/9]

Most recently, a renewed appreciation of the indigenous tradition in architecture has resulted in a literature devoted quite expressly to its analysis, not only from an interest in cultural preservation, but for the lessons offered to modern designers working within similar climates and cultures.

Indigenous and vernacular building at its best is a direct expression of adaptation to climate and resource constraints.[1]

AMERICA

It is generally agreed that the American Indians stemmed from Asia and that the waves of their migration across the Bering Strait established their populations across both North and South America. As they spread throughout North America, the Indians entered into a broad variation of climatic environments, from the cold-cool northern territories to the

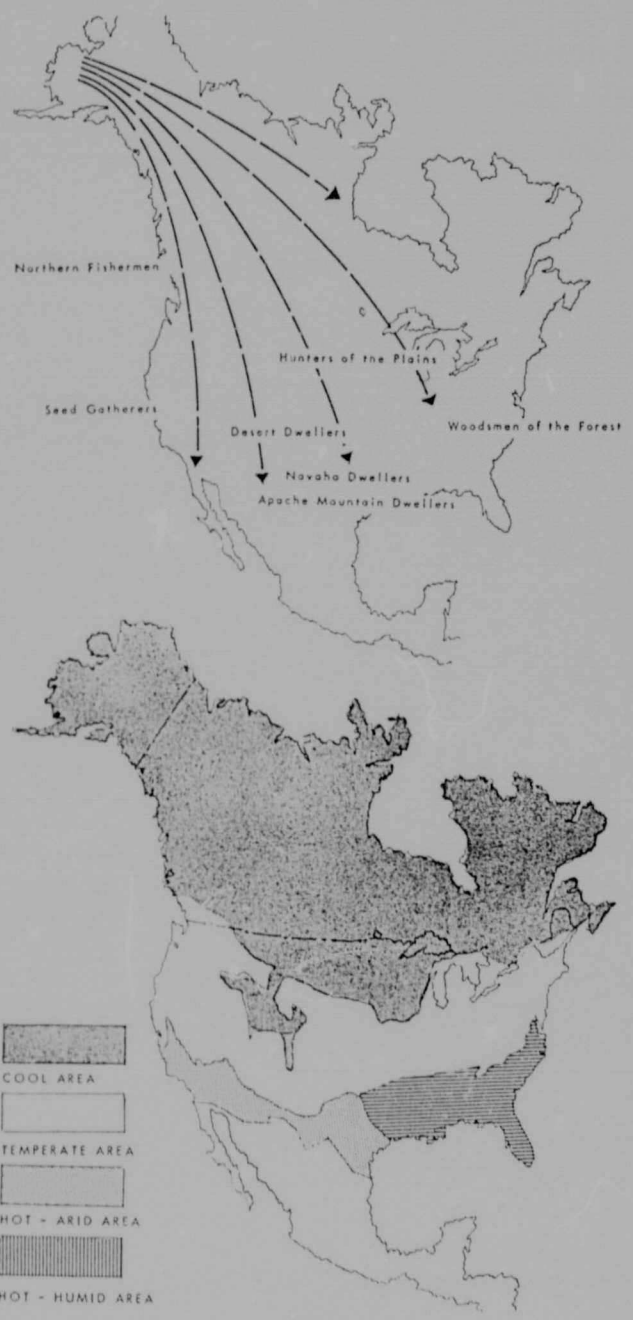


Fig.8.

warm-hot areas of the south, from the dry western areas to the humid parts of the southeast. Fig.8.

The tribes entering the cold zone of the North encountered extreme low temperatures and relatively scarce fuel. Under these circumstances, the conservation of heat became essential, so their shelters were compact with minimum of surface exposure.

The Eskimo igloo is a well-known solution to the problem of survival in extreme cold.

These low hemispherical shelters deflect the winds and take advantage of the insulating value of the snow that surrounds them.

The smooth ice lining which forms on their interior surface is an effective seal against infiltration and their tunnel exits are directed away from the prevailing winds to reduce drafts and prevent the escape of warmed air.

The heat retention of this type of structure makes it possible to maintain a temperature of 14°C inside when the exterior temperature is -50°C. Such structures may be heated by a small lamp supplemented by body heat. Fig.9.

The Pacific Coast tribes of British Columbia encountered a less extreme climate, although the need for heat conservation remained acute.

