PASSIVE METHODS
FOR
COOLING INDOOR ENVIRONMENT

(with Special reference to Khammam Residential Buildings)

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of

MASTER OF ARCHITECTURE

By

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February, 1985

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for [illegible] this dissertation at [illegible]

Dated [illegible] 2.85

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I am oblised to Dr. N.K. Bansal, I.I.T., Delhi and Dr. N.K. Garg, Scientist, CBRI, Roorkee, for their moral support rendered through their discussions, held with me, in the initial stages of this assignment.

I will fail in my duties, if I won't acknowledge the pains taken by my father, Sri. V. Raghuram, in procuring the much needed information regarding the case study of my problem, even out of his busy schedule.

Last but not least, I would like to quote with thanks the affability and help extended by my friends, Varadaraj, Ramkumar and Krishna Mohan, in many a way.

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C O N T E N T S

PASSIVE METHODS FOR COOLING INDOOR ENVIRONMENT

1.0 INTRODUCTION :

In 1973, the oil prices were increased by 'OPEC' countries, which created a great impact on economic condition of developed countries like U.S.A., Japan, etc. Then they started thinking of alternative to substitute for the costly oil. While searching this, they realized the importance of energy conservation, in all spheres including Building activity. The present topic passive cooling methods' is a part of energy conservation techniques.

The main difference between active and passive cooling (or heating) is, in active method - heat transfer takes place with the help of some auxillary forces but whereas in passive methods - heat transfer takes place by itself. Some scientists argue that there is no harm in using a small amount of mechanical energy, for example fans, etc. (2 to 5 % of the total energy required by an active method), which can still be called as passive method. So the line of separation between active and passive methods is still not clear.

In traditional buildings, our ancients took so much interest and gave considerable importance to climatic conditions while constructing their houses. Now people are either aware of the importance of traditional way of construction nor they are in a position to instal coolers, to achieve comfort conditions inside a building.

The rapid advancement in industrialization and introduction of motor vehicles have made considerable impact on life style of human habitat as in terms of width of the roads and open spaces. Very few buildings which are constructed aware of the climatic conditions, while selecting materials and in town planning systems.

It is economical to design a building with climate rather than against. So I fell that it is the duty of an architect to convince people about the existing comfort condition and suggest them the different methods in making their house confortable by the use of simple techniques.

Some scientists in International Workshop on energy conservation held in CBRI expressed opinion that architects have an important role to play in energy conservation in buildings by applying different techniques according to the climatic conditions.

This study is limited to Khammam which falls under hot-dry climate. The study will be based on existing construction methods and on local material. The building types which are under study are of single storey type and double storey type. The selection of passive cooling techniques will be dependent on economic condition of the in habitants, and available resources around.

In very few houses, the passive cooling techniques are used, like shading and evaporative, but they are not effective, because they do not know the way in which it can be used effectively. People are suffering from excessive ventilation and light, as they are fascinated by western type of construction, which is absolutely not feasible in this type of climates.

In the second chapter the climatic condition of Khammam is discussed along with some case studies of buildings of different nature ie traditional, contemporary and rural. The study of the traditional building is done on about 12 buildings in the Khammam old town. As the contemporary building constructed of cement are about 70% of the total housing, a typical house is taken for casestudy. Similarly rural house is done on different places of the town and its surrounding villages also.

By comparing the existing Khammam residential building's characteristic to that specificalions given Olgyay and others, it gives clear picture of the entire housing conditions and how far it is from comfort conditions inside a building.

In the same chapter general information of Khammam is given to show the back ground of people and their resources. How heat transfer takes place in a typical existing contempory building is discussed in the 3rd chapter.

In the fourth chapter the factors affecting indoor environment, other than solar radiation is discussed. General discription of each passive cooling techniques are given, except those which were selected for specific study. The three techniques selected were (i) gain prevention techniques (ii) evaporative cooling (iii) ground cooling. The first two cooling techniques can be used for both existing and proposed building. But the last techniques is for proposed buildings only, because there are no earth-shelter structures existing in Khammam along with the possibility of implimenting each techniques.

In the last chapter recommendation are given to suite the case study requirement.

After seeing the condition of houses in Khammam this topic 'passive methods for cooling indoor environment' is taken so as to give some solution to the people living in houses in Khammam and should feel comfortable within their financial capacities. It will simultaneously increase their efficiency of work.

The main objective is to arrive at a comfortable temperatures inside the residential buildings in Khammam by applying passive colling techniques.


ANDHRA PRADESH
HYDERABAD
SECUNDERABAD Jn.
VIJAYAWADA Jn.
GUNTAKAL Jn.
BIBINAGAR Jn.
TELAPUR
PATANCHERU
MANUGURU
WALTAIR Jn.
DRONACHELLAM Jn.
DHARMAVARAM Jn.
KRISHNA CANAL
Anantpur
Nalgonda
RENIGUNTA

location	KHAMMAM
latitude	17°15' N
longitude	80°09 E
altitude	112 M

dry bulb temperature °C

	J	F	M	A	M	J	J	A	S	O	N	D	
extreme maximum	35	38.9	43.5	45	47.2	46.7	39.4	37.8	37.2	37.4	33.9	33.4	
mean monthly maximum	33.1	36.8	39.6	42.5	44.8	43	36.3	35.2	35.2	35.4	33.9	32.0	
mean daily maximum	31	33.6	36.8	39	41.3	37.6	32.6	32.2	32.6	32.5	30.6	30.1	
mean	24.3	26.8	29.4	32.4	34.9	32.8	28.7	28.4	28.5	27.7	24.8	23.4	
mean daily minimum	17.6	20	23.1	25.9	28.1	27.2	24.8	24.7	24.4	22.9	19.1	16.7	
mean monthly minimum	13.5	15.9	19.6	22.2	23.8	22.9	22.4	22.7	22.3	18.9	14.6	13	
extreme minimum	9.4	11.7	16.1	18.9	21.1	21.7	20.5	21.1	20.6	16.7	11.7	10	
mean diurnal range	19.6	20.9	20	20.3	21	20.1	23.9	22.5	23.1	16.3	18.3	19	

relative humidity

mean daily maximum	80	73	75	73	67	69	81	80	81	81	77	78	
mean daily minimum	40	33	32	31	33	49	67	70	69	66	50	44	
mean humidity	60	53	53.5	52	50	59	74	75	75	73	63	66	
mean vapour pressure	18.2	18.7	22.1	24.2	26.3	27.8	28.7	29.1	29.1	27.3	20.7	18.1	
no. of days of fog	0.1	0.8	0	0	0	0	0	0	0	0	0	·2	

precipitation

mean monthly (mm)	1.6	7.3	10.5	25	27.1	126	260	185	164	107	39	3.9	
maximum in 24 hours	11.4	39.6	47	63	46.7	92.7	299	107	152	130	86	23	
days with 0.25mm/more	0.2	2.5	0.8	1.6	2.2	7.2	13.7	11.2	8.8	6.6	1.9	0.4	

sky

hours of sunshine	11.15	11.42	12.06	12.32	12.56	13.1	12.56	12.3	12.06	11.42	11.25	11.06	
cloud cover, oktas · %	2.0	2.5	3.1	3.5	3.5	5.5	6.5	6.2	5.6	4.2	3.3	2.1	

wind

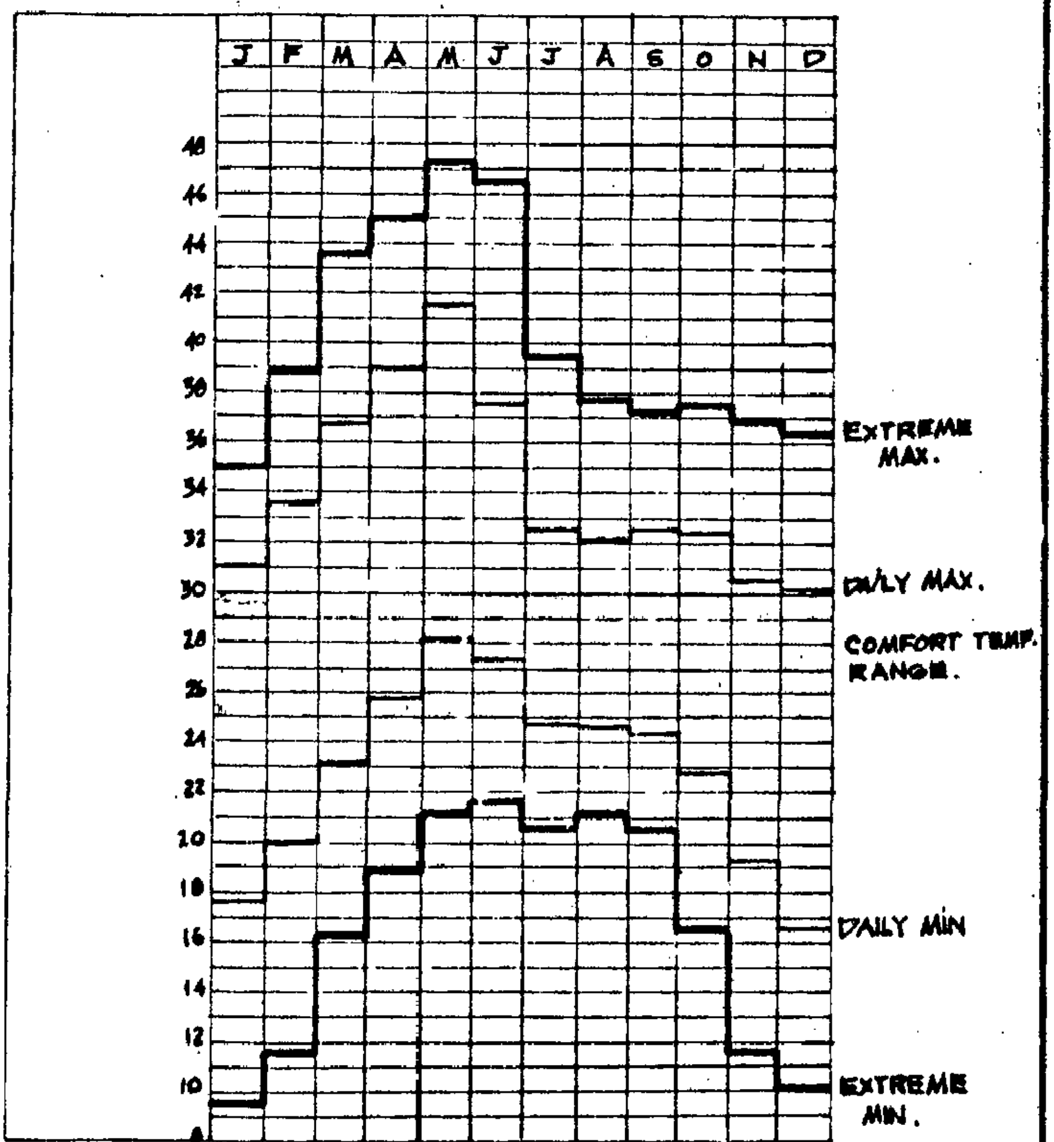
maximum velocity	32	36	35	37	37	64	55	58	32	40	30	37	
mean velocity	5.6	7.2	8.8	8.7	9.7	10.9	9.7	8.1	5.7	4.4	4.0	4.0	
prevailing direction	E	SE	SE	SE	SE	W	W	W	W	N	N	N	
secondary direction	N/SE	E	E	S	S	NW	SW	SW	N	E	E	E	

notes

duration of records 1941-1960

time of day when humidity was measured.
8.30 hrs & 17.30 hrs.

location KHAMMAM
latitude 17°15'N
longitude 80°09'E
altitude 112M



2.0 CASE STUDY OF KHAMMAM :

Location :

Khammam is one of the hottest places of Andhra Pradesh. It is situated on latitude 17°15' N, longitude is 80°09' E and its height from M.S.L. is 112 m.

2.1 Climate :

As the climate of Khammam is hot dry, the daytime air temperature in most of the days, especially in summer months (i.e. from March to July, nearly 5 months in average) varies from 35 to 45°C with low humidity varying from 30 to 50%. In peak of the summer i.e. May-June one would feel hot winds even at the nights. The minimum temperature in summer months lies nearer to comfort temperature range, i.e. from 25° to 30°C.

The prevailing wind directions in most of the summer months are West and Southeast direction with almost equal velocities,

The average rain fall is very less (950 mm), occasionally it exceeds, otherwise in most of the years it faces deficit.

The average direct solar radiation in summer months are as follows, in deçending order.

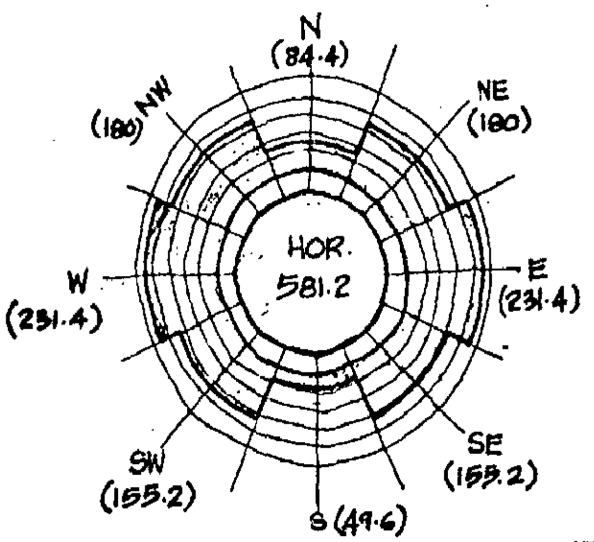
(i) Horizontal surface - 581.2 M.Cal/cm^2/bay

(ii) East/West - 231.4

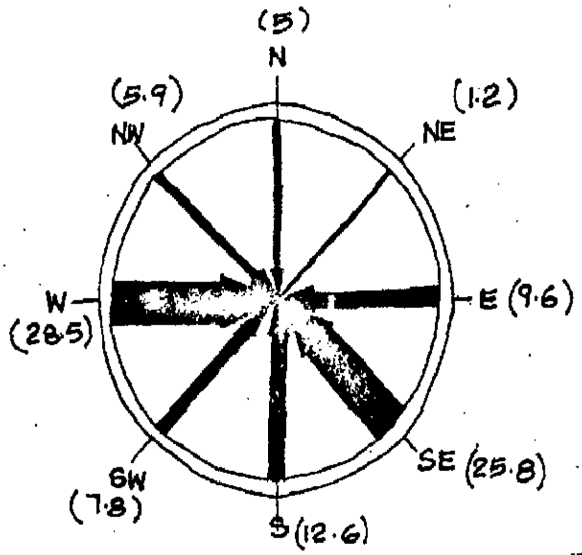
(iii) NW/NE - 180.0

SUMMER MONTHS		N	S	E	W	NE	SW	NW	SE	HOR.	
MARCH		-	12.06	6-03	6-03	7-08	7-08	4-58	4-58	12-06	hrs
		-	188	216	216	99	231	99	231	524	RADIA-TION•
APRIL		5-18	7-14	6-16	6-16	6-44	6-44	5-48	5-48	12-32	hrs
		19	59	232	232	155	183	155	183	575	RADI-ATION•
MAY		12.56	-	6-28	6-28	6-19	6-19	6-37	6-37	12-56	hrs
		99	1	237	237	202	134	202	134	599	RADIA-TION•
JUNE		13-10	-	6-35	6-35	6-06	6-06	7-04	7-04	13-10	hrs
		163	-	236	236	226	110	226	110	605	RADI-ATION•
JULY		12.56	-	6-28	6-28	6-19	6-19	6-37	6-37	12-56	hrs
		141	-	236	236	218	118	218	118	603	RADIA-TION•

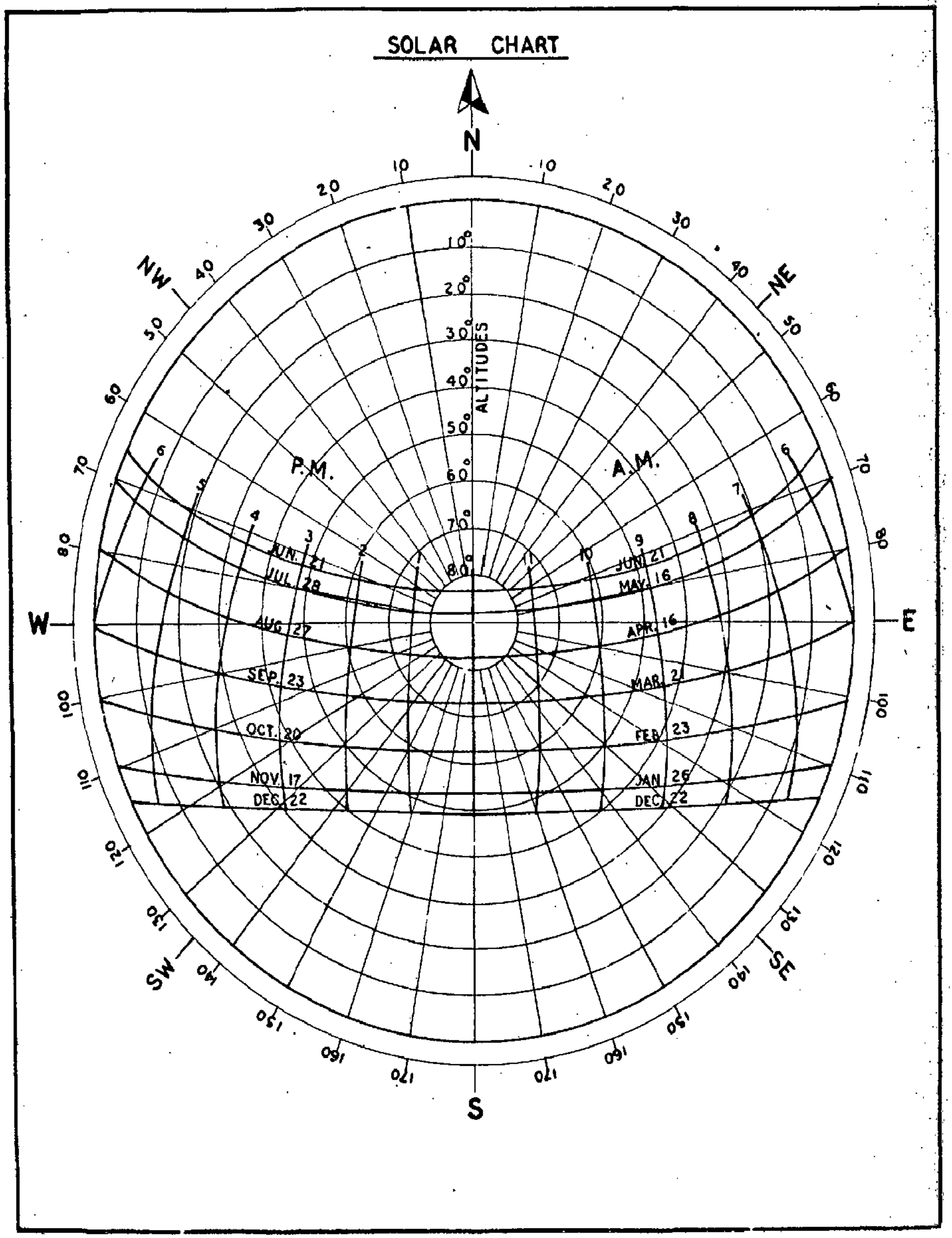
INCIDENT DIRECT SOLAR RADIATION ON HORIZONTAL ROOF AND DIFFERENTLY ORIENTED WALLS INCLUDING DURATION OF SUNSHINE

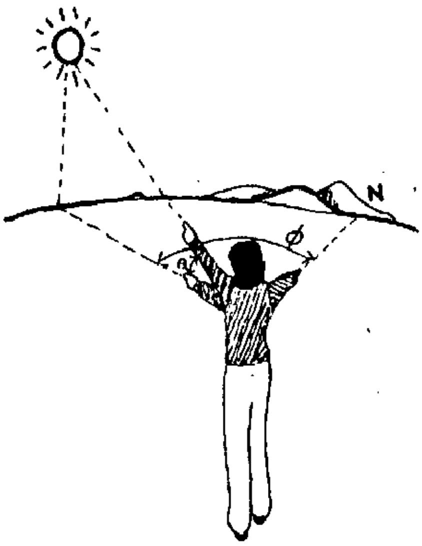


AVERAGE DIRECT SOLAR RADIATION• IN SUMMER MONTHS.
•(GM.CAL/CM²/DAY)

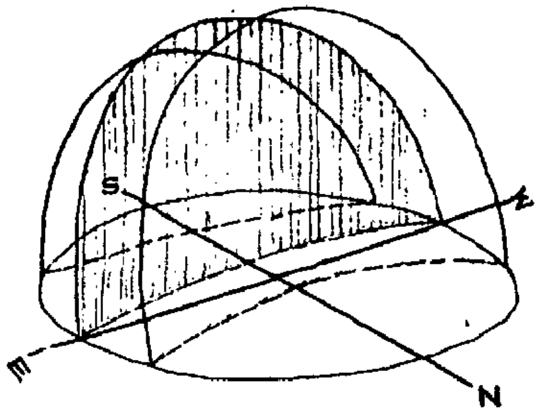


AVERAGE WIND DIRECTION. (SUMMER) WITH SPEED (Km/hr).