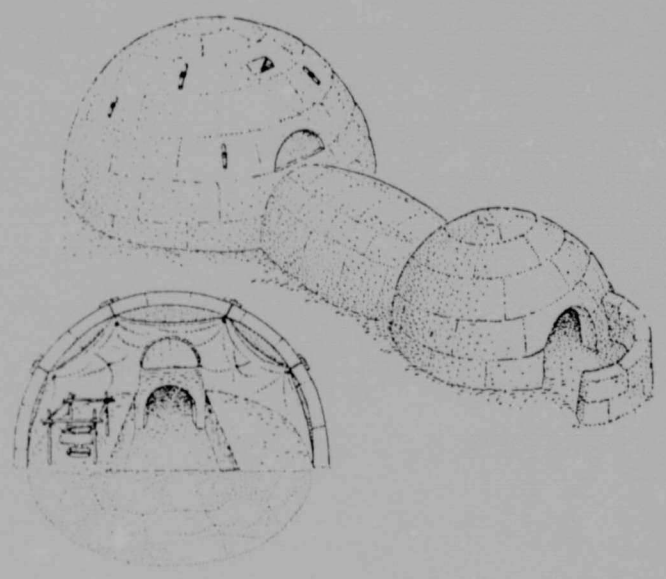


Fig.9.

To meet this demand these Indians adopted a form of communal living where the homes were joined together to reduce the exposed surfaces.

The large plank-and-timber shelters were built as double shells, an arrangement that produced an insulating air space and provided an enclosed ambulatory between family units for the snowy winter months.

In the summer, the outer shell could be removed for ventilation. Further mutual

benefit was achieved by the placing of fire pits within individual apartments along a centre aisle, thus creating a concentrated heat source.

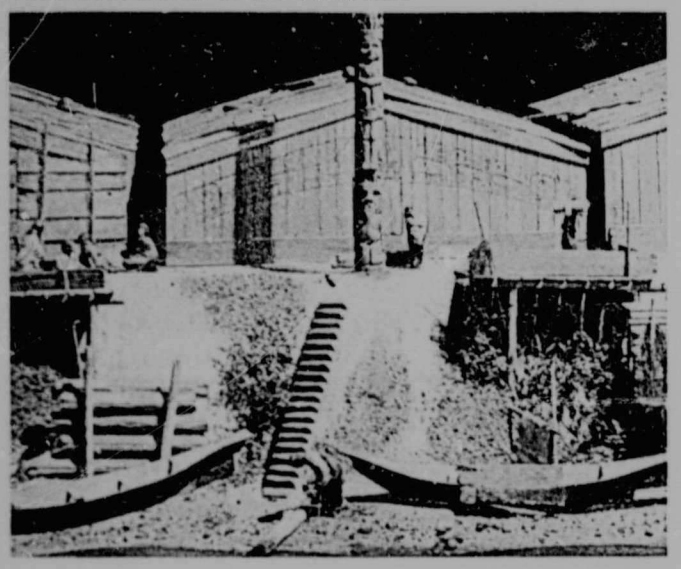


Fig.10

In the MacKenzie Basin, shelters were constructed of bark and timber covered by low pitched roofs with long poles anchored to the covering to retain the snow as an insulating blanket . Fig.10.

The temperate area, offering a naturally favourable climate, made fewer thermal demands on its inhabitants, and there is a corresponding diversity and freedom in the structures of these peoples.

Unlike the communal grouping of the Pacific Coast, the villages of the eastern woodsmen and plains dwellers were freely organized and spread out, with peripheral units merging into surrounding the landscape.

The typical dwelling unit of these tribes was the wigwam, a conical structure of poles covered by skin, which effectively shed wind and rain and was easily heated from a central source. It could be readily transported - an essential to migration. Fig.11.[2]

In contrast, the hot arid zone made extreme demands on the constructors of tribal dwellings.