SOLAR CHART
N
S
W
E
NW
NE
SW
SE
ALTITUDES
P.M.
A.M.
JUN. 21
JUL. 28
AUG. 27
SEP. 23
OCT. 20
NOV. 17
DEC. 22
JUN. 21
MAY. 16
APR. 16
MAR. 21
FEB. 23
JAN. 26
DEC. 22

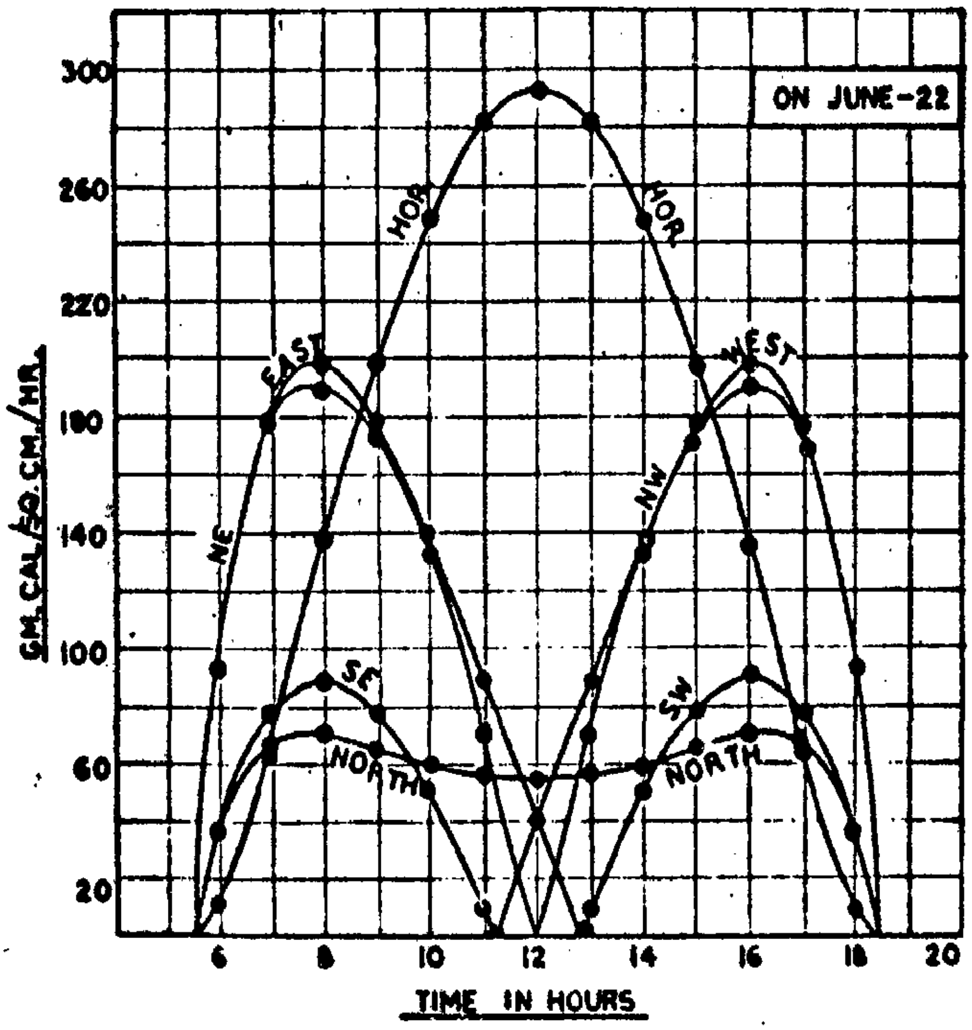


MEASURING THE SUN'S POSITION
(θ - SOLAR ALTITUDE
ø - THE AZIMUTH IS MEASURED FROM TRUE NORTH.)



IMAGINARY SKY-VAULT WITH THE SUN-PATHS.

RADIATION ON DIFFERENT ORIENTATIONS :



(iv)	SW/SE	-	155.2
(v)	North	-	84.4
(vi)	South	-	49.6

It is obsered from graphs ( ) that in the month of March, the solar radiation (direct) received by East/West and SE/SW walls are more that, in the month of June, similarly the radiation received by NE/NW wall in month of June is more than that of March.

Sun Movement at latitude 17°15' N :

The sun's movement in Summer creates shadow on both north and south sides of the building. The rise takes in between East and northeast (22.1/2° N of East). Similarly in the evening it sets between West and Northwest (22.1/2° N of West). Sunshines on the northside of the building in the months of May, June and July i.e. peak summer months and the rest of the months sun shows inclination towards south, as indicated in the chart.

At noon, in the summer months, the sun angles 1° i.e. altitude, varies from 73°C to 90 + 6° (84° from North). It clearly indicates that the roof receives most of the solar radiation and radiation receive by north and south walls is very less because the angle of incidence on these walls is low, and it is to cover the walls by roof projection.

The average of hours of sunshine on each surface of the building walls and roof in Khammam during the day is : north is 8.86 hours, south is 3.84 hours, East/West is 6.36 hrs, NE/NW is 6.56 hrs., SE/SW is 6.54 and horizontal surfaces (roof) is 12.66 hrs. (Table No.).

From the above reading it is evident that the walls oriented towards East, West, Northeast, southwest, southeast, Northwest is receiving almost equal number of sunshining hours. The maximum duration of sunshine is on roof then comes north. Even though north wall receives maximum number of sunshine hours, the radiation received by that wall is less because, its angle of incidence is low.

2.2 Case Study of Buildings

2.2.1 Traditional Buildings:

Thirty per cent of the residential buildings in Khammam are of traditional nature, constructed of mud or lime as chief binding material. It is interesting to observe, the traditional houses are still serving one of the main purposes, i.e. comfort when compared to present contemporary buildings which are no where near to comfort conditions inside the building.

In connection the case study, a dozen traditional houses were studied. It was observed that even in these traditional buildings, a few techniques are followed which will suite the climatic requirement. In most of the traditional houses, the common things we can find are : roof and walls are massive, shutters of the openings are thick, every door opening has carpet strip, with high ceiling (more than 11'-0"), roofs are of two types, flat and inclined. The houses are both independent and row houses. All buildings have verandah infront and in most of the houses has rear verandah also. The plinth height is higher in case of traditional buildings. Surprisingly the two main elements which are very popular in hot-dry climate the courtyard and underground rooms are almost not existing in the traditional buildings in Khammam.

In some of the houses, the windows are small in size, well protected, cross ventilation to sleeping areas, row houses, kitchen is seperated from main building, vegetation in the site, double purpose doors which can satisfy both daytime and night time ventilation requirements, out of which one door is louvored and another is solid. The building walls are white washed both externally and internally. The openings are not properly shaded. The ventilators, in most of the cases are near to the ceiling. During the day time in summers the openings are kept closed. In the traditional building the parapet walls are grilled, to avoid stagnation of hot air above the roof.

The building material that are used are brick, stone, lime, mud, shabad stone, teak wood, bamboo, clay tiles, etc.

2.2.2 Contemporary Buildings :

The contemporary buildings are neither stick to the traditional way of construction nor one could see any modernization in the building structure. The psychological feelings and the economic conditions of the people dominated the constructions. Peoples wanted to construct their buildings with (costly) cement for better strength and durability, that too within the reach of their economic conditions thereby loosing the basic requirement of a house that is comfort !

Usually buildings are constructed into two portions, Each portion has it's rooms in straight line having three side open, instead of four as in the case of a single portion unit. The fourth and the longer side in most of the cases, is overshadowed by the other portion of the building. Due to limited space around the building, the wind movement inside the building is adversely effected. Usually the height of the compound wall is slightly higher than window sill level, which is also another factor.

Even now, very few houses are designed by architects. In most of the cases owner himself decideds design to his house. Whenever his economic condition is good he keeps on adding some-thing to the building as an extension.

Usually room size varies between 10' and 11' as one of its sides. Height will be at about 10' and width of the windows vary from 3' to 5' having a lintel height about 7' from floor level. Now-a-days people are not constructing inclined roof i.e. mangalore tile etc. The usuage of lime and mud is also declining. As wood is available, the shutters of door and windows are thick. But the size of window is bigger than required.

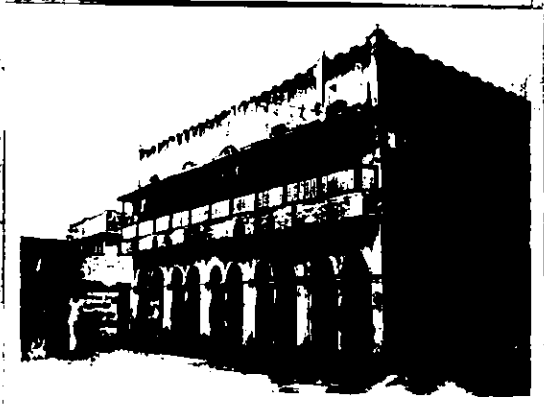
The chajjas are ment to protect window both from sun and rain. But here the window chajjas are not designed according to sun, it is serving the later purpose only.

Now-a-days thé area division for each unit of house is hot-dry climate. So every house is built in a seperate plot, having set-back of atleast 5' in sides and 10' in the front and rear.

The building are usually unpainted on its external surface but internally painted with different mono colours according the owner's choice.

Even in some contemporary buildings one can see toilet block is seperate from the main building, usually in the rear side. May be due to inadequate site around the building and water, people are not showing interest in growing



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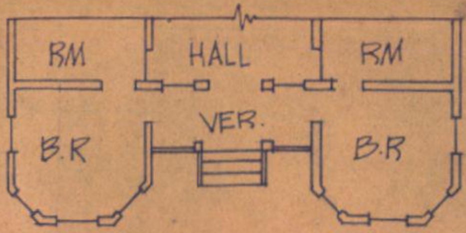
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HALL
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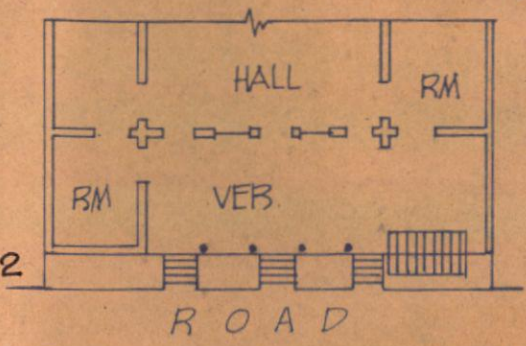
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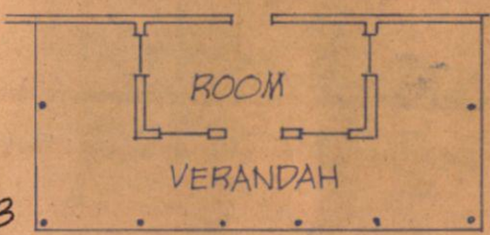
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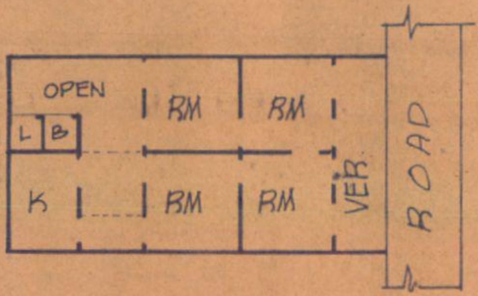
OPEN
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5

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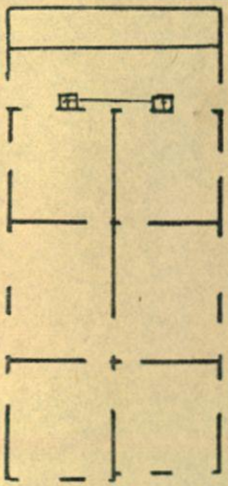
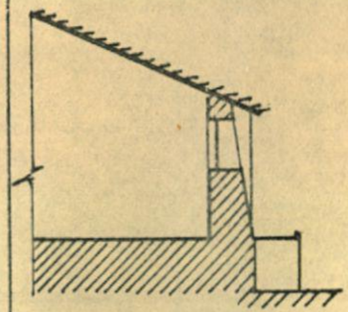
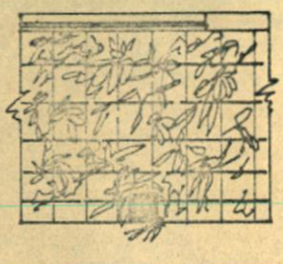
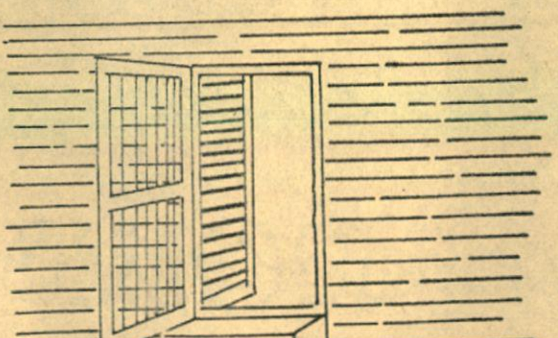
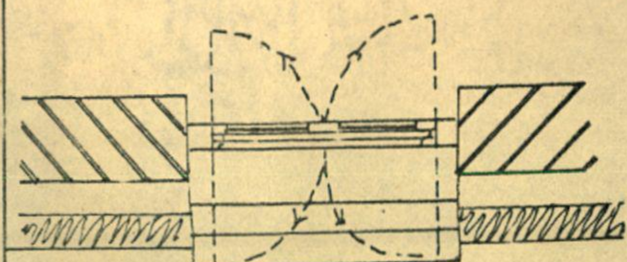
JOIN IN











case study

Residence number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
VERANDAH	Y	Y	Y	Y	Y	Y	N	Y	Y	NA	Y	Y	N	N	N
COURTYARD	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
SMALL WINDOWS	N	NA	N	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	N
THICK SHUTTERS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
THICK WALLS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
THICK SLAB	Y	Y	Y	Y	NA	Y	NA	Y	Y	NA	Y	Y	NA	NA	N
CARPET STRIP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
WELL PROTECTED WINDOWS	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	NE	Y	Y	N
HIGH PLINTH	Y	Y	Y	Y	N	N	N	NE	Y	Y	N	Y	N	N	N
HIGH CEILING	NE	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	N
KITCHEN IS SEPERATE	NA	NA	NA	Y	NA	Y	NA	N	NA	NA	NA	Y	N	N	N
PAVING	N	NA	N	Y	N	Y	NA	NA	N	NA	Y	N	Y	N	Y
CROSS VENT. AT NIGHTS	Y	Y	Y	N	N	Y	N	NA	Y	N	Y	Y	N	N	N
CONSTRUCTION: MUD	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA	NA	Y	Y	NA
CONSTRUCTION: LIME	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	NA	NA	NA
CONSTRUCTION: CEMENT	Y	Y	NA	NA	NA	NA	NA	NA	Y	NA	NA	NA	NA	NA	Y
ROOF: INCLINED	NA	NA	NA	NA	Y	NA	Y	NA	NA	Y	NA	Y	Y	Y	Y
ROOF: FLAT	Y	Y	Y	Y	NA	Y	Y	Y	Y	NA	Y	Y	NA	NA	Y
ROOF OVERHANG	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
VEGETATION	N	NA	N	N	N	NE	N	NA	NA	NA	Y	NA	N	NE	N
HOUSE: ROW	NA	NA	NA	Y	Y	NA	Y	Y	Y	NA	NA	NA	N	[illegible]	NA
HOUSE: INDIVIDUAL	Y	Y	Y	NA	NA	Y	NA	NA	NA	Y	Y	Y	Y	[illegible]	Y
DRAIN INFRONT	N	Y	N	Y	Y	N	Y	N	Y	N	N	N	NA	[illegible]	Y

NOTES:

- ● YES
- O NO
- ○ NOT EFFECTIVE
- • INFORMATION NOT AVAILABLE

vegetation in their site. Besides they prefer to pave the surrounds to achieve neat and beautiful surrounding with less maintenance.

One can rarely see the varandah in these buildings. The new buildings are giving chance to outdoor sleeping only to men and children but not for ladies. It would be better to have courtyard house where all family members including ladies can have outdoor sleep. One can hardly see a underground house in Khammam.

2.2.3 Rural House

The rural house, which is made out of indigeneous material like mud, stone, thatch, bamboo, the inside temperature is relatively cooler than our contemporary buildings. The houses constructed with mud is having wall thickness varying from 9" to 2'-0" with stone or from brick as chief building material. The roof is constructed of different varieties, i.e. mud, thatch, grass, tiled, reeds of red gram dry plants etc. It depends upon the economic condition of the owner. The chief supporting material of the roof frame consists of bamboo and for lintels and doors, mango tree wood is used.

The foundation depth is only 1', the plinth height is varying from 3'' to 6'' from ground level. Flooring is done with mud layer, smoothly plastered with the cowdung.

The houses planned, are small in size, with maximum inclined roof height of 8' and the lower portion of the roof is 3' from ground level. Openings are relatively small i.e. door size is 4' x 2' and window 1' x 1'. In these houses roof acts as ventilator, hot air can escape through porous roof. Sometimes doors are made out of dry plant with a bamboo frame. They leave small gap on the top of the shorter side wall to get light (sky light).

Most of the rural houses are having front portion is shaded, either by extending roof or a special roof is constructed. Almost in every house premises, there is a tree Sometimes they grow creeper on the roof of their house. They try to protect their house external wall from rain, which also protects from direct solar radiation. As roof is of light colour and it is made up of leaves, it would not absorb heat from the Sun, so the effect of solar radiation on indoor environment is diluted upto some extent.

As the walls are thick, the heat transfer from outside to inside is reduced. But the only drawback is, that convective currents can pass through doors and openings. They prefer to sleep outside in nights, especially in summers. They do not follow any specific orientation for their houses, If the door is facing the sun they put shelter against it.

2.3 KHAMAM IN GENERAL

Location :

Khamam township is about 250 km from Hyderabad, it is situated between Kazipet and Vijayawada railway line.

According to 1981 Census the population of Khammam town is 98,757 and area is about 8.7 sq.km. The total number of buildings are 12,000 in number, out of which residential buildings are 10,000. About 70% of residential buildings are constructed with cement as chief building material.

2.3.1 Socio-economic Conditions :

As most of the people are dependent either on some jobs or on a small business, as there is no agricultural land in town very few people are dependent on agriculture. People are not rich enough to purchase cooler or air-conditioned to keep their houses cool during summers.

Now-a-days people are almost deprived of combined family system. They prefer to live in independent houses. Mass gatherings are very rare. The only places where people regularly meet, are religious places and cinema halls. Most of the people are migrated to this Khammam town during the construction of Nagarjuna Sagar left canal project. This place is a big business center also. As it is being a district headquarters, it has good transportation facilities both by rail and road. People prefer to live in Khammam even they are working in nearby villages.

2.3.2 Locally available building materials

There are lime deposits near Ellandu about 30 km from Khammam and timber is available from nearby forests in Bhadrachalam, Ellandu and Mahaboobabad forest. Sand is from river Maneru. Brick and tile are manufactured locally and s tone (granite) is available within the town itself. Shabad stone is available in the neighbouring districts.

2.3.3 Water Sources :

There is a big drinking water reservoir about 20 Km from Khammam which supplies water for entire township throughout the year. There is one small river (Maneru) passing by rural areas. It would not get dry even in summer. There is one irrigation canal passing through the town, but it only flows seasonally. There is one water body in the outskirts of the town, usually get dried during the summer.

Most of the people are dependent on groundwater so that bore wells were dug at most of the places. And there is the municipal water supply about 3 hrs even in peak summer months. The water table is about 15 to 20' below the ground level. Frequently they will get dried in summer months except a few.

2.3.4 Soil Conditions :

According to local agricultural research centre, the quality of soil is sandy loam, sandy clay loam. It is good for vegetation but not for cultivation usually dry in nature. Hard strata occures at the depth varying from 45 cm to 60 cm below ground level.

2.3.5 Vegetation

There are very few trees seen on the road side. In very few houses people are showing interest in plantation. The locally available or seen trees are neem (at about 70%), coconut trees (10%), Tamarind (10%) and rest of the plant varieties are 10%. In the creepers boganvilla is mostly seen. Gulmohar tree is recently introduced in one of the Govt. offices. As a matter of fact, no public garden is seen in the town.

2.3.6 Mode of Construction in Practice :

In almost all constructions, cement replaces lime, including the building industry which is fully dominated the other building materials. As cement has better strength and stability, the thickness of building envelope has got to reduce to a minimum which is absolutely against the one of the fundamental requirements of building in the hot-dry climate where thick walls and roof are preferred.

In general, the external walls of abuilding is of 13.1/2" thick and internal walls usually 9" and in some cases it is 4.5" thick also. Coming to the slab, it is constructed of 10 cm thick R.C.C. slab, without any insulation layer above or below it.

One interesting feature is that in construction of building, especially residential is : in any type of residential building, whether it is big or small, people are trying to construct two portions, one for him and one for hiring within the limited site and money. By doing so, he is sacrificing the comfort condition, due to lack of cross ventilation, proper care and financial support.

2.4 HOT-DRY CLIMATE - KHAMMAM

CLIMATE :	
• Day-time Air Temperature may range between 27 and 49°C	• Similar
• At night it may fall as much as 22°C	• Similar
• Humidity is continuously moderate to low	• Similar
• There is a litile cloud cover to reduce the high intensity of D.S.R.	• Similar
• The clear skies do permit a considerable amount of heat to be reradiate to outer space at night	• Similar
• The dry air, low humidity and minimal rainfall occures the dry dusty ground reflects the sunlight-create glare	• Similar
• Local thermal winds often carry dust and sand	• Similar
SITE SELECTION :	
• On SE-E slop exposures, lower portions are preferred where cool air flow effect can be utilized and controlled. high altitudes. and locations with evaporatime possibilities, are advantageous.	• It is situated on deccan plateau. high altitudes present are unfit for living conditions

TOWN STRUCTURE :

• The walls of houses should provide shade to outdoor living areas	• The walls of houses are hot providing shade to outdoor lying
• Unit dwellings or groups should create patio-like areas; concentration is desirable	• The patio-like space are hot present even in old buildings
• The town structure should react against heat with a shaded and dense layout.	• Here houses are staggered, the town structure is traping the heat, neither shaded nor dense layout.
• There should be a close connection between public residental areas	• Public spaces are slightly away from residental areas
• Half and full shade protection is desirable.	• Connection by road/ways are not shaded.
• Paved surfaces should be avoided	• Paving the surrounding is seen in most of the houses
• Pools of water are benificial.	• No water pools placed in any house

LANDSCAPE :

• As vegetation is generally sparse, concentration of plant and grass covered areas in the manner of 'oasis' is desirable.	• Very few trees seen on the roadside and res areas grass covered areas are out of question, as the water supplied is just sufficient for house hold use.

● Vegetation is desirable both as a radiation absorbent surface and for its evaporative and shade giving properties.	● Very few trees are shading the road and those placed in res areas are not properl located to get good shade and cool air.

HOUSE TYPES :

● Compact 'patio'/courtyard house type is preferred.	● There are neither patio houses nor courtyard houses.
● Adjoining houses, row houses and group arrangements (all in e-waxis).which tend to create a volume effect,are advantageous.	● No adjoining houses no group arrangements but in some traditional house the concept of row houses without specific axis.
● High massive buildings are preferable.	● In traditional bldgs the walls are massive but in contemporary bldgs the-wall thickness is less than required.

GENERAL ARRANGEMENT :

● Heat loss, rather than gain, is objective.	● Heat gain, rather than loss is taking placing in the bldgs.
● Closec building appangement around green areas are prefered.	● No bldgs are arranged around green areas.
● Utilizing evaporative cooling effects and night out-going radation losses	● Even the evaporative cooling technics are not effectively used night heat loss is also not effective due to improper placement of openings.
● Lythosphere arrangements are applicable (subterranean utilization)	● subterranean utilization is not in practice

Outdoor or roof sleeping possibilities should be considered.	Outdoor or roof sleeping is common here
PLAN :	
Inward looking layout can benefit from microclimatic advantages.	No bldg in Khamman is inward looking layout
Walled-in house arrangement can benefit from cool air pool effects.	No courtyard type house is there to cool air
Single floor and a convehient plan with economy of movements avoids h-gain	Bldg are not conveniently planned to avoid heat gain
Heat-producing areas should be seperated from other area of the house.	Heat-producing areas not seperated except in some traditional bldgs
Non-inhabited spaces should be placed on west side to baffle sun impact.	Arrangement of room are no according to sun
Compact shapes (optimuml:1.3) are preferable, with slight elongation (e-w)	No compact shaped houses are seen, elongation of the houses does not have specific axis
Building forms should have minimum solar projection.	Not followed
Orientation should be desided inorder to get least solar radiation.	Not followed
Beep room arrangement can be used as a cooling contrast to intense outdoor heat	Not in practise
Dark use of low emissme 'cool' colours reduce heat reflection on interior surfaces.	Upto some extent

● White paint has high reflection ratio on sun exposed surfaces.	● Upto some extent
● Dark absorptive colours are adaptable where reflections toward interior expectd	● Not in practice
OPENING AND WINDOWS :	
● Relatively small openings reduce intense radiation.	● In some traditional bldgs the windows are small but in present bldg those are big.
● Windows should be shielded from direct radation and protect from gradiation	● Windows are neither properly shielded from dr nor protected from dr
● Openings should be tight-closing as protection against high diurnal heat	● Openings are not tightly closed so infiltration takes place
● External shades are preferred.	● Only openings are externally shaded that too not properly designed
● Openings should be located on s.n. and to a lesser degree on east sides	● No specific orientation for opening is followed
WALLS :	
● Walls of daytime living areas should be of heat-storing materials; walls of night-use rooms of material with light heat capacity.	● Wall thickness is hot in relation with ant specific living condition
● East and west walls should preferably be shaded.	● East and west walls are not (Properly) shaded

• High reflective qualities are vesirable for both thermal and solar radiated roof	• Surface reflectivity is absolutly nil. except sometimes walls are white wash

ROOF :

• Heat storage insulation type is the best	
• A shaded, ventilated roof is good, primarily over night-use rooms.	• Roofs are neither shaded nor ventilated
• Water spray or pool on roof is effective.	• Not in practice
• High solar reflectivity is a basic req. emissivity is essental	• Only one house's roof is white washed, emissivity occures

MATERIALS :

• Required insulation value relative to s is:11; w-12;N-10;roof-16.	• The building surfaces are hot properly insulated
• High capacity walls are essental	• In traditional bldgs the walls are high capacity
• Necessary time lag for internal heat are:E-Oh$_{rh}$; S-10H$_{rs}$; W-10Hrs; N-No log; roof-12H$_{rs}$.	• Time lag of every surface is less than req.

SHADING DEVICES :

• Divices should be separate from structure, and exposed to wind convection.	• Divices are not separated, but exposed to wind convection.

VENTILATION AND AIR FLOW :

• During day opening should kept closed	• Samc in practice
• Vent should be kept min, to minimise the entry of hot and dusty external air	• Due to big windows heat enters through gaps
• Opening should be located so as to get cool and dust free air	• Opening are not properly located
• Amplé ventilation is necessary at night	• Due to lack of cross venth even in night also people wont feel comfortable
• Ventilators should be near to ceiling	• In most of the cases it is true
• Ventilation of roof is useful	• Not in pratice
• Roof oriented towards privailing wind	• Not accoding to P.wind
• High solid parapet walls arround the roof would create a stagnant pool of hot air and should be avoided.	• In more cases the parapet walls are grilled general ht. is 3'-0"

2.5 POINTS NOTEWORTHY FROM CASE STUDY:

During the case study of Khammam residential buildings, it was observed that very few things which they follow are suitable to that climate. Out of 55 points list only in 3 cases they are effectively used, in the case of 10 point they are not effectively used, rest of them 42 are not at all in practice. This figure shows the people live in Khammam are how ignorant of the comfort condition.

The points in favour to the climate are

(i) The shutters of the opening are closed

(ii) people prefer to sleep outdoor.

(iii) Ventilators are nearer to the ceiling and points where are not effective but in practice are

(a) It was observed at one place roof is painted with white wash.

(b) In most of the cases the parapet wall is grilled.

(c) The concept of row housing can be observed in some traditional buildings.

(d) in traditional building walls are massive but in contemporary building wall thickness is less than required.

(e) Even the evaporative cooling technique is not effectively used and night heat loss is also not effective due to improper cross ventilation.

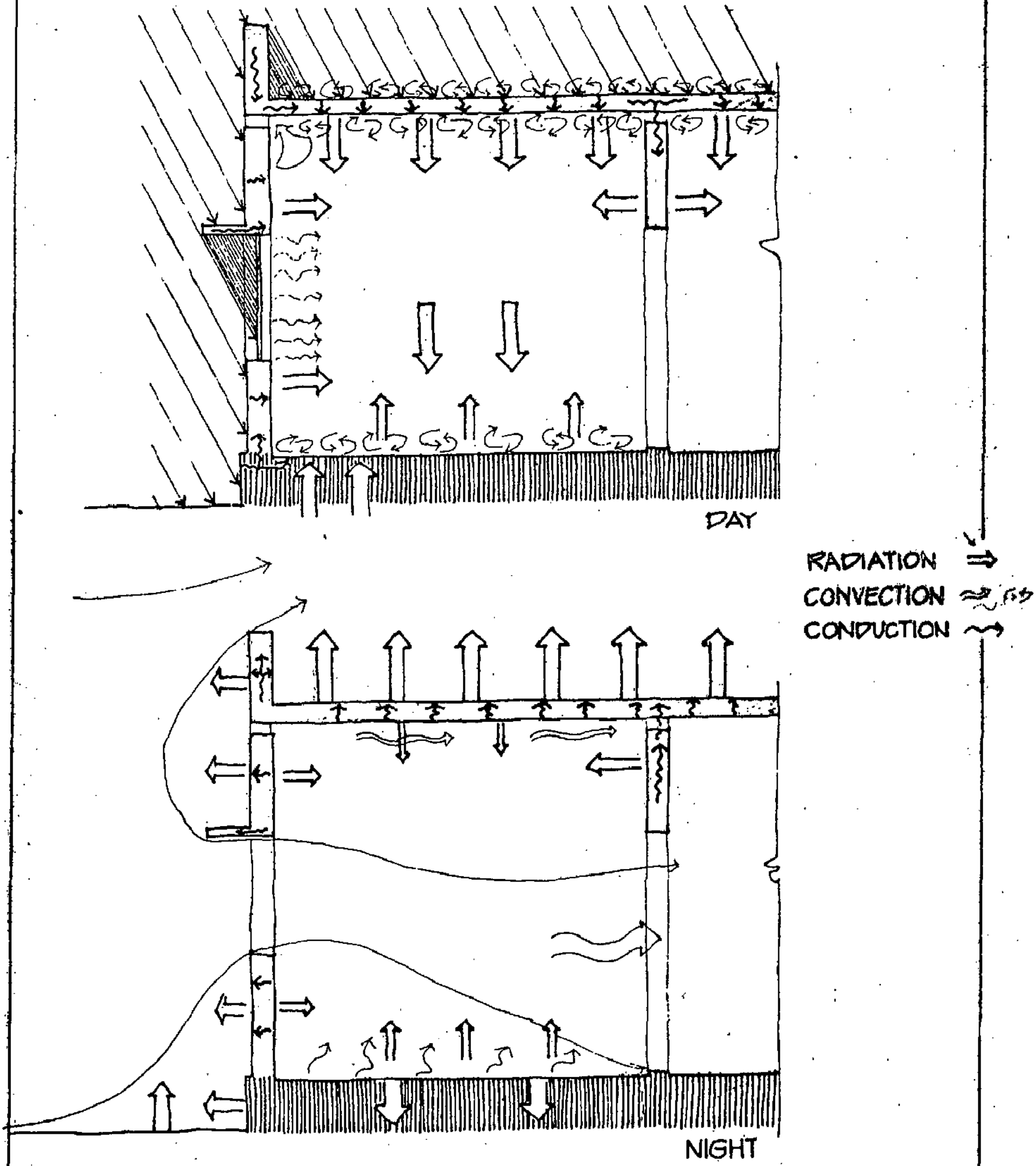
(f) except in some traditional building the rest of the seperate from the main building.

(g) In some buildings interior walls are painted with cool colours

(h) some of the residential buildings are painted with white wash, some are left unpainted for number of years, the rest are having unpainted external building surfaces.

(i) In some of the traditional and rural houses the opening are small but the contemporary buildings are having big windows.

(j) The openings are shaded but not effectively shaded from Sun.



HEAT TRANSFER THROUGH VARIOUS BUILDING ELEMENTS.

3.0 CAUSE OF UNCOMFORTABLE CONDITIONS INSIDE THE BUILDING

The general condition of house in Khammam, in summer is - the outside temperature is high and the inside temperature is unbearable, body comfort is absolutely intolerable. At this time even though one has work to do, disgust and tiredness will retard his work's progress. There are many cases, where people got 'Sun stroke' even though they stayed inside their house. The unfortunate thing is that, even though people are suffering from Sun's impact, they are not taking any precautionary measures while constructing their building.

The houses constructed are neither insulated nor properly designed to suite the climatic conditions. Even though the external wall thickness is 13½" may be because of the sand content in the brick, its thermal conductivity is more. Similarly roof, it is made out of 10 cm R.C.C. slab, plastered on both sides. It does not have any insulation above or below the slab to prevent the heat transfer. The windows designed are bigger than required and are not properly shaded from direct sun. The jointing between frame and shutter and between two shutters is not proper. In the openings, they are allowing infiltration of heat from outside to inside through convection. Similarly the position of the windows are not encouraging the cross ventilation during the night.

Now-a-days, people are paving the surroundings with shabad stone, rather than giving preference to home gardens. Even trees which were planted are not giving any shade to building during the summers. Very few buildings are externally painted with white wash.

It was observed, when the effective temperatures are plotted for throughout the year it is showing that : percentage of comfort is only 23.5% (20 and below), warmness is 32% (between 20 and 25), hotness is 39% (between 25 and above). It (Table No.) clearly shows that, only during the winters it is in and around comfort zone, rest of the year is warm to hot.

And the temperature readings that are taken in a contemporary building (on which case study is done), gives surprizing results that indoor temperature is closely following the outdoor temperature. At two instances the readings are taken one on March 30th at 1 pm in all rooms the maximum difference that is observed between indoor and outdoor temperatures is only 3°C. In the second instance, the temperature readings are taken for daytime starting from 8 am to 5 pm (21.9.84), the maximum difference between indoor and outdoor temperatures (in a room) is 4°C only ! So this is the state of comfort in buildings of Khammam.