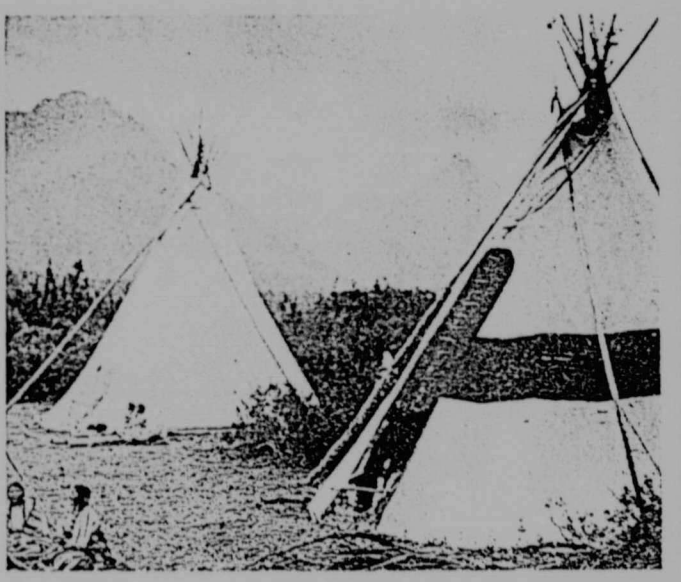


Fig.11

Characterized by excessive heat and glaring sun, this area requires that the

shelter be designed to reduce heat impact and provide shade.

The southwestern tribes like those far north of them, often built communal structures for mutual protection in this case, from the heat.



Fig.12

These structures were constructed of massive adobe roofs and walls, which have good insulative value and the capacity to delay heat impact for long hours, thus reducing the daily heat peaks.They also used very small windows.

By packing buildings together the amount of exposed surface was reduced. Pueblo structures of this type, usually extend on an east-west axis, thereby reducing morning and afternoon heat impacts on the two end walls in summer and receiving a maximum amount of south-sun (Nothern Hemisphere) in the Winter months when heat is welcome. Fig. 12.

Pueblo Bonito in Chaco Canyon, New Mexico, is one of several extraordinary examples of early Southwest Indian settlements.

Built from 919 to 1180 AD and now in ruins, the pueblo once housed 1200 inhabitants within its semicircular structure which measures about 160m in diameter and stood in tiers up to four storeys high.

The determining points of the plan's geometry were based on the position of the sun at the summer and winter solstice. [2]

Mathematical analyses by Professor Ralph Nowles and students at the University of Southern California have revealed that the Pueblo structures could not be improved upon for natural control of seasonal climate impacts, given the then available adobe construction technology,[3] Fig.13.

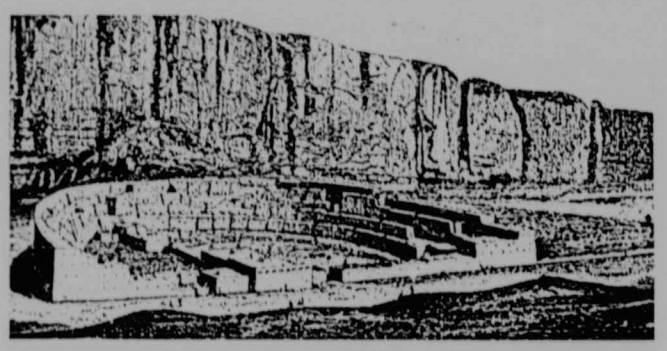


Fig.13

The hot-humid area on the other hand,

presented two major problems to its inhabitants: the avoidance of excessive solar radiation and the evaporation of moisture by breezes.



Fig.14.

To cope with these problems, the southern tribes built their villages to allow free air movement and the scattered individual units were built into the shade of surrounding flora.

The Seminoles raised large gable roofs covered with grass to insulate against the sun and throw large areas of shadow over the dwellings which had no walls.

The steep angle and extensive overhang of these roofs protected against rainfall, and the floors were elevated to keep them dry and to allow air circulation underneath, Fig.14.

As may be seen from these basic building forms used by the North American Indians in various regions, these people possessed a remarkable ability to adapt their dwellings to their particular environment difficulties.

An awareness of climate was integrated with innate craftsmanship to solve problems of comfort and protection.

The results were built expressions of true regional character.[2]

ASIA

One very exciting example of a climatically responsive house in a humid warm climate is the traditional Malay timber house.

MALAYSIA

The region where the Malay culture predominates has an equatorial monsoon climate.

A large percentage of the land area is covered by equatorial forest, so timber and other plant material is the natural choice for building materials, Fig.15.

The roof is thatched and the structure and walls are made of wood.

The basic floor plan is generally oblong with added variations or extensions according to the various local styles.