The present study is done on heat transfer in a

TABLE NO. 3.1

Hrs.	J	F	M	A	M	J	J	A	S	O	N	D
0.0	21.1	23.2	25.2	27.2	28.8	27.8	26.0	25.7	26.0	25.4	22.5	20.4
2.00	20.8	22.9	24.9	27.0	28.7	27.6	25.9	25.6	25.9	25.3	22.3	20.2
4.00	20.3	22.7	24.7	26.7	28.5	27.5	25.9	25.4	25.8	25.2	22.1	19.8
6.00	20.25	22.3	24.4	26.6	28.3	27.3	25.8	25.3	25.7	25.0	22.0	19.6
8.00	20.5	22.8	24.8	26.8	28.7	27.7	25.9	25.4	26.6	25.2	22.2	20.0
10.00	22.8	24.8	26.5	28.4	29.4	28.4	26.8	26.4	26.7	25.0	23.5	22.2
12.00	24.0	25.8	27.5	29.2	29.9	29.0	27.2	27.0	26.9	26.3	24.2	23.4
14.00	24.6	26.3	28.0	29.1	30.1	29.3	27.3	27.2	27.1	26.6	24.6	24.1
16.00	24.2	26.0	27.7	29.6	30.0	29.1	27.2	27.1	27.0	26.4	24.3	23.7
18.00	23.2	25.1	26.9	28.8	29.7	28.7	26.9	26.7	26.8	26.2	23.7	22.6
20.00	22.0	24.1	26.0	27.9	29.2	27.9	26.4	26.2	26.3	25.8	23.1	21.4
22.00	21.5	23.6	25.5	27.5	29.0	27.5	26.2	25.9	26.2	25.5	22.8	20.9

COMFORT 23.5%

SHADING 71% (WARM 32% + HOTNESS 39%.)

COOL 5.5%

Contemporary Building :

This building is of two room deep, facing towards east and its orientation is almost in north-south orientation (The building line is slightly towards north of east). The material used in the construction are : walls are with brick and cement mortar, roof is of R.C.C., windows and doors are of thick teak wood, flooring is with C.C. bed and shabad stone, plinth is of CRS masonary. The building envelope is plastered both internally and externally.

The whole building is made into two portions, the three rooms facing north is one family portion and three rooms facing south is other family portion. The toilet block (bath and W.C.) is seperated from the main building. The front room of each house is living room, the second one is bed room and the third is kitchen.

The width of windows varies from 3'-6'' to 5'-0''. It seems windows are designed of good strength in security point of view rather than climatic point of view. The window size is bigger than required. The window shutters are solid and good but the jointing of two planks and the gap between sill and shutter is not perfectly sealed. It is giving way to infiltration of heat from outside to inside. Windows are not fully shaded from direct sun even in early afternoons. Sunshade is not designed according to Sun's movement. Similar situation is for doors also. One good thing in this door design, each has a carpet strip, which upto some extent stops infiltration. Ventilators are directly under the ceiling, except one ventilator (4'-6'' x 1'-3'') rest of them are small size (2'' x 2'-6''). The two sides in which wind is coming, got big obstruction.

- Staircase at South east corner
- Toilet block on west side.

Front and rear open place of the building is got shabad stone paving, which is creating glare and stores the heat in it. There are some trees in the northern side and in Northeast corner of the plot, they are neither preventing sun from falling on the building nor it is giving elevation effect to the building.

Roof is made out of R.C.C. 10 cm thick, this flat roof is radiating high amount of heat to interior along the walls, whose contribution still worsening the indoor comfort. The quality of brick is also poor, it has some sand content in it. There is about 2'-0'' wide roof overhang infront (eastern side) covering the big ventilator. There is a portico (10' x 15') in N.E. corner of the building, it protects building from morning sun and glare in the late morning hours. Flooring is constructed of rough shabad stone, cement mortar and cement concrete creating discomfort upto some extent by absorbing both from roof and ground. The plinth height is about 2'-0'', exposed sun during mid window facing admeasures 3'-6'' x 4'-0'' and the other is 5' x 4'. It has a big ventilator and a small ventilator The big one creates lot of discomfort during summer daytime. The air flow into the building is being obstructed in the most crucial times (i.e. morning times, in evenings and in night times) by the staircase and toilet block situated in south eastern side and western side respectively, which is ironically the prevailed wind direction too. During the day time the paved portion and the staircase railing infront of the buildings are creating glare and make air above hot, from which heat is being radiated to the room, besides the direct solar radiation. If both the windows are opened, we can have a cool breeze from southern window into the room during night time.

Room - (facing South)

This room has 4 doors and one big window with two ventilators on the top. One door is permanently closed. Because it has only one window, the ventilation rate is very poor, the doors and windows are not perfectly shaded in south side, they are exposed to direct sun for most of the time. If door on south side is opened it will have good ventilation effect on indoor, except in overheated hours.

Room (On SW corner facing West)

This room has two doors and a window with two ventilators on top. The door and window facing west side is badly effected by strong solar radiation between early afternoon and late afternoon hours. It is directly exposed to sun. As the rear yard is paved, it is creating same effect as it is in the case of Room at S-E corner of the building. The toilet block is obstructing the western winds which ventilate the rooms. Due to usual usage of water in the kitchen, it is cooler in the above said rooms.

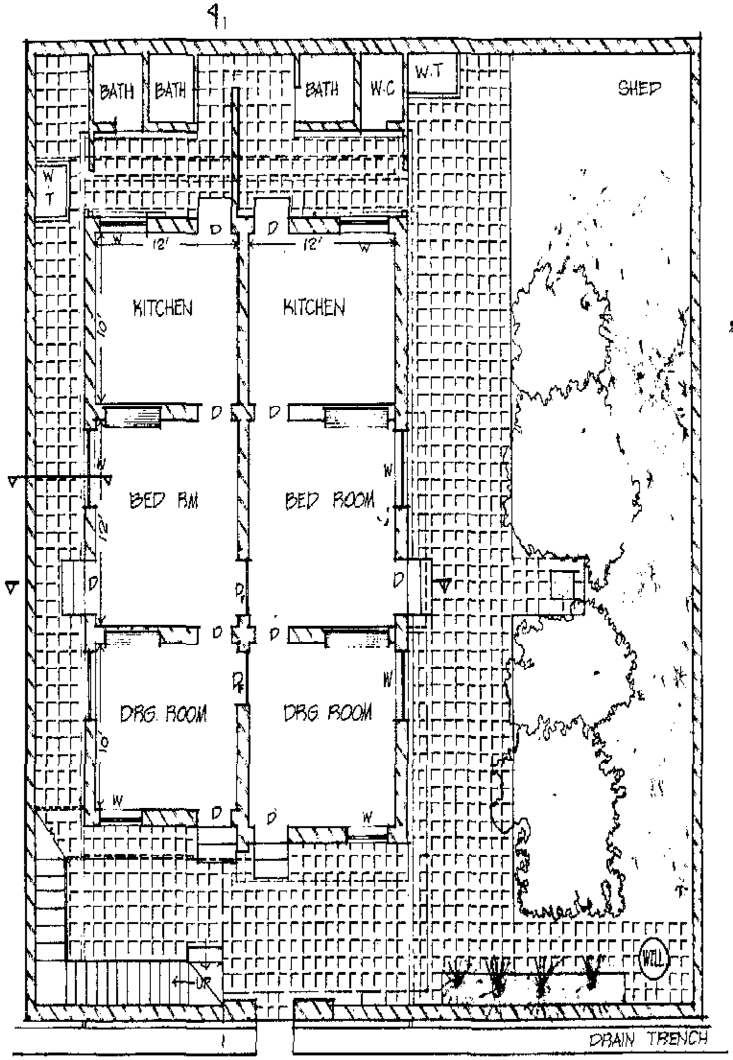
Room (facing north)

It is seriously affected in summer due to very less amount of air which will come from north. As it got only one window, there is a little chance of ventilation, windows are protected from sun.

Room (NE corner)

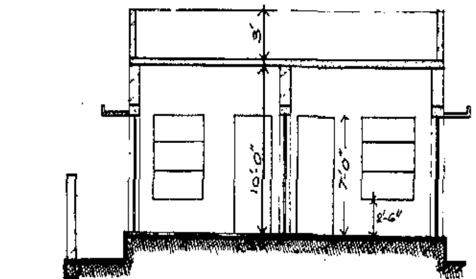
This is the coolest room in the building. It has satisfactory cross ventilation. Eventhough it has got paving infront, the portico is protecting the room both from direct sun and glare.

A Typical Contemporary building

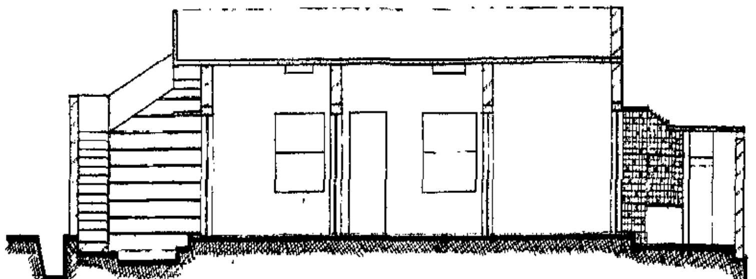


PLAN

R O A D



SECTION AT AA



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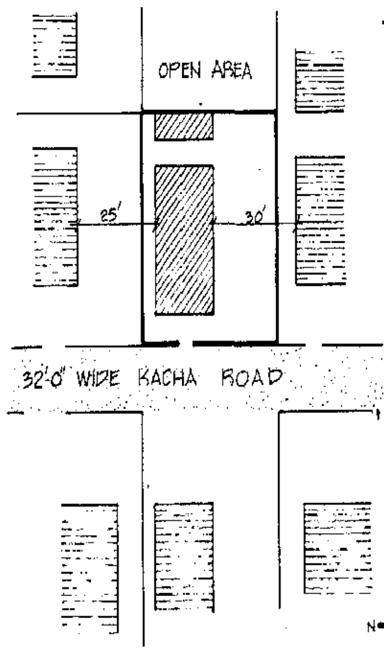
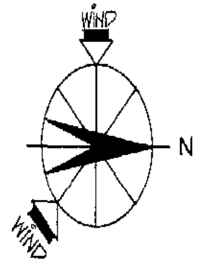
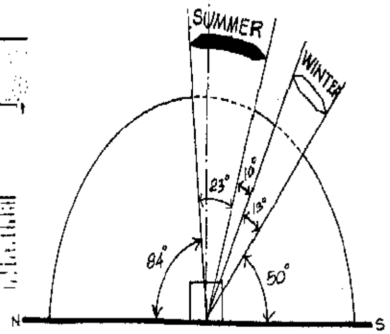
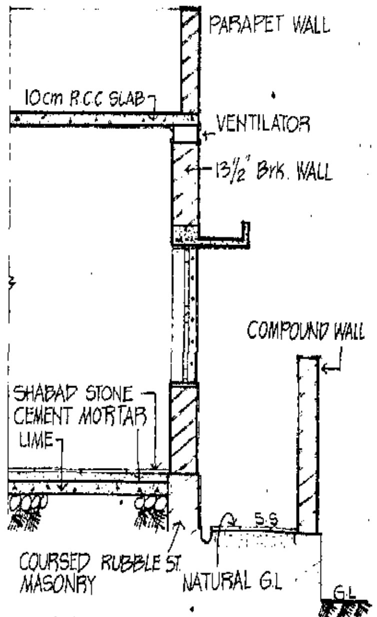


BUILDING AND IT'S SURROUNDINGS





BUILDING AND SUN'S MOVEMENT ON IN SUMMER & WINTER (AT NOON)



SECTION AT CC

FRONT ELEVATION

S-E CORNER →

N-E. CORNER ↓

Case Study

In this latitude, the average direct solar radiation in summer months, on the building envelope is as (decending order) follows : roof, East/west walls, NW/NE walls, SW/SE walls, north and then comes south walls.

Roof receives more radiation in this case, that too it has a thin roof section instead of thick, these two together effecting the indoor environment. As roof receives the solar radiation from the sun, and gets heated up it conducts heat to the internal surface, from there heat is emitted to the indoor space by radiation (longwave) and by convection as well. In some places, where roof is in contact with walls, conduction of heat takes place into the wall whether internal or external. As the roof's external surface temperature sometimes reaches upto 10° to 15°C more than the ambient air temperature, the air immediately above the roof gets heated up and makes the surrounding air hot. Similarly inside the surface of the roof losses its heat to the air in contact with it, thereby making the air still hotter. Due to stack effect the hot air tends to move out through the ventilation, the replacement of air in this place is done by air near floor level. This void is filled by the air outside, which is already hot, through infiltration. This infiltration generally occurs through the gaps in the joints of doors and window shutters and frame.

As already mentioned above roof also emitts heat to indoor space through longwave radiation. This radiation is readily absorbed by floor which is opposite to it. The Shabad stones on the floor get heated up and store it. Actually the floor should be coolest part of the room but here the case is different. The flooring is getting heat not only from the roof, but also from ground and plinth. The surface expose on plinth, which is constructed of granite stone of 1'-6" height, absorbs heat during the day-time and conducts heat to the wall and to the flooring. The contribution of ground in heat transfer to indoor environment is there upto some extent. Here the bare ground heats up during the sunshine hours and tries to lose heat to the cool surfaces nearby. The indoor floor surface temperature will naturally be cooler than that of sun exposed bare ground. So heat tends to travel from outside to inside through ground.

Coming to the walls, it is interesting to observe that in summer months almost all, except north and south wall, receives same amount of sunshine hours. But since the angle of incidence of solar radiation is different, the quantity of radiation received will differ.

According to latitude, the average amount of solar radiation received in summer months by wall is given in Table No. . Among the walls East/West walls receive more solar radiation during early morning and in late afternoons. Then comes NE/NW walls, SE/SW, north and south respectively.

The walls are not externally painted. So, its colour is grey and its texture is also not smooth (cement plastering). First the surface of the wall exposed to sun receives heat and it transfers heat to the inner surface by conduction, then after making it hot, it transmits heat to the interior by longwave radiation. Walls also get heat from roof, sunshade and plinth. The roof conducts heat to the walls, especially to internal walls. As the walls get heated they radiate heat to indoor environment through longwave radiation. Similarly in case of sunshades (Horizontal surface) heat is received from direct solar radiation and conducts that heat to wall, from there it reacts to indoor space. The contribution of plinth is already explained.

As the openings are not properly shaded, they impact direct solar radiation, on the window and door making them hot. The gaps at jointing of two planks in shutters and the gaps between frame and shutters are not properly sealed. Through these gaps infiltration of heat from outside to inside is taking place, through convection.

Another uncomfortable condition is created by the glare. The front and rear sides of the building are paved with shabad stones. The tendency of the shabad stone is to absorb heat quickly and store; and its surface which is smoothened by regular walking over it, Reflects light from early morning to noon, the paved surface on eastern side receives heat, part it stores and rest it reflects to the wall surface. It stores heat in it and makes the air above it, hot. Then in the afternoons it will start reradiating, but by that time the ambient temperature also gets increased, so there will not be so much heat loss from it till late evening and night. But here due to constant usage of water its effect is reduced considerably.

One of the main reasons for uncomfortable conditions inside the building is utilisation of fan in the day time. People, so as to control hot winds coming inside, usually close the openings in the day time. For getting enough air circulation to make their body comfortable through evaporation of sweat,they use fans. By doing this, the air accumulated at the ceiling level, which is in fact too hot, is dragged down to living level, making the indoor temperature uniform, may be more or less equal to ambient temperature (outside). Then what is the difference between living inside and living outside the building, when comfort is considered ? The answer is 'absolutely nothing'. This is the case in the existing buildings in the Khammam.

The comfort temperatures suggested by CBRI, is achieved during the winters only in this place. Even the people are accustomed to feel comfortable even at 40°C (outside air temperature).

The thermal performance index suggests that in hot dry climate 10 cm R.C.C. is the worst among the roof sections and 13½" wall is also considered as bad. It clearly indicates all problems of discomfort are due to roof itself, which should be controlled to achieve comfort conditions inside the buildings.

Two types of indoor temperature measurements were taken. One is, temperature reading in all rooms at one time (March 30th) daytime. Temperature reading in a room (NE corner). In the first reading the temperature difference is at the maximum 3°C, from inside and outside. In SE corner the temperature difference measured is only 1°C.

Surprisingly in the second case the indoor temperature reading followed the outdoor temperature. May be at that time, all openings are opened.

As already stated the rooms are not properly ventilated for night time cooling. In the night time, the temperature comes to comfort range, that too the minimum temperature only lies in the comfort temp. range. Due to lack of cross ventilation the stored heat in the building envelope is unable to lose their heat to the surroundings. If all the doors are opened the ventilation is very good. Opening all windows resulted in adequate ventilation.

There is another obstruction to cross in meeting ventilation requirement, i.e. the bottom portion of the window is always kept close. If it is opened, residents lose privacy. The same is in case of opening the door, especially in nights. Because of this reason, the indoor temperature in this case is higher than surrounding air temperature.

If the building has cross ventilation the heat is transferred to outside air through convection besides by the longwave radiation emitted by roof and walls. From case study of this building it is understood that cross ventilation of the rooms is essential specifically during the evenings and nights.

Generally in the kitchens, cooking of food is done using either gas stove or kerosene. Thus there will be considerable heat loss to surrounding indoor air, making it hot. But due to constant usage of water this room is relatively cool.

4.0 FACTOR AFFECTING INDOOR ENVIRONMENT :

4.1 Effect of Ceiling Height on Indoor Environment :

One of the features traditionally associated with housing in hot climates is high ceilings. A ceiling height suggested by Le Corbusier as 2.26 m but this varies among nations according to the people's average height, and it also depends on the type of electrical fittings like fans etc., and several other factors.

High ceilings might be expected to create cooler conditions : high heated ceiling would transmit less radiation to the occupant than lower ceilings, assume the same room area, since the solid angle of the ceiling subtended by the occupant would be less than that with the lower ceiling. The convected heat transfer would have less effect with high ceilings as the heated air would form a layer under the ceiling above the heads of occupants.

The hot ceiling will transfer most heat directly to opposite surfaces and occupants by radiation, unless internal air movement is high.

Rooms with high ceiling height would have larger surface areas, any heat gain would result in a smaller rise in temperature spread over a large surface, rather than a large rise with a smaller space. (This is true in case of shaded walls). But due to high ceiling the external walls area will also get increased resulting in larger heat gain. High ceilings increase the volume of air within the room, ventilation rate can therefore be reduced when outdoor temperatures are high, as the larger volume of air will not become 'Stale' so quickly.