The most prominent feature characteristic

of all houses in South East Asia are stilts.



Fig.15.

Here, houses are built on tall wooden poles which range anywhere from 0,9 m to 2,10 m high. A few extreme cases have stilts that are even higher.[4]

The Roof

Thatching is one of the best methods of preventing excessive heat gain through the roof.

This type of roofing can be found in nearly all the equatorial regions of the world.
In the peninsula, this roofing is made from the linear shaped leaves of the "nipah" palm folded over a strip of bamboo and entwined with a type of vine.

A series of these leaves are then overlapped over the rafters to form the roof.

The nipah leaves have biological resistance against rotting and this type of roofing will last for a considerably long time.

These roofs are not highly reflective enough to prevent excessive absorbtion of solar radiation, but when the overall heat transfer is evaluated, thatch roofing excels as a heat barrier.

The leaves (which consist of cellulose) have low thermal conductance, and with the large amount of trapped air between the layers, the roof as a whole has a high insulation value drastically reducing the conduction heat transfer into the house.

Furthermore, thatch roofing has an extracrdinarily large surface area with an extremely uneven texture.

Therefore, it has a higher convection heat loss, reducing the outer surface temperature of the roof exposed to the sun.

Another unique heat transfer process that can occur in the thatch roof which is rarely found in any other building material is evaporation.

When the rain falls, the first few layers of leaves get soaked, even though water does not penetrate the roof.

Part of this moisture is trapped between the leaves and when the sun shines, the water in the roof heats up, evaporates and the temperature drops.[4]

The Walls

An example of a minor detail which is imbedded in a building tradition can be seen in the construction of the wall.

Most of the classical houses in the peninsula and Indonesian islands have wooden walls.

The "builder" always makes sure that the wood is placed with its grain on the vertical direction.

This will line the tiny channels in the grain in the direction of the natural convection flow, and will theoretically increase the laminar velocity of the rising warm air.

Orientation and Sun Control

In building a house according to old Malay customs, the planning and "procuring" is an elaborate affair.[4]

The location is first very carefully chosen according to some mystical rules and omens.

After a suitable site is located the area is then cleared and certain rituals follow.

The orientation of the house is most important. It has been observed that in remote areas the house tends to be positioned according to the direction of prevailing breeze and path of the sun.

Raising the whole house on stilts is the most common method to expose the house to higher velocity winds.

Windows

The Malay house has numerous windows because good ventilation and proper air-flow is extremely im ortant.

Each window, about 0,9m wide, has two wooden shutters pivoted on the sides and is made to swing open outwards.

These multi-purpose shutters may be

utilized as vertical shades to block some of the beam radiation from the sun or they may function as baffles to redirect the breeze into the house, Fig.16.

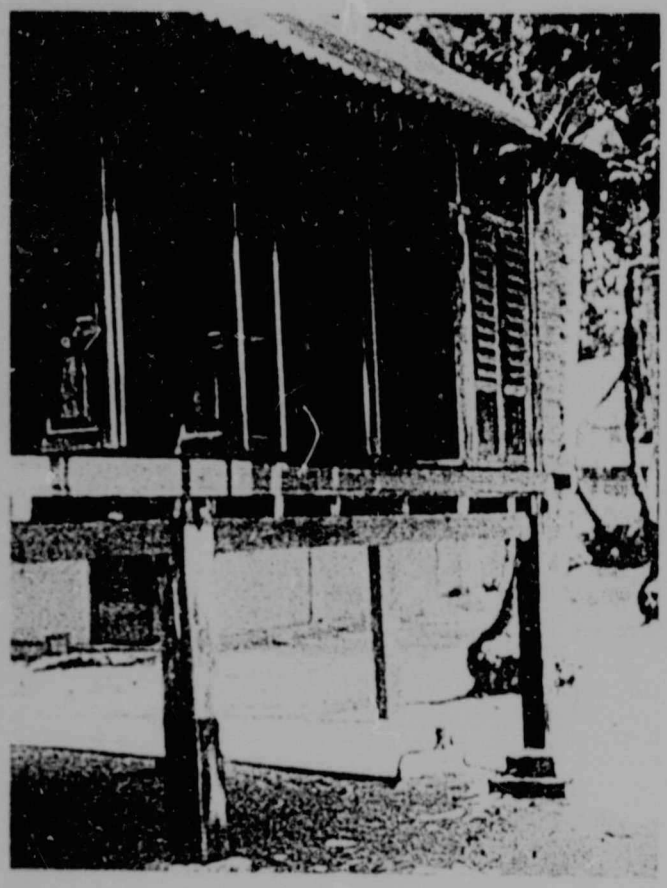


Fig.16.