It is also observed that ceiling has an indirect influence on ventilation (stack effect) and but on lighting it has quantitatively insignificant effect because both are more dependent on other factors like area, position, orientation of opening, reflectivity of surface to light and microclimatic conditions.

The heat exchange process depends mainly on longwave infra-red radiation, invisible, but highly perceptible to the skin, and, to a lesser degree, on conduction to the air immediately below. In the latter case ceiling height does have a certain influence on air temperature as the ratio of ceiling area to air volume varies. In practice, this influence is limited by the poor thermal conductivity of air and by the continuous air changes that normally occures in non-air-tight rooms.

The human body exchanges radiant heat with the ceiling or any other surface depends upon the temperature, longwave emissivity of the ceiling and the angle factor* between two bodies. As far as ceilings are concerned it is the resultant rise in mean radiant temperature in relation to the body that is the major contributor to thermal discomfort.

Taking different ceiling height, we can calculate the mean radiant temperature in each case in relation to the person by the following simplified expression.

$$T_{mrt} = 4\, T_w F_w + T_f F_f + T_c F_c$$

where T_w, T_f, T_c are the temperatures of walls (assumed identical), floor and ceiling respectively ($^{\circ}$1C) and F_w, F_f, F_c are the angle factor between these surfaces and the person.

A study of the thermal effect of ceiling height is computed when a person seated in the middle of a room with the following parameters : room dimension is 3.0 m x 3.0 m with all the walls and floor surfaces assumed isothermally at 27°C and with the ceiling at 35°C (Figure)

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*The angle factor between the human body and a surface denotes that proportion of the body area, projected on to a plane perpendicular to the direction of radiation from the surface, which is expected to the surface. The sum of angle factor is equal to unity. The angle factor depends on height of ceiling and on the location, orientation and posture of the human body.

It is clearly understood that the increase in the ceiling height is not proportional to the decrease in the mrt. A 0.90 m increase in height produces a reduction in mrt of 0.58 °C while further increase of three metres produces a subsequent reduction of no more than 0.51°C.

It is observed at the same conditions when ceiling height is fixed at 2.7 m but the temperature rises progressively from 27° to 47°C (Figure), and it is giving clear sign that the rise in mrt is directly proportional to the ceiling temperature. But when it was done experimentally the rise in mrt is much higher, because it is highly unlike that all other surfaces maintained at constant temp. of 27°C when the ceiling is at 35°C and wild heat is being evolved contin ously from the occupants.

In Australia Lee found that a reduction of a ceiling height at 35°C by 1.2 m i.e. from 3.60 to 2.40 m, produced an increase in radiation load 2 KCal/hr which is negligible. In India 2.70 m was fixed as the height above which no useful improvement was obtained, the drop in air temperature due to increasing the ceiling height to 3.0 m and 3.30 m being less than 0.25°C. It is observed that at a height of 2.40 m higher maximum air temperature were obtained i.e. up to 1°C rise, but the globe temperature remained consistantly unchanged. A difference of less than 0.25°C is observed by Givoni in the rooms of different

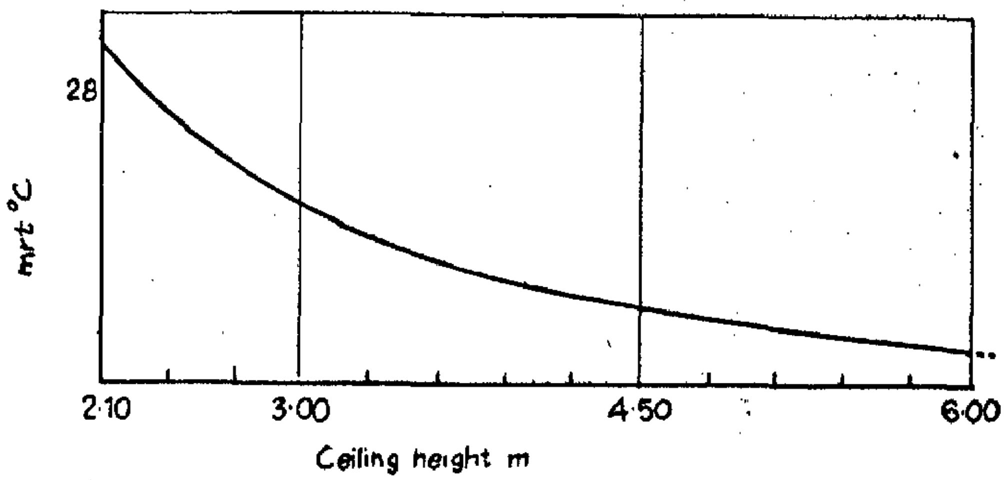

FIG. NO. 4.1 A mrt AS AFFECTED BY CEILING HEIGHT

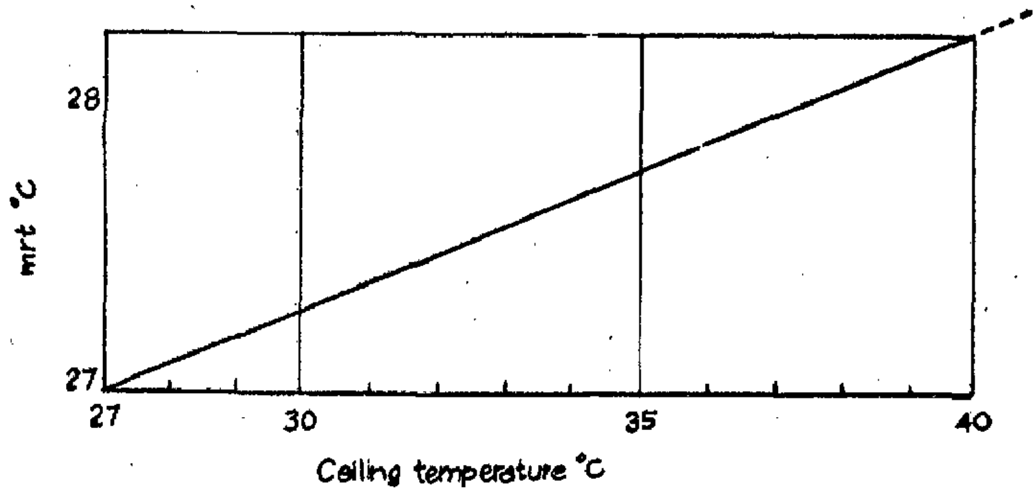

FIG. NO. 4.1 B mrt AS AFFECTED BY CEILING TEMP.

ceiling height (2.50, 2.80, 3.00 m). Still interesting observation is done at the National Building Research Institute, that no significant difference was affected by altering the ceiling height from 2.70 to 2.25 with surface temperature at 43.3 or 49°C.

A low ceiling is often associated with definite notions of economy in space and cost and a pleasant feeling of comfort.

Conclusion :

The effect of ceiling height on the indoor environment tends to be grossly over-estimated. It is the ceiling heat and its height which is the cause for discomfort*. As the ceiling height is limited factor on indoor climate, the choice of select of ceiling can be on economic, aesthetic or purely psychological grounds. A height upto 2.70 m is recommended, the effect of further increase in height is thermally insignificant.

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*Ahmad, A. M. on ceiling heights and human comfort, Building in hot climates, Building Research Establishment 1980.

4.2 EFFECT OF ORIENTATION ON INDOOR ENVIRONMENT

The orientation is the direction, perpendicular to the axis of the building block. In case of square building, each room has a different orientation and in accordance with those individual room requirement, the building orientation is decided. While deciding an orientation, the demands of the natural agencies should be fulfilled as far as possible. There are some other factors which influence the orientation: Contours of the site, zoning, Building Code practice, the relative humidity, the surrounding buildings, surface cover such as trees and shrubs etc. Before going into several aspects of design and orientation, it is necessary to decide what kind of comfort needs should be given more attention, summer or winter. In the areas where ambient temperature has greater physiological influence than ventilation (places like Khammam with low humidity), orientation with respect to the sun is an important consideration. If the place comes under humid climate, in building orientation wind should be given more preference to sun.

Under condition of excessive heat, the orientation of a building should be such that the heat impact of sun is mitigated as far as possible. The maximum radiant heat is gained by the roof (horizontal surfaces) and in walls facing east and west, receive the highest intensities of radiation. They should normally be kept as short as possible.

The thermal effect of orientation is meaningless, unless reference is made to the external colour of the surface . It was observed that external surface temperatures of lightweight curtain walls facing the four cordinal directions having two external colour grey and white. Difference in temperature of different orientation of grey surfaced walls is as much as 23°C and that of white surfaced is less than 3°C ! (1)

The magnitude of thermal effect of wall orientation on the interior is dependent on many design and construction characteristics. It varies from a negligible to a very significant factor.

Consider a building with rooms facing several directions, externally white, the thermal resistance is medium to high and windows are effectively shaded. Because the low absorptivity of all surfaces, the indoor temperature will closely follow the external air pattern, showing little variations, with orientation and the internal surface temperature will be virtually uniform, "with adequately insulated walls of light external colour, and effectively shaded windows, internal differentiation with orientation may be negligible".

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(1) Givoni, B. Man, Climate & Architecture

The magnitude of the temperature elevation above the ambient level also depends on the wind direction. For example, in an area where prevailing winds are westernly infact both East and West side walls should receive equal amount of radiation, but because prevailing wind in the west, the elevation of surface temperature in west wall is less than east.

The wall thickness of building envelope have considerable effect on indoors temperature pattern. The maximum difference between the warmest (East and West) and the coolest (norths) walls were again larger for the thinner than for the thicker. Lightweight walls of low conductivity, the internal temperatures will be higher than high capacity heavyweight walls, which absorb appreciable quantities of heat without significant increase in temperature. In addition to it surface colour has its own impact on it.

TABLE - 1

* Internal surface temperature of walls of West(North) orientation, thickness and external colour.

Wall Thickness / Colour	Type	Ambient Temp. °C	Internal wall surface(recorded) Temp. °C West (North)	°C differrnce West (North)
10 cm	max.	29	38 (33)	+9 (+4)
grey	min	23	26 (24)	+3 (+1)
10 cm	max.	29	28 (26)	-1 (-3)
white	min.	23	23 (22)	0 (-1)
20 cm	max.	29	33 (30)	+4 (+1)
Grey	min.	23	28 (28)	5 (+5)
20 cm	max.	29	26 (25)	-3 (-4)
White	min.	23	24 (24)	+1 (+1)

- ( ) North wall
- (+) Greater than ambient temperature.
- (-) Less than ambient temperature.

The effect of window orientation on indoor temperature is largely determined by ventilation conditions and the degree and efficiency of the window shading. When shading is not effective building interior, the temperatures will be influenced by the orientation of the windows.

A set of four identical models of front Wall of each has a window and rear has a small opening with insulated shutter. Models were orientated so that the window of each face one of the four cardinal directions, for experiment.(1)

Immediately after sunrise, the model with the eastern window showed a steep rise in temperature, 13°C in four hours when compared with 5°C outdoor during the same period. In the west-window model the temperature rise was moderate until noon, but on exposed to direct radiation in the afternoon this rise accelerated and a maximum about 11°C above the outdoor level was recorded. The south-window heating pattern is slightly above that of north-facing model, the maximum temperature 3.5°C above that outside temperature.

Window orientation with respect to prevailing wind direction is likely to have a considerable influence on the ventilation of interior. The openings should be both at the windward end the leeward side of the building. Wall having

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(1) Givoni, B Man, Climate and Architecture.

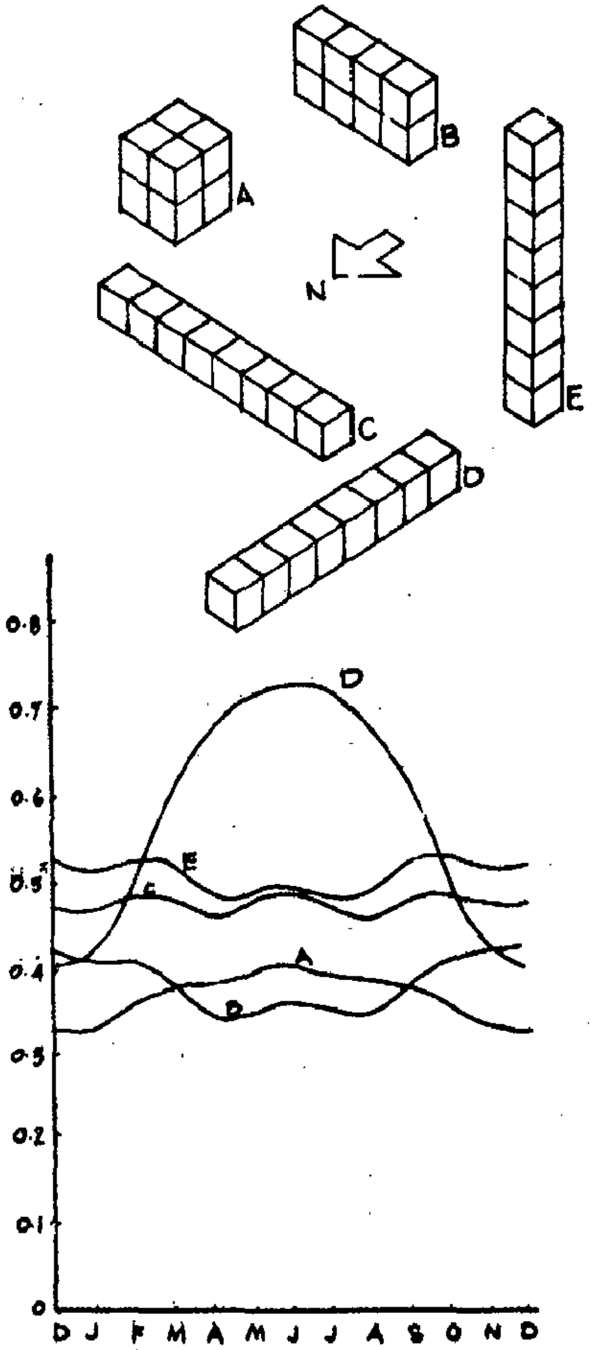


FIG. NO. 4.2 IMPACT OF SHAPE AND ORIENTATION ON THE DAILY INSOLATION OF A BUILDING THROUGHOUT THE YEAR.

inlet need not directly face prevailing wind incidents to wall upto 45^{o} angle can provide satisfactory ventilation without much depletion in wind speed.

4.3 Surface Area to Floor Area Ratio :

The solar heat gain to the building interior takes place through the external surfaces exposed to the environment and get distributed more or less evenly by various heat exchange processes throughout the enclosed volume. Therefore the relationship of the external heat breathing, surface area to the floor area enclosed or to the volume enclosed is of significant importance. In a single storeyed building when perimeter increases, the surface area to floor area ratio (SA/FA) decrease considerably. This is because surface area decreases with respect to floor area when perimeter increased, it can be said that the heat gain per unit area reduces considerably as the perimeter of the building envelope increases. In case of multistoreyed building the SA/FA ratio will get smaller when number of floors are increased.

4.4 Infiltration :

Heat tends to travel from higher to lower, temperatures in the process of heat transfer. It modifies its form to reach the cool area. Due to the pressure differential in outside and inside, the air through the gaps and cracks in the building envelope. This process is called infiltration. This infact is very difficult to be controlled. It needs perfect workmanship, good design of openings etc. usually heat transfer takes place through the gaps between shutters and frame. If the temperature difference between inside and outside is more, the heat transfer through infiltration will be more. Heat transfer takes place through convection air currents.

4.5 Material :

Right from the ancient times mud is popular as one of the building materials, then comes lime. In recent times cement dominated the earlier two, due to its high strength and durability. We do not observe any sort of discomfort reported by our ancients and forefathers been pointed out. Now this discomfort is a common complaint of each and every house especially in hot-dry climates like Khammam. But cement does not give good thermal performance. While mud and lime got better thermal performance, to the buildings. Building materials definetely has role to play in achieving comfort inside the building.

4.5.1 Mud Construction :

Earth construction has continued to be the principal building process in the non-industrialised countries, it has undergone a steady decline, mainly over the last century and it is virtually disappeared from some western countries. The reasons for this decrease are manifold and have their roots in the profound socio-economic changes which the industrialised countries have experienced. The large-scale urbanisation, increasing centralisation; the predominance of the monetary system as the principal method of exchange and break down of collective forms of organisation. Industrialisation introduced competitive new building techniques, products of easy transportation, the increased division of labour and change in the pace of life, rendered people, even in the countryside, which ultimately reduced the usage of indegeneous materials like mud which is very relevant in achieving comfort condition at that particular climate. People are not that free to build their own houses and feel deprived of the time needed for the regular maintenance .

Some of famous architects like Le corbusier, Frank Lloyd wright, Hassan fathy, did to implement mud in their project,but only Hassan Fathy did achieve success in implementing their proposals. Now architects are considering earth construction in the light of the additional advantages provided by modern techniques. The preparation of earth construction requires a minimal amount of energy not only for the production adobe bricks and earth mixtures but also for heating and cooling the completed buildings, of course, the thermal inertia of earth building is due to the thickness of the walls, rather than the property of the material. It is interesting to observe that inhabitant in an earth house feels warm in winter and cool in summer.

4.5.2 Lime Construction :

Lime has been the binding material used in construction such as the Agra Fort, Golconda Fort, etc. which have stood the test of lime. But lime has gradually replaced by cement. Scientists are now focussing the importance of lime, to replace costly cement, once again as the ideal binding material for construction of houses. As lime-plastered houses do not develop cracks and are ideally suited for tropical climates to take much expansion and contractions. It keeps low temperature inside the building than those buildings built with reinforced cement concrete.* Scientists feel that lime is good for mortars, plasters and foundations but not for columms and lintels.

Brick can be made out of hydrated lime for construction of walls. Rapid setting lime plaster adheres wall to wall faces and is resistant to water, has good accoustical properties and also fire resistant. The plaster which is mixed with sand and applied to the wall starts setting in two hours and become fairly hard in 24 hrs. CBRI has experimented on lime bricks in Hyderabad.

* The Hindu, July 13th, 1984.

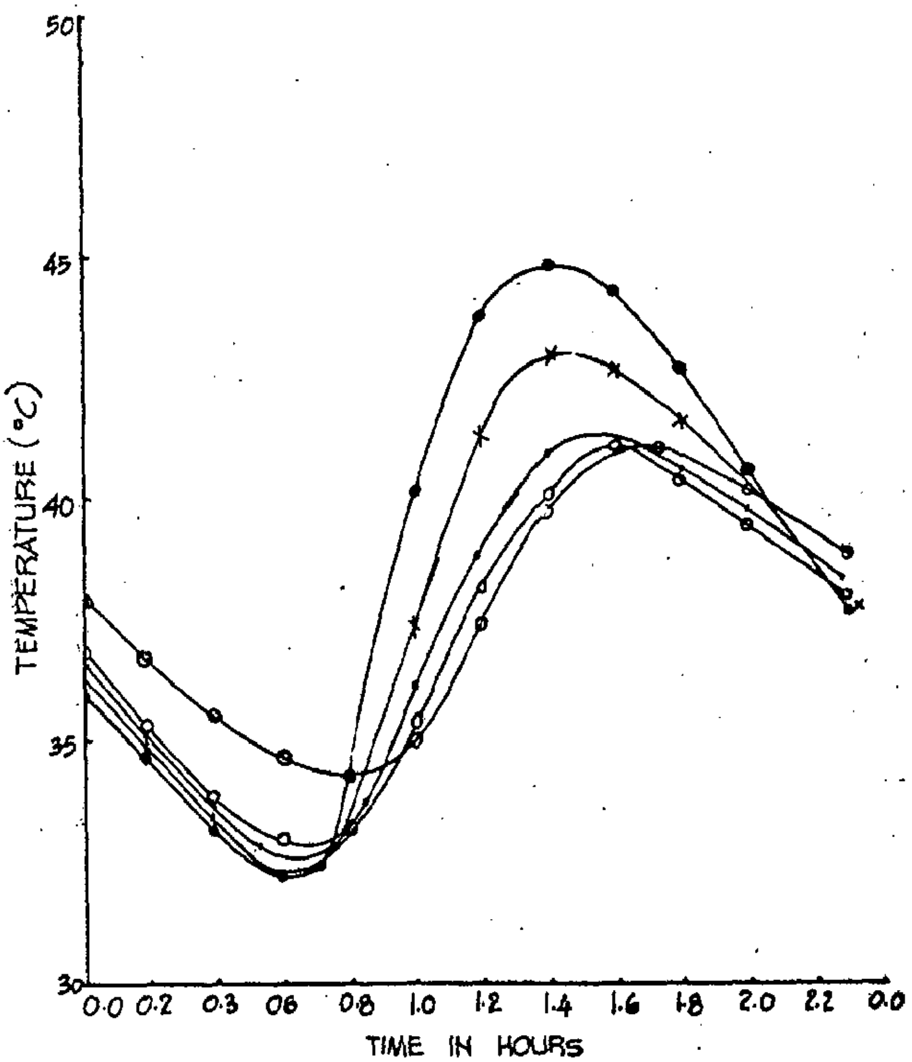


FIG. NO. 43 VARIATION OF INSIDE SURFACE TEMP. SHOWING EFFECT OF DIFFERENT PLASTERS & WHITE-WASH.

NOTES:

o—o	11.5 CM	SOLID	BRICK	PANAL	WITH	2.0 CM	LIME-SURKI	PLASTER	BOTH SIDES
⊗—⊗	23.0 CM	SOLID	"	"	"	"	CEMENT	"	" "
●—●	11.5 CM	"	"	"	"	"	"	"	OUTSIDES
—•—	11.5 CM	"	"	"	"	"	LIME-SURKI	"	"
—x—	11.5 CM	"	"	"	"	"	SAND	"	"

AND WHITE WASH OVER IT.

In the graph No. it is clearly shown that how the lime plastering is effecting in cooling the indoor environment.

4.5.3 Concrete Construction :

The general thickness of concrete structure in residential building envelope won't be more than 15 cms in some places it only 10 cm. But according to CBRI reports, that even 15 cm thick roof of the building are not suitable to the hot dry climates until unless it is insulated above (roof is the only one where most of the concrete is used in building which is exposed to atmosphere). As B.S. Saini from Austrialia has presented in the table below :-

Time log	Temperature in concrete roof slabs (air temp. 26.7°C)	Upper surface	Lower Surface	Mean
85 min	2 " conc.	49.4	46.1	46.7
150 min	4" conc.	40.0	36.4	36.9
360 min	8" conc.	38.3	28.9	31.1
300 min	8" hollow conc.	37.5	31.1	32.2

But due to high strength, it entered into most of the parts of the building envelope, like, it replaced wood in terms of frame a opening, thin partition walls for show cases etc. Apart from strength, it has durability, weather resistance, fire resistance and good binding capacity.

4.6 Surface Treatment :

Surface treatment has considerable effect on thermal behaviour of the building and on comfort conditions. The surface of building envelope can be treated with different materials having different absorption and reflection co-efficients.

The bright surfaces like Aluminium sheets, white washed surface will show less absorbance toward radiation, in fact bright metal are better than other treatments in reflecting the solar radiation. Dark colours are not at all advisable in this climates. Different material will have different values of absorption and emission which are given in Appendix No.

4.7 Colour :

It is well knownfact that colour can create psychological effect, in different ways, it can create a feeling of comfort, nurves - strain, either increases or decreases the physical activity.

The temperature of a colour plays a large part in its applications. Red, orange, yellow are warm colours. Where Blue, greens . are classified as cool colours. Yellow is the lightest of the major colours. It is pleasant on the wall and ceiling, because it fills the room with sunshine and brightness. But one thing, should be remembered that yellow looks twice brighter than the sample when painted on the wall. Orange is used to brighten surface and these type of colours look even brighter in direct sunlight. One should choose colour scheme that combine cool and warm colours to complement the changing light.

A colour like red might infact the feeling of hotness where as greens and blues bring the freshness to nature and living thing into the room. Green cools the eye and many shades of it work well together.

The places where, the outdoor temperature is more often greater than indoor temperature, there interior are advisable to use cool colour to get some sort of comfort feeling (apparent).

5.0 PASSIVE COOLING TECHNIQUES IN PRACTICE :

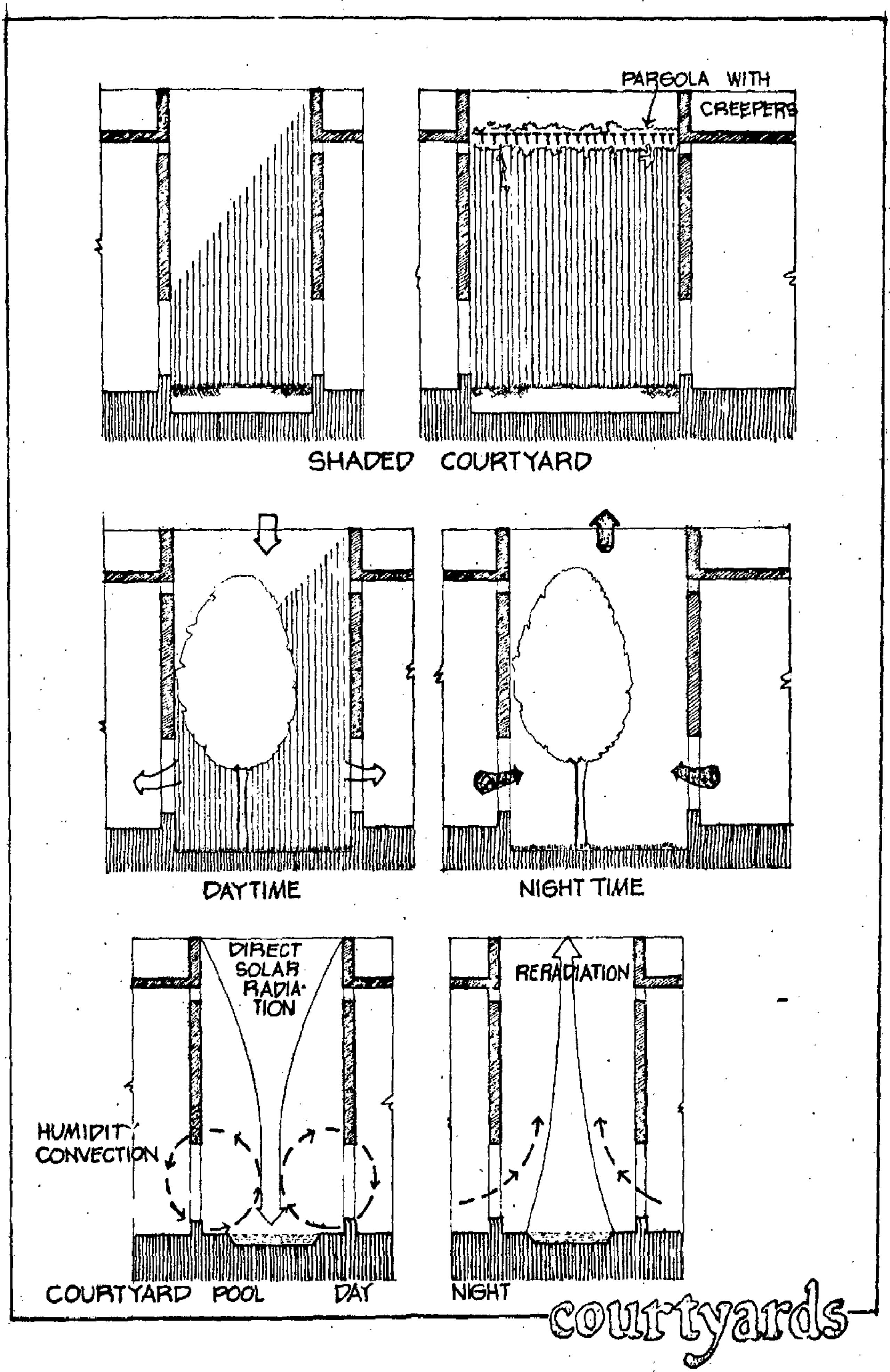
Introduction :

Even though cooling is much more complicated, diversified and climate related than heating, especially in passive systems. There are different methods of cooling indoor environment was invented in different countries and for different climates. Thanks to William W. Holmes, who classified the entire passive cooling techniques into 10 simple comprehensive categories on the basis of applications over theory. Those are gain prevention techniques, site cooling, earth cooling, skycooling, ventilative cooling, vapor cooling, flywheel cooling, solar cooling, venturi cooling and hybrid cooling. Even after this broad classification, sometimes it will be difficult to say on which type of the cooling does a method belongs. For example, windscoop, it comes in both evaporative cooling and ventilative cooling. Coming to the traditional way of cooling, which we generally observe in old palaces and building are : water wall (Agra fort), windcatcher (Golconda fort), underground living (Rajasthan desert area), courtyard houses, etc.

5.1 Courtyards :

This is one of the traditional cooling method for indoor environment, in the tropical climates which is still existing in some countries but in most of the areas it disappeared, may be due to rapid urbanisation and high land prices.

The concept of the courtyard house was developed in the hot dry regions. Examples of the traditional courtyards house shows that design of houses which include social, cultural, technical and enviromental factors. The concept of arranging rooms


PARGOLA WITH CREEPERS
SHADED COURTYARD
DAYTIME
NIGHT TIME
DIRECT SOLAR RADIATION
HUMIDITY CONVECTION
RERADIATION
COURTYARD POOL
DAY
NIGHT
courtyards

rooms around an open space to solve climatic problems was continuously maintained from our forefathers. In courtyard houses, it is observed that the interaction between external climatic condition and thermal condition of the indoor environment passing through the envelope of the courtyard, is well banced in achieving thermal comfort.

The present problem is how to reduce the heat loads which are effecting the indoor comfort in hot dry climates. Internal courtyards and a compact layout for a group of buildings would provide mutual shading between surfaces with the consequence of reducing the thermal load on them. In summer a pleasant continuous circulation of moistened air is kept up through by using grass, trees, vines and water bodies in a courtyard which acts as 'cooling well'.

Trees have been planted in alternate rows of courts which is being shaded, have cooler air. This air at lower temperature circulated from the shades to the sunny courts, where the rising hot air creates lower pressure. In its passage the moving cool air from shaded courts ventilates the rooms, which are located between the sunny and shaded courts via perforated gates and louvered walls. Compact planning based on the courtyard concept has proved successful because courtyard is an excellent thermal regulator.

Courtyard having trees in it reduces heat load on exposed surface by obstructing the passage of direct solar radiation, which is achieved by using high percentage of energy through the process of photosynthesis and also because of reflective nature of some foliage. The cooler surfaces on the ground will draw heat from the surrounding areas, remitting it to open sky during the night.

The purpose of the courtyard pool, is to serve the purpose of air humidification as well as water is an excellent thermal regulator when it is enclosed. During the hottest hours of the day an average of 90% of total solar radiation is absorbed, at that area, by the pool surface. As it increases the humidity by evaporation the dry bulb temperature drops. At night time, the relay of heat from the pool to the outer air, aids conventive movement and allow cool air from roof (explained in the later paragraph).

It is better if the courtyard's size is kept small enough to achieve shade during day, it will allow less thermal impact and more heat dissipation from surrounding indoor spaces. It is suggested that the courtyard's dimension in plan should not exceed its height* and oriented to East-West.**

It is observed that increasing the courtyards height from one storey to two, showed a decrease of 2 or 3 hrs of solar penetration. The shading of courtyard can be done by covering with purgola carrying creepers or by louvers. It was also suggested that the roof of the courtyard house should be surrounded by a parapet at the outer edges to restrict heating of air layer above the roof by the warmer external air and the roof should slope towards the courtyard to channel the air cooled by night into the courtyard space.

~~PASSIVE COOLING TECHNIQUES IN PRACTICE~~

5.2 Ventilative Cooling :

Ventilation effects have direct influenc.. on humen body comfort, which depends on air purity and movement and has an indirect effect on indoor air and surface temperatures by influencing its temperature and humidity.

Ventilation serves three purposes : One is to maintain the quality of the air in the building above a certain minimum level by replacing indoor air. Second one is to provide thermal comfort by increasing the heat loss from the body and preventing discomfort due to sweating. And the third one is to cool the building structure, when the indoor temperature is above that of outdoor(Structural cooling). The later two comes under ventilative cooling so we discuss in detail about them.

This process will be different for different climates, seasons and wind speed etc. The purpose of thermal comfort ventilation (convective cooling) is to provide comfortable thermal condition inside, this prevents the discomfort created by sweating. It mainly depends on the temperature and vapour pressure within the building. Ventilation in terms of air velocity should be specific for a particular period. Excess and less ventilation rates create discomfort.

The relation between air flow rate and velocity depends also on geometry of the space, location and sill height of the window, orientation of window according to prevailing wind, overhang at window top (lintel level) both internal and external etc., which is explained in detail (appendix No.) in the building digests No. 100 and 121 of CBRI.

The air velocity required to attain comfort increases with air temperature because the same cooling effects must be obtained through a small temperature difference between body and environment until 35°C, irrespective of humidity. But above 35°C the increase in air velocity elevates the convective heat gain which ultimately leads to discomfort, here it depends on humidity, clothing conditions etc.

As air has a very low heat capacity and therefore when a building is not ventilated the temperature of the indoor air attains that of the surrounding internal surfaces and fluctuates nearly about the average external surface temperature which is dependent on external surface colour structure's heat capacity, thermal resistance and temperature difference between inside and outside.

It was observed that when external colour is grey, ventilation reduced the indoor air and western surface (temperature) maxima and minima. When the same surface is treated with white, the maximum temperature is lower or increased depending upon wall material. Ventilation lowered the minima in all cases considerably.

Even the night time ventilation, which is most important in hot dry climates, is affected by external surface colour. When it is grey, the permanent ventilation had a much greater cooling effect than night ventilation, but with white exterior night ventilation had a great cooling effect. There is a chance that indoor air temperatures were even elevated when the experiment models were ventilated during the day. Thus, grey painted concrete walls were more affected by ventilation than lightweight concrete walls of the same thickness.

When indoor temperature is above the outdoor level, ventilation lowers the indoor temperature, but in reverse conditions the effect is opposite. During the evening and night the indoor temperatures are above the outdoor level in all ordinary conditions so the ventilation at this time always has a cooling effect.

It may be predicted that building with light external colour, medium to high thermal resistance and heat capacity, relatively small and shaded window, have daytime indoor temperatures lower than the outdoor.

In hot dry climate it is desirable to reduce to a minimum the ventilation required during the daytime and windows are generally opened in the evening, especially in the summers.

Rate of ventilation can be accelerated by different methods like : Solar induced ventilation system, wind catchers etc.

In the first system, a solar radiation trapper is a special envelope on the roof and it makes the air below it hot and allows it to go out, then this places is replaced by hot air near ceiling, and by allowing room to get air from outside which is cooled on the way (Fig. No.).

Iranian wind tower (Fig. No.) are best example to this method of cooling. This wind tower is built on massive walls, facing prevailing wind direction. During the night, when no wind movement is there outside, the tower acts as chimney. The hot air passes through the tower taking the heat of massive wall along with it to outside. Then the building get air from outside. In case windy night, the air moves inside through the tower and make the indoor space cool.

During the day time, wind is allowed to pass through the tower (which is cooled in the previous night) got cooled when it come in touch with wall surface, then the air will get cooled. The air movement can be controlled by the doors, By arranging some water body or a fountain in the passage of air, the air is further cooled by evaporation. There are number of other designs in the wind towers which are working on the same principle.