Cross ventilation is further simplified by the long elongated floor-plan of a relatively small cross-section area of the house.

The early Malay house is not even partitioned into rooms, so there will be no obstructions to the air flow.

Later, outside influences caused some partitioning into bedrooms but they are basically thin and do not extend all the way up to the roof.

Owing to its importance for comfort, the construction of air-vents has been made into an elaborate art. Some houses of the well-to-do, have air vents which are made of beautiful carvings and fretwork.[4]

JAPAN

The peoples of the Far East especially of China and Japan also have many lessons to teach us.

In Japan nature comes first; the architect does not try to subordinate the natural surroundings to the house, rather he tries to render homage to the surroundings.

There are some instances of this mode of thinking in Japan as reported by Harada: "Projecting eaves are another feature of Japanese houses ... Such eaves were necessary to protect a house against heat and rain and to allow it to be kept open on rainy days.

Furthermore, these eaves do not prevent the sun from st ng into the house in the winter ... n the Far East, where the family is the unit of society, the home assumes a position of prime importance in the life of people ...

The health and prosperity of a person were considered to depend on the location and planning of the dwelling house, chiefly in reference to direction" ...

"An ancient book has it that it is lucky for a man to live in a house on ground which rises at the back and slopes down in front; woe unto the person who dwells in a house standing on ground with a rise in the front and a downward slope at the back.

In these statements, it presumed that the house faces the south (Northern Hemisphere) whence comes sunshine and good cheer.

On ground which is low and open both to the east and to the south, and high on the west and north, the house may face east, south-east, or south and still have rising ground at the back and is hence desirable.

However, should a building be facing west or north and have hills at the back, then the sunshine and warmth from the east or south would be shut off, and the location be undesirable ...[5]

The plan of the house, of course, depends on the location but it should have due regard to direction determined by imaginary lines drawn from the north-east to the south-west, and from the north-west to the south-east, intercepting each other at right angles at the heart of the house.

The north-east is called "Ki-non" (devil's gate) and care should be taken not to build anything unclean in that direction.

Undesirable things are said to come from that direction and the house should be so planned as to be protected by a wall or a closet in that direction and not to be left open.

The southeast is designated as the "Chi-mon" (earth's gate) or "Fu-mon" (wind's gate), the north-west as the "Ten-mon" (heaven's gate) where the well and store-house should be located, and the south-west between the heaven and earth gates as the "Fin-mon" (man's gate). ...

Speaking of the comfort of the Japanese houses, Harada says that "houses are usually built to face the south,

(Northern Hemisphere) that is, they are open to the south.

There should be enough opening on the northern side also to permit a current of air to pass through from north to south and vice versa; this gives warmth in winter and coolness in summer."[5]

The climate being very damp, especially during summer, a closed house (that is of small windows and openings) would be oppressive.

AFRICA

TUNISIA

Over the last four centuries, Berbers of southern Tunisia have lived in underground villages as an appropriate response to the bioclimatic region.

In the mountains of southern Tunisia a traditional form of shelter has been underground housing.[6]

There are basically two types: the cliffside dwellings where one digs horizontally back into the hillside (usually directly beneath a horizontal layer of hard sedimentary rock) and pit dwellings on more level ground where a central pit atrium with rooms off it is excavated.



Fig.17.

A typical pit dwelling as the ones found in and around the village of Matmata consists of a central pit atrium seven to twelve metres deep, and ranging up to fifteen metres across off of which are the rooms.

The pits are usually excavated in rectangular shape, but weathering and

erosion of the soft clay soil reshapes the pit to a rounder form as the years go by. Fig.17.

After completing the digging of the central pit, an entry tunnel from the side is dug, and finally the rooms themselves are excavated.

Generally the rooms are three to four metres wide and six to eight metres deep.

The ceilings are vaulted and generally the walls diverge outward for increased structural stability Fig.18.