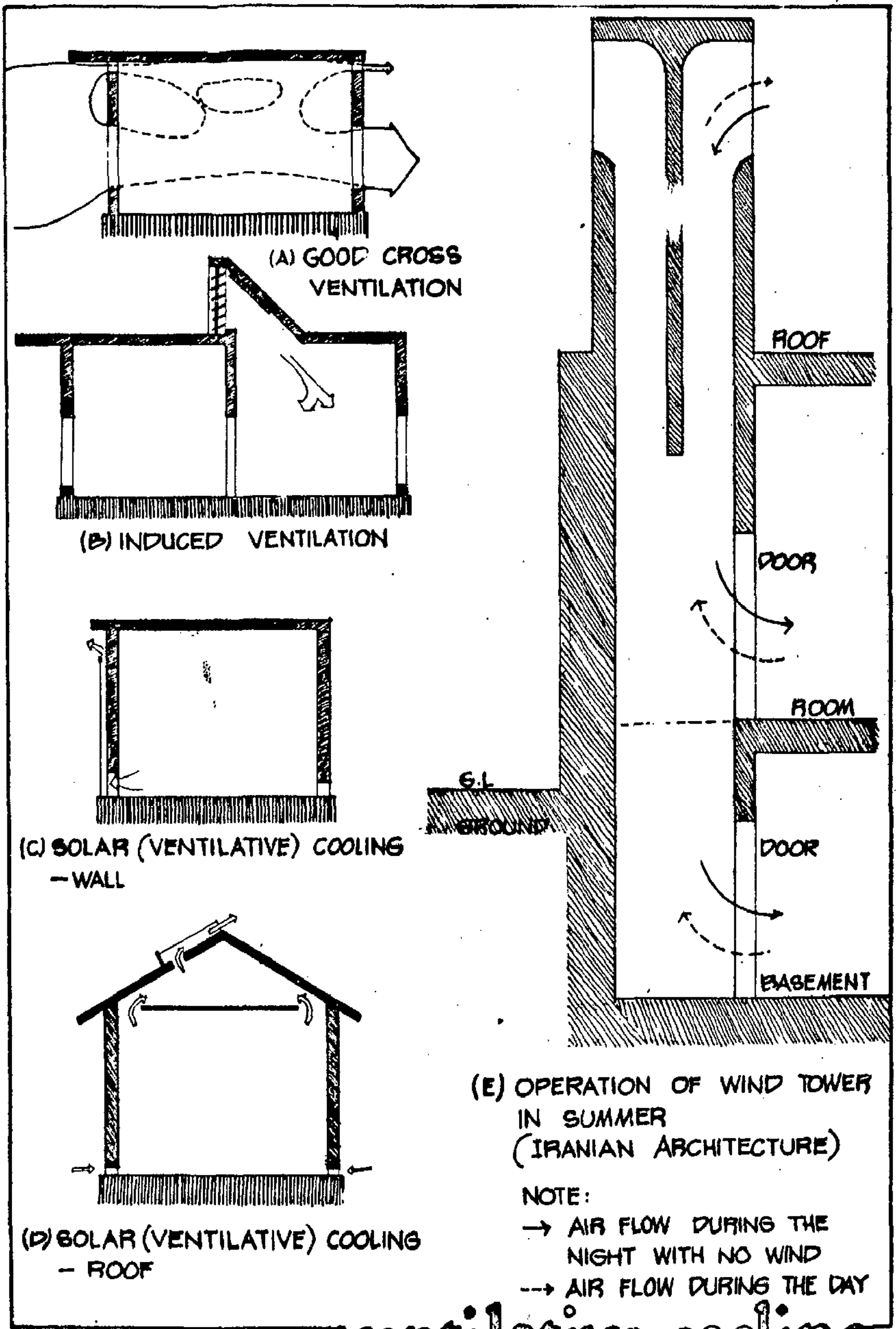


FIG. NO. 5.1 ventilative cooling

Induced ventilation can be achieved by projecting, the building envelope in the direction of prevailing wind (Fig. No.) and can be controlled by special arrangement like Louvers and shutters etc.

5.3 Solar Cooling :

The use of solar energy for cooling of building seems most appropriate for tropical and subtropical climates. There are some techniques which are used for cooling with solar energy but most of these were too technical to implement. Even then those techniques come under hybride cooling but not passive cooling.

In passive solar cooling one method we trace, which can be easily implemented is as shown in Fig. No. . This system can be used for both roof and walls. In this process the surface which is facing sun will have two layers, one is a thin sheet and other one is building surface (wall/roof) with a gap in between them. The thin member will have an opening at the top and for the structural member at the bottom. When the external thin sheet, either it is metal or asbestos, exposed to direct sun, it gets heated rapidly and make the air in between hot. The general tendency of hot air is moves up, due to stack effect, to replace this void, the indoor air moves into this gap. Then to replace air void inside the room, air oomes from outside, before it enters the room it is necessary to make it cool either by allowing it over water surface or from a courtyard, otherwise the outside air temperature, in summer will be hotter than inside temperature.

5.4 Site Cooling :

Besides the effect of building envelope and different arrangement like surface treatment, placement of opening and air flow inside the building, there are some more factors which will have considerable influence on indoor environment like vegetation, water and the surroundings. These factors are particularly important in the places like Khammam which comes under a hot-dry climate.

Due to excessive radiant heat, high air temperature, glare, low humidity and inadequate water, the microclimate will show definite variation in summer indoor comfort when compared to other seasons. In some of the places of our traditional Architecture we can observe the landscape had definite provision in their designs, like water, vegetation and Landforms etc.

(1) Water :

Water pool acts as a heat reservoir in an enclosed space and during the hottest hours of the day. An average of 90% of the total radiation absorption is obtained by the pool surface. The water placed in the surroundings of a building can be a still pool, a falling stream, or a fountain. Water increases the humidity content in the surrounding air by evaporation and decreases the dry bulb temperation. Air is made to pass over a wet surface before it enters the building. The rate of evaporation of water depends on the velocity of air which is passing over it and also depends upon the area of exposer of water to the air. If farmer is increased the later also will get increased.

Water creates glare too which leads to uncomfortable conditions if it is not shaded property. There are some places where people grow water hycinth (or any water plant) to avoid glare without loosing its purpose.

(ii) Vegetation:

The growth of vegetation results in immediate and drastic changes in microclimate, because the plant like humanbeings evaporate moisture for maintaining their foliage temperatures. This unique Sun breaker provides surface shading without getting heated like concrete and other building materials.

Vegetation (Trees, shrubs and grass) in any form, ameliorate air temperature in urban environment by controlling solar radiation. Tree leaves intercept, reflect, absorb and transmit solar radiation. The effectiveness depends on the density of species foliage, leaf shape and branching patterns. Trees and other vegetation also aid in ameliorating summer air temperature through evapotranspiration by orienting their leaves towards sun. Because trees screen sunlight and transpire moisture, the air below the forest canopy can be as much as 14°C cooler on a still summer day than in an open area plants can be used to screen and soften both primary and secondary glare (direct and reflected excess light).

The area under thick and large foliage cover take more time to cool. The cooling takes place due to process of photosynthesis and upto some extent the reflective quality of some foliage, within the vegetation.

Similarly grass preserves moisture in the root system and mitigates thermal transmission. It creates a thick heat absorbing layer and gives shade to the soil below, thereby preventing a large amount of heat absorption and re-radiation. All the vegetational cover also prevents soil erosion created by winds, and glare due to excess light.

If a tree is too close to the building, it may damage the foundation, by absorbing the moisture which is underneath the foundation. But the vegetation like shrubs and plant do not possess this problem. If they are placed well in position, they can cool the incoming air (Fig.). Sometime due to improper placement of trees, may obstruct the incoming air. Even by putting the trees in a line we can achieve higher wind velocities if required. Trees need time to grow in achieving the effective shading height and in the initial stage it needs maintenance also. Meanwhile, it is possible to plant some quick growing creeper as a temporary measure. It is better to select a native tree rather than introducing a new tree at a particular place. It was observed that speed of cooling which took place over an area that on bare ground the temperature was reduced by as much as 22.2°C in 5 minutes after it got shaded*.

To get maximum benefit out of trees in getting maximum shading, their best position are on east, south east, south west and west in the northern latitude. Low sun rays in early mornings and late afternoons are difficult to control but using shrub it can be minimised. Trees are classified by Dr. Datta K. L.** into three groups like round, oval-shaped, vertical and he recommended their position like round shaped trees (spread and height are almost same) may be located on south east, south and south-west side in northern latitudes. In the second type (oval-shaped) of trees (spread is nearly half the height) can be used on east and west a little away from the building. The third type (vertical) of trees (spread is not wide) can protect the south wall and some part of the roof if it is placed nearer to the wall.

Mr. Everest, in Lesotho, built a tree house (not houses in trees) in which he did not use any building

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*Saini, B. S., Building in hot-dry climates, John Wiley and Sons Ltd., U.K. 1980.

**Datta, K. L. Contribution of Landscape to building comfort. Indian Construction news, December, 1961.

material at all but he shaped it entirely by natural means. He bent the growing branches so they had no choice but to grow. He cut off trunk to stop the tree growing too tall and also to make it grow bushier. This slow process took him eight years. Except in heavy rains and severe cold, he is spending his whole life on the tree, since 1967*. Similarly there is a chance of bending trees to get more shade on the building, but it needs patience.

The creepers require a certain amount of support and spread in accordance with the available space and facilities, selection of ereeper should be on the basis of coverage and growth.

Land forms :

The effect of surrounding surfaces of a building has a definite impact on indoor environment as well as the environment of the town as a whole. All surfaces which are exposed to solar radiation for a considerable time will absorb heat and reradiate to the surrounding especially the surface like, concrete, pavings, bare ground and roads etc. This effect is severe in the afternoon. Solar radiation varies considerably according to topography and physical characteristics of the land. It was observed that by

*Everst Kabelo, Home on top of a tree,
Life style abroad, THE HINDU, Sunday, July 1, 1984
(A South Indian newspaper)

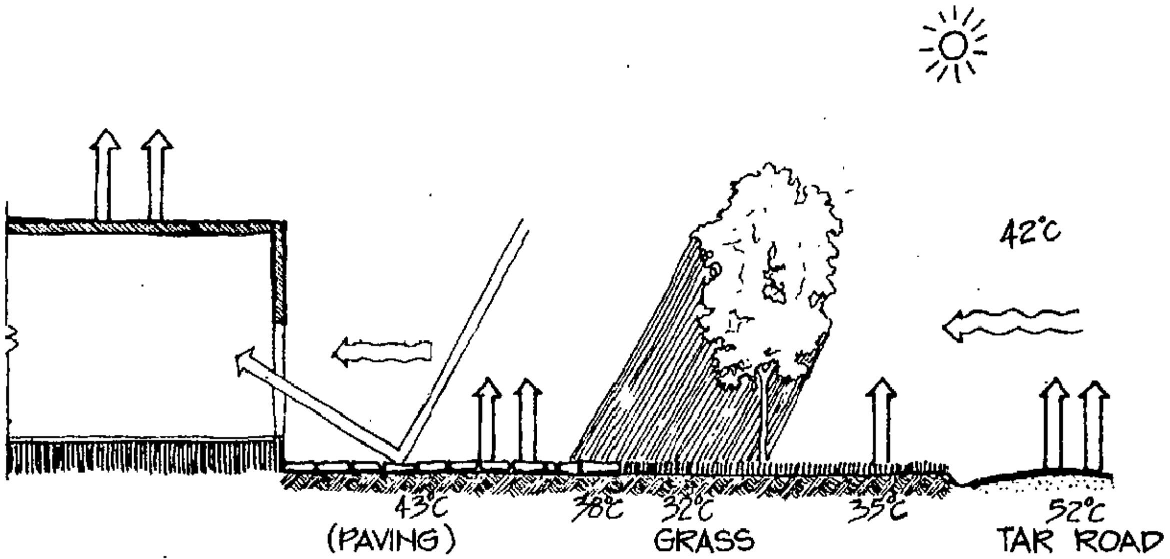
increasing the slope with respect to south at different angle 0°, 30°, 60° it was recorded a decrease in the solar load of 293, 267.6 and 172 W/m^2 °C respectively*, when measured on June 22nd noon at Roorkee.

Heat transfer takes place in four ways, in the ground that is: by absorption, conduction, convection, evaporation (Fig.). The thermal behaviour will depend upon the conductivity, absorptivity, texture, density, moisture content and colour of the soil,

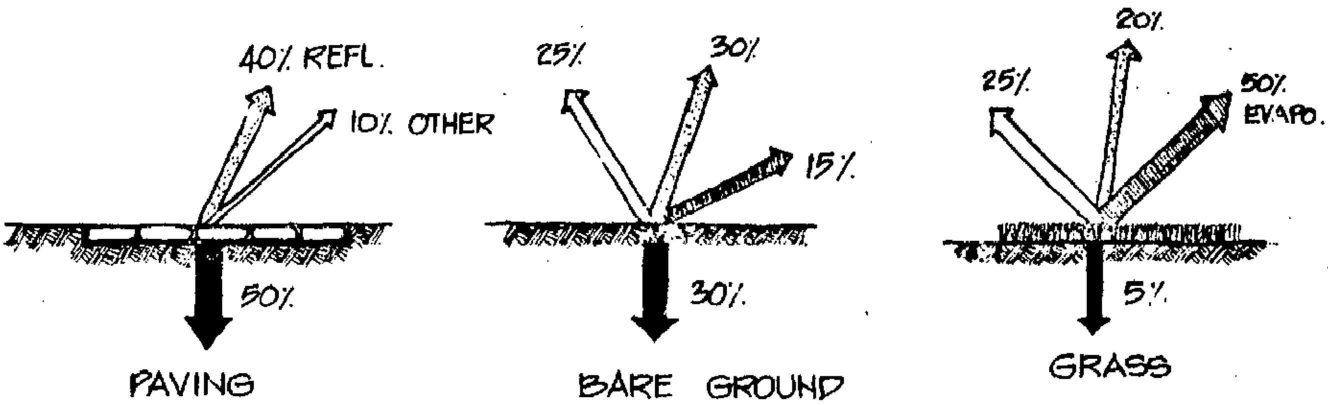
The air temperature near the ground depends on the surface treatment. The surfaces like concrete, asphalt, heat the air above it hot and which is carried into the building, ultimately creating uncomfortable conditions inside the building (Fig.). The surfaces like sand, paving, and water will create glare too, besides it reradiation. The surfaces which are well shaded and ground covers like grass will minimise the air temperature above it.

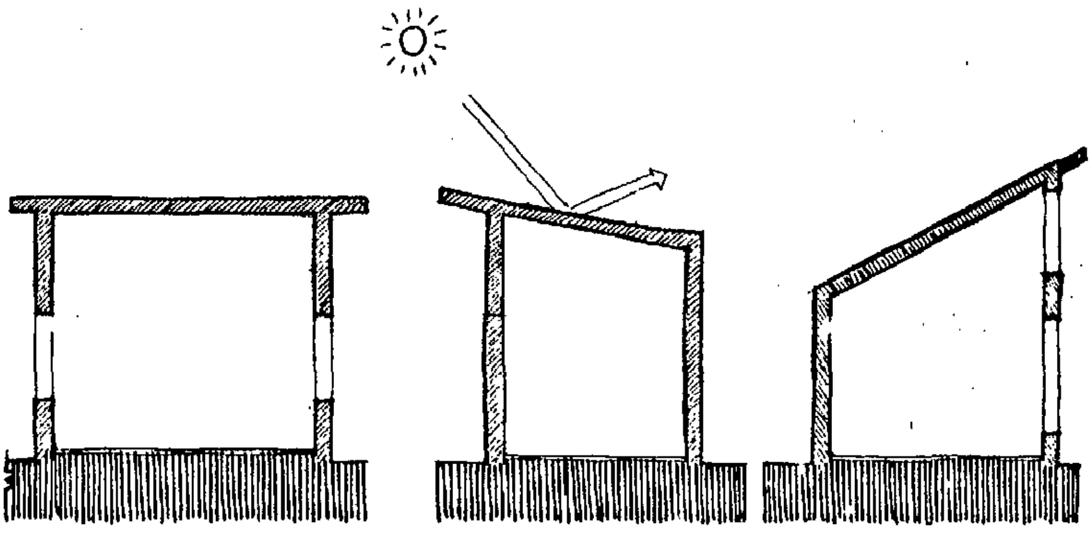
Now-a-days, people prefer to construct their houses as an individual block instead of compact and row housing. In case of individual isolated building the area exposed to atmosphere is more (5 surfaces) when compared (3 surfaces) to row houses, naturally the more area expose to the environment, the more heat transfer takes place from outside to inside.

*Saini, B. S. Building in hot dry climates



SURROUNDINGS





NOCTURNAL RADIATION   INCLINED ROOF   NORTH SKY RADIATION

In compact or row houses as much as 2/5 surface is not exposed to environment which certainly will have great reduction in the temperature of the surroundings. Similarly roads should be properly shaded by encouraging the road side plantation.

Conclusion :

By treating the surroundings, the micro-climate around the building will considerably be improved. It not only keeps cool surrounding of the building but also can change the town climate itself when every one's contribution is there. Here method adopted is by eliminating heat storing bodies from surrounding and adding the non-heat absorbing material to achieve cooling effect.

5.5 Venturi Cooling :

When a hole is made at the apex of a dome or cylindrical roof the low pressure created at this point vents the hot air under the roof. In areas where wind direction is predominantly constant the roof are cylindrical with axis normal to this direction, whereas when wind blows in almost all directions then one finds dome type roofs. This principle is based on Bernoulli pressure velocity - temperature cooling effect.