No attempts were made to orient the pits to the sun's motion or to place certain rooms (e.g. kitchen) in any particular location.[6]

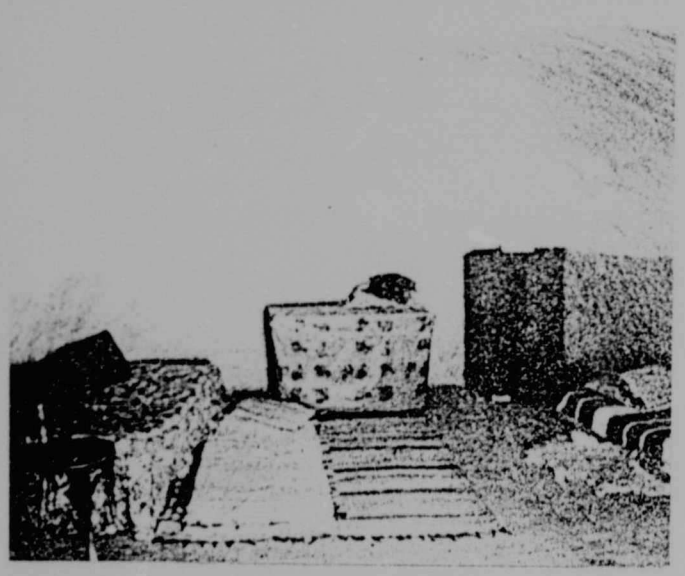


Fig.18.

The only acknowledgement of orientation to microclimate was that the rooms on the side of the pit that received the brunt of the rainfall (less than 20 cm/year) had their doors recessed deeper and a 15 to 20 cm lip carved around the door opening to deflect dripping water.

The climate of this region is hot and arid being on the northern edge of the Sahara desert.

Summer temperatures frequently reach 50°C.

The earth cooling is significant, however, because of the depth of the rooms.

The ceilings are four to ten metres below ground level and the temperature remains remarkably constant.

When the outside temperature reaches 49°C the wall temperature is as comfortable as 27°C, and remains constant within 2°C for a period of several days.

On very still nights cool air sinks into the central pit causing it to be slightly cooler than the surrounding surface temperatures.[6]

SOUTH AFRICA

In traditional South African black rural architecture, we can point out two basic different types of construction: the mud hut and the grass beehive.[7]



Fig.19.

In the Highveld for instance, we have the cylinder house with walls, made out of mud reinforced with timber poles, small windows and thatched conical roof, Fig.19.



Fig.20.

The wall's time lag works well for the highveld climate which is characterized by considerable day/night temperature variation.

The thatch is a good insulater, allowing at the same time enough ventilation

A very interesting variation of these houses is the verandahouse, where the roof eaves are extended beyond the walls and supported by a series of posts set at the house perimeter.



Fig.21 a)

The roof extension creates an overhang which protects the walls from the high Summer sun. Fig.20.

In the land of Zulus and Basutos we find the entire hut made out of thick woven grass which provides good thermal resistance to Winter heat loss and insulation and shade in Summer. Fig.21 a), b).

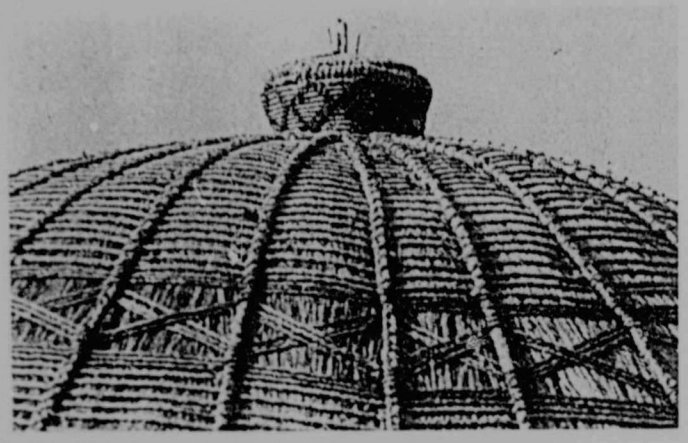


Fig.21 b)

Because of its topography mountains in the north and flatlands in the south and external climate influences: the warm current of the Gulf; the winds from Spain and from the Sahara desert, many different micro climates exist.

To summarise we can consider two basic types of construction.

EUROPE

PORTUGAL

Portugal is a small country about 200 km wide and lying only along 5° of latitude.



Fig.22 a)



Fig.22 b)

In the north east parts of the country which has a continental type of climate, they say:" six months of cold winter and three of hell".

The houses are made out of granite, with small windows protected with timber

shutters; the roof is made of thatch, slate or tiles on a timber structure, Fig.22 a)[8]

There is no kitchen, but an open fire in the middle of the house is used for cooking in winter, 22 b)

In summer the cooking is done outside.

Going south, approaching the flatlands of the Alentejo and Algarve, we encounter a Mediterranean type of climate.

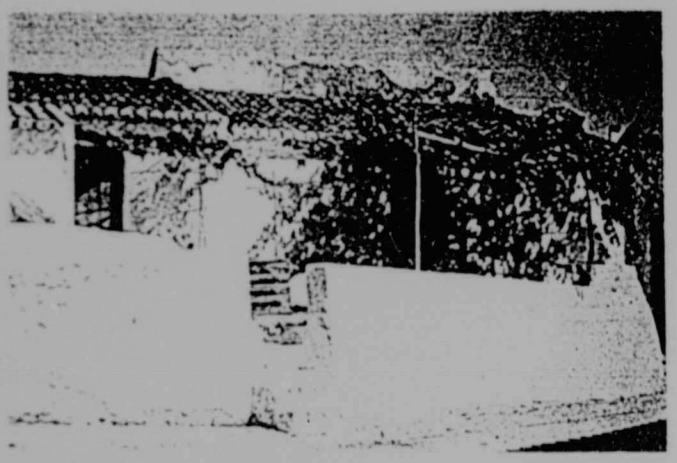


Fig.23 a)

Here the houses are made out of adobe whitewashed inside and outside, Fig.23 a) ; the floor finish is often clay tiles ; the windows are protected with lattices from the bright sun but allowing good ventilation, Fig.23 b) ;the roof is either a brick barrelvault with a terrace on top or otherwise a tiled roof above a suspended ceiling made out of cane.

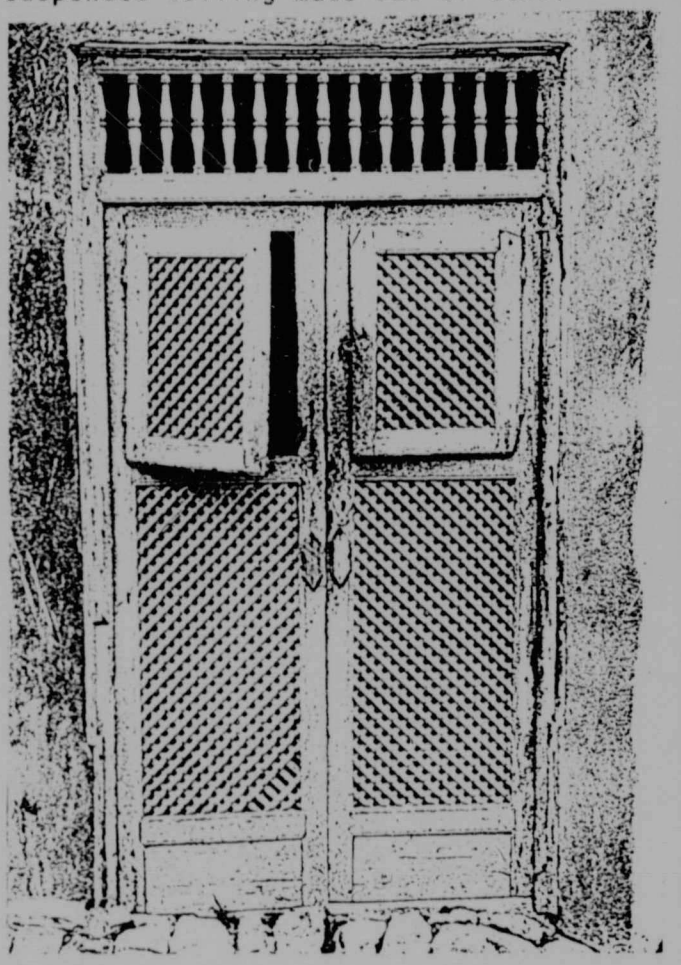


Fig.23 b)

The kitchen appears completely isolated from the rest of the house.[8]

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