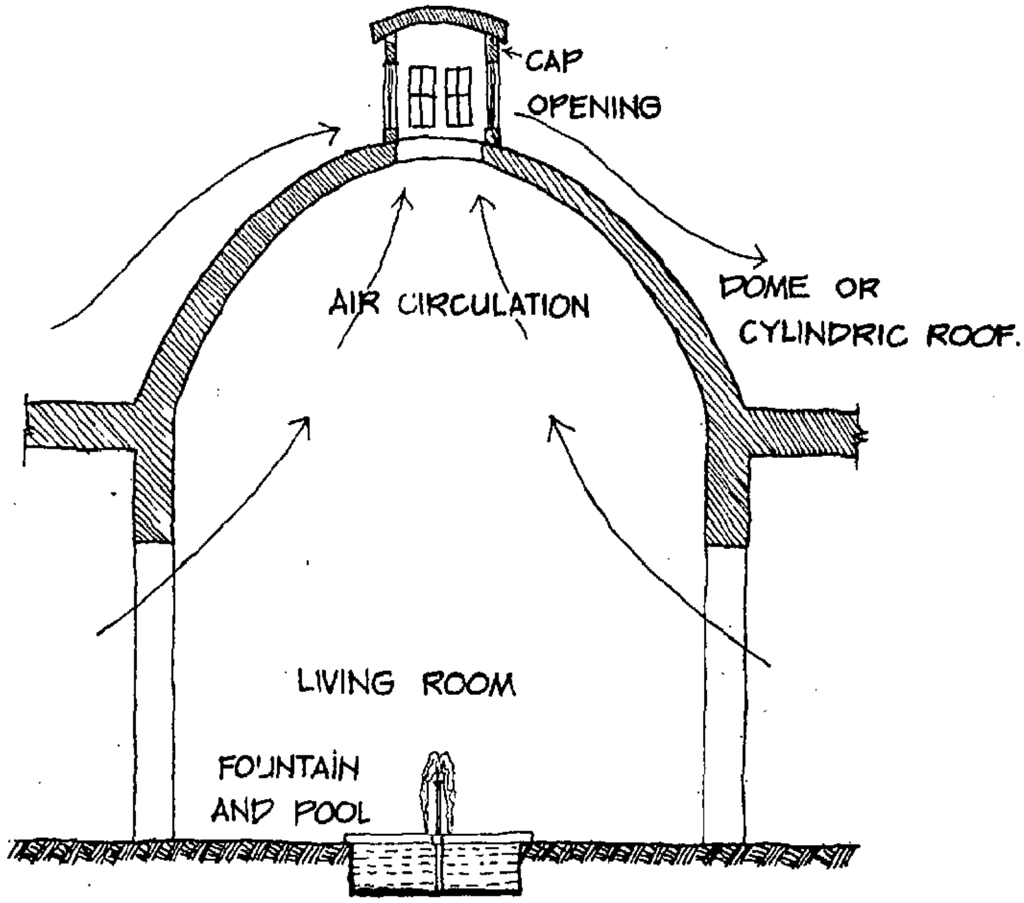
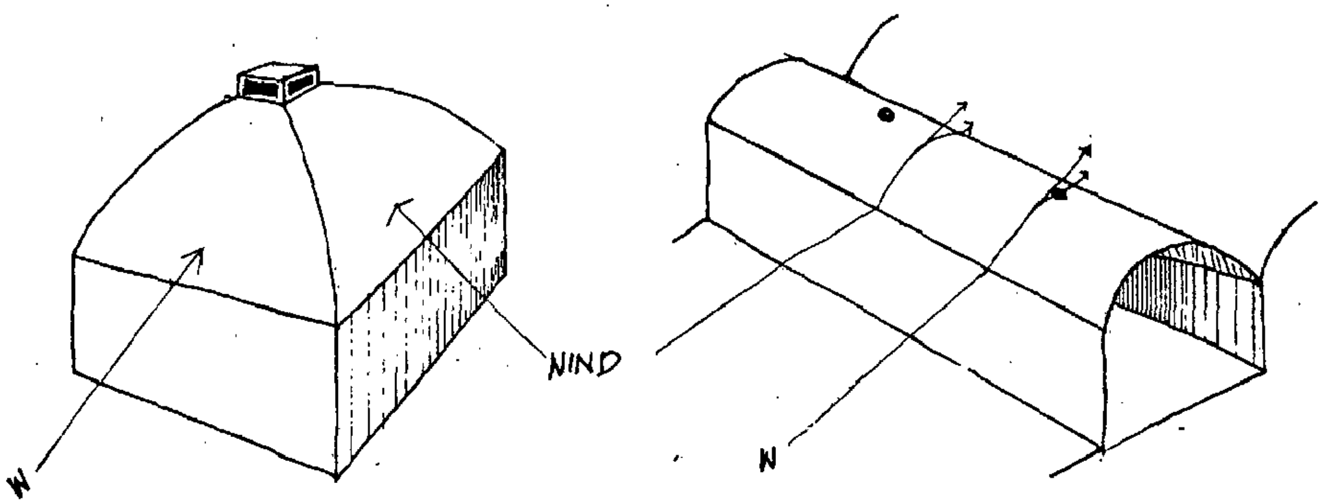


FIG. THE AIR CIRCULATION PATTERN IN A ROOM WITH A CURVED ROOF.



EXAMPLES

FIGURE NO. 5.3

5.6 Sky Cooling :

Any element of the external envelope of the building which sees the sky, loses heat continuously by the emission of longwave radiation. As the roof is the building element, most exposed to the sky, it is the most effective longwave radiator, especially during the evening and night.

Sometimes, the sky will have cloud, water vapour, CO_2, dust which will absorb and emit longwave radiation. Thus at night, there is a balance between the radiation emitted by the roof towards the sky and the downward radiation from the atmosphere. Only the net radiant heat loss is effective in cooling the building. This in turn depends upon the temperature difference between the emitting surface, which closely follows the temperature of the ambient air, and effective temperature of the atmosphere (it depends on cloudiness conditions and ambient humidity) The net radiant heat loss decreases greatly with cloudiness. While utilizing outgoing longwave radiation to cool building, when the radiative surface is below the ambient air temperature, the overall heat loss depends not only on the net radiant loss, but also on the convective heat gain from the ambient warmer air which, in turn, depends on wind velocity near radiating surface. This wind reduces the temperature depression of the radiation and its cooling potential. One way to increase the efficiency of radiant cooling is to protect the radiating surface from the wind effect by a screen transparent to longwave radiation.

Even in a humid region, Givoni observed, depression of a radiation made of ordinary material under clear sky condition, is about 4 to 7°C, depending mainly on wind speed at night. This temperature depression forms a potential for utilizing the longwave nocturnal radiation as a source of natural energy for cooling the building.

The relationship between the temperature of the radiating surface and the ambient air depends on the heat capacity of the radiation. When a roof with a high heat capacity serves as the radiator (concrete roof) its external surface will usually be above the ambient night temperature, because the heat absorbed in it during the daytime. But in case of lightweight radiation, its temperature drops below the ambient air immediately after sunset and sometimes even before it.

For high mass roof, which are to be used for nocturnal radiative cooling, does not require windscreen above the roof but convection helps the night cooling process together with the longwave radiation. Windscreen should be used only in case of lightweight radiation.

A radiative surface with high emissivity and reflectivity, combined with specially treated polyethylene windscreen, a stagnated temperature depression of 16°C below ambient temperature has been recorded. These observed no difference between an ordinary and a selective radiation, both recorded 8.5°C, when ventilated.

The places where dew takes place, the temperature still drops, radiative heat loss will be more.

There are two methods in practice in the building, those are : sky therm and radiation roof trǿp which are explained in the later chapter in detail.

6.0 SELECTED PASSIVE COOLING TECHNIQUES :

Some time using one passive cooling technique may not be fruitful, there we have to use a combination of two or three techniques to achieve comfort conditions inside the building. So here three passive cooling techniques are studied in detail. Those are (i) gain prevention techniques (ii) Evaporative cooling, (iii) earth cooling. Among these the , first two cooling techniques can be used for both existing and proposed building. But the third cooling technique is studied for proposed building, as this system is not in practice at Khammam.

6.1 (i) GAIN PREVENTION TECHNIQUES :

This system is based on principle 'prevention is better than cure'. Different building elements are taken individually and their performance. The building elements which are taken are roof, walls, openings and flooring respectively. More emphasis is given to the roof as it receives more solar radiation than other building elements. The main element of discussion is prevention of heat transfer from outside to inside by shading or by other methods, like surface treatment etc.

6.1.1 (I) ROOFS

Introduction

Like other building components, roofs often do not receive adequate attention to their thermal performance at the design stage. Careful designing, planning and selective use of materials of walls and opening will not improve thermal performance of a building, if the roof is not properly designed. Most of the solar radiation is received by the roof than any other envelope in a building, especially in the tropics. Roof also loses the greatest amount of stored heat by longwave radiation to nightsky, for the same reason.

Roofs are not meant only to possess the structural safety but also should protect from the direct sun and rain, in attaining the thermal comfort and minimise maintenance cost of a building. An average of about 41% of the total cost of a single storey building is taken up by the roof construction alone. Even then people are not comfortable inside the building due to inadequate design measures that are taken while designing a roof. The design is mostly based on experience of the architects, as there are no building regulations as such for determining the minimum thermal insulation nor enough knowledge about the thermal performance of different roof construction to make design decisions relative to roof performance.

The traditional type of roof construction is basically heavy with thick layer of material which give high degree of resistance and modifies the diurnal variation in temperature. But application of this type of roof is practically difficult to apply. Modern roof construction are generally not heavy as traditional roofs. They may have high thermal insulation value than the traditional materials but they lack adequate thermal capacity resulting into rapid fluctuations in internal conditions, due to non-steady state of heat flow in hot dry climates in the calculation com become complex.

Dr. Ahmad has conducted a study at the University of Khartoum, during 1973 a half scale model building consisting of 10 rooms of equal dimensions (2m x 2m x 1.5m high) all facing the north/south, to determine the thermal performance of roofs and their surface finishes on internal air temperatures.

The experiment took place in four different stages as given in the Table-1. The point that are observed;

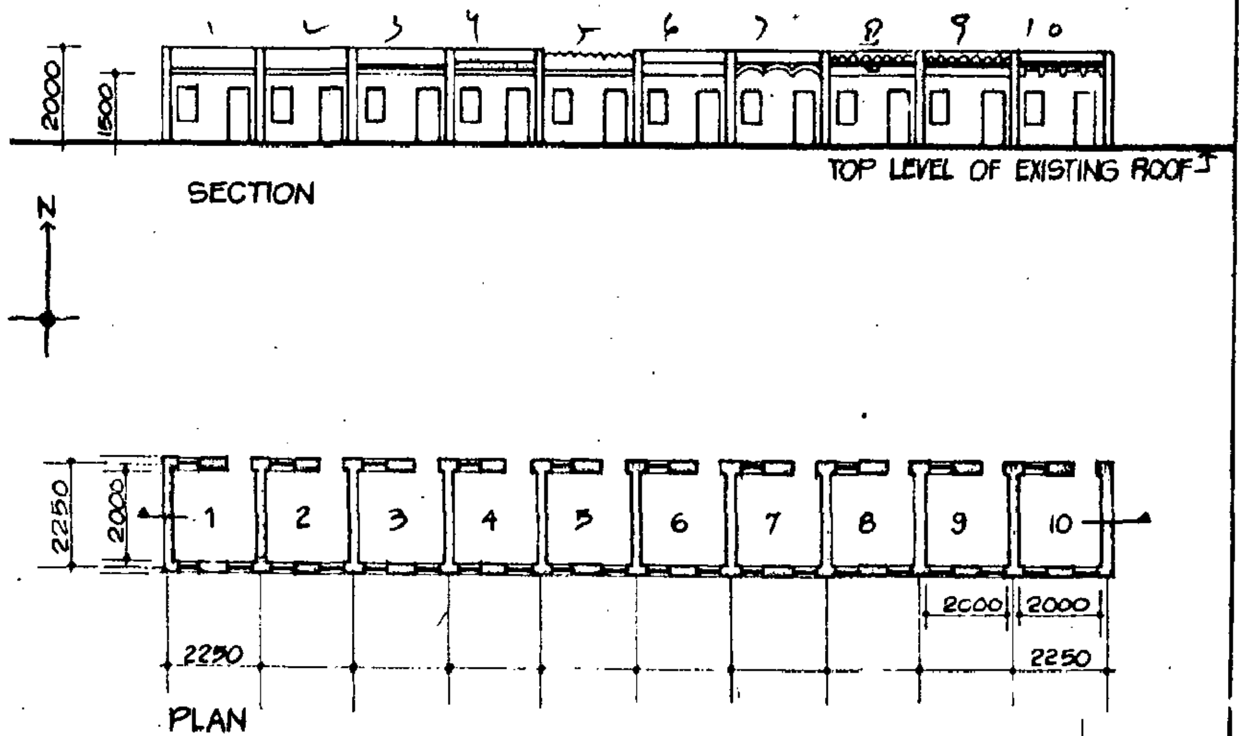
I. Initial Roof Construction :

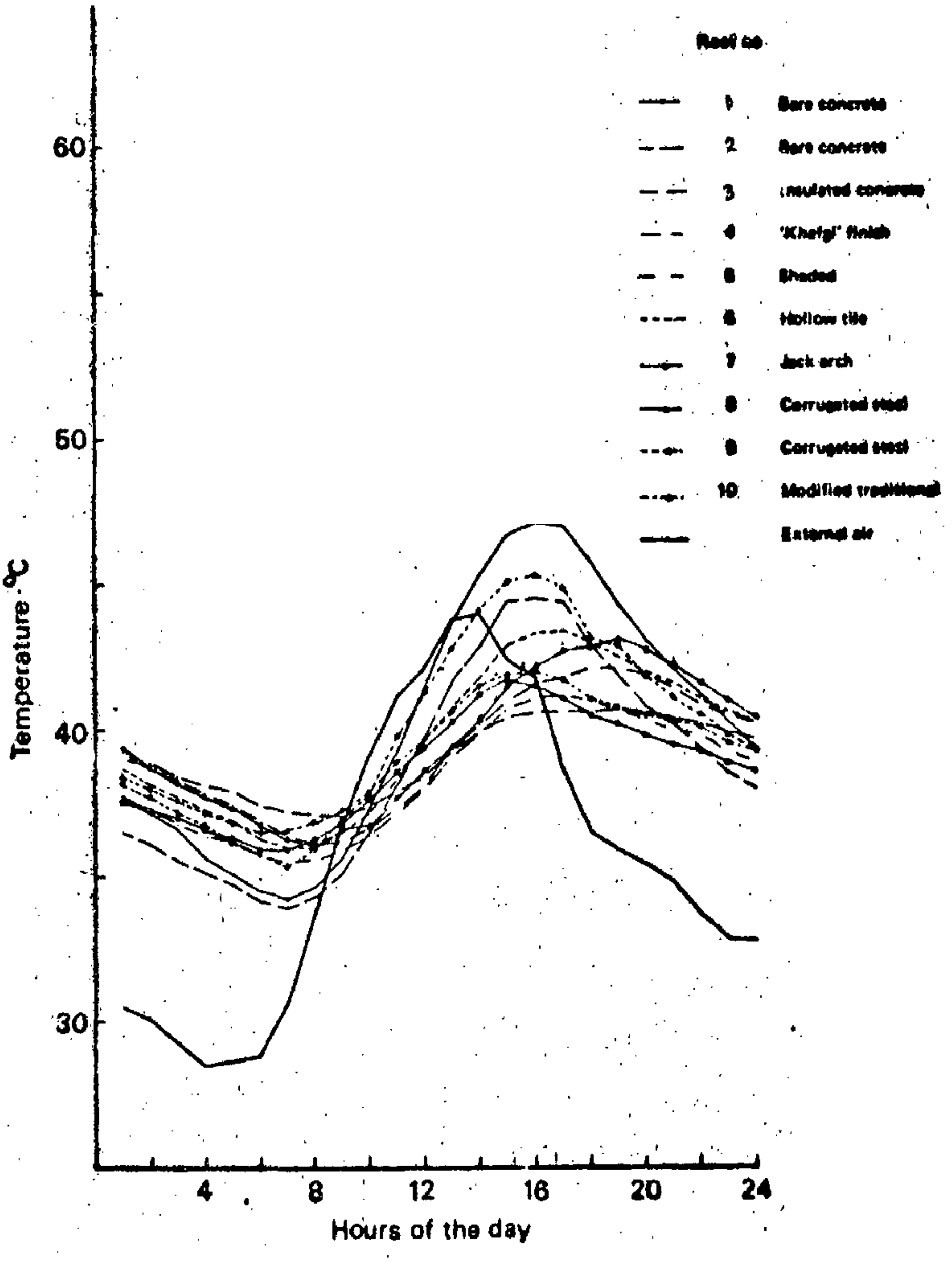
(i) The r.c. roof slab (Roof No.3) with a 50 mm thick expanded polystyrene layer on top, achieved the greatest reduction in both maximum slab temperature and its diurnal variation. Temperature of black roofing felt

TABLE.6 THE INITIAL ROOF CONSTRUCTION AND THE MODIFICATION DURING THREE STAGES OF THE EXPERIMENT

ROOM NO.	STAGE NO. 1 (INITIAL CONSTRUCTION)	STAGE NO.2	STAGE NO. 3	STAGE NO.4
1.	100 mm THK. R.C. SLAB			
2.	" " "	WHITE WASH	50mm LAYER OF WHITE GRAV.	75mm LAYER W. GRAVEL
3.	100mm THK R.C.SLAB + INSULATION + ROOFING FELT	"	WHITE R.C. TILE	
4	100mm THK R.C.SLAB + ROOFING FELT + KHAFGI*			WHITE WASH
5	100mm THK R.C. SLAB + CORRUGATED GALV. STEEL SHEETING (Ventilated air space in between)			"
6	HOLLOW TILES + ROOFING FELT + SCREED TO FALL (Ventilated air space)		UNVENTILATED AIR SPACE	"
7	JACK ARCH ROOF + ROOFING FELT + KHAFGI			"
8	CORRUGATED GAL. STEEL SHEETS + CEILING (Ventilated air space)	UN VENT. AIR SPACE		
9	CORRUGATED GALV. STEEL SHEETS + CEILING (Unvent. air space)	WHITE WASH		
10	TRADITIONAL MUD ROOF + ZIBALA FINISH**			WHITE WASH

* Khafgi is a mix of cement, sand and lime with small chippings of ordinary red brick.
** Zibala is a mix of animal dung, straw, and mud for rendering walls and roofs.





[illegible] Internal Air Temperatures – Initial Construction. Average measured hourly temperatures of the internal air at 100 mm below the ceiling and the external shade air temperature.

reached 79°C and internal conditions were almost stable with very little fluctuations in temperature. The average delay in internal air temperature is about 4 hours.

(ii) The shaded roof slab (Roof No.5) and the roof with cement, sand lime mix (Roof No.4) are having similar thermal efficiency as Roof No.3. They have nearly similar roof temperature curves and time lag.

The shaded reinforced roof had recorded a comparatively low night temperatures because slab is cooled due to convection.

The 'Khafqi' roof had a slightly higher temperatures in the daytime and due to its thickness minimum temperatures were recorded later than others.

(iii) Both brick Jack-arch (Roof No.7) and hallow tiles roof (Roof No.6) had shown a reasonable reduction in maximum temperatures and diurnal variation. Beside both are heavy and have similar temperature curves.

The lower surface and internal temperatures of the hollow files roof were slightly higher than the other roof but had lower upper surface temperature. Its maximum internal temperature is also an hour earlier.

In both these roofs reduction in maximum air temperature is small and internal temperatures are above average at night.

(iv) The corrugated glavanised steel roofs (Roof No.8 and 9) with 20 mm fibre board) had recorded a reduction in maximum temperatures and diurnal variation but with very short time log of about one hour.

Internal air temperature follows the corresponding external air temperature very closely.

Temperature curves are similar.

Effect of the ventilation of air space is not giving significant result (0.5 °C).

(v) Both bare concrete roof slab (Roof No.2) and the modified traditional mud roof (No.10), were offering very little resistance to heat flow.

Their diurnal range was the greatest (10 °C).

Maximum internal air temperatures were higher than the corresponding external shade air temperature.

Temperature curve has steep rise and fall at maximum and minimum temperatures.

R.C. roof slab having white washed above had its maximum surface temperature about the same time as that of external air.

R.C. roof slab having black roofing felt had its maximum surface temperature about the same time as that of the maximum solar radiation.

II. Effect of Ventilation :

Ventilation of rooms only during the night time (i) reduced the maximum internal air temperatures (ii) increased the diurnal range (iii) delay the time of their accurrence. This was found more effective in heavy roof construction, shaded and top insulated roof construction.

Ventilation only during daytime hours in summers, offsetting the thermal protection property due to roof itself. When the openings were closed after sunset the heat gained by the internal structure during day had an adverse effect on night temperature and temperature of the following day.

It was noticed that continuous ventilation was a little more effective in improving the thermal condition, compared with the unventilated condition and with the ventilation at daytime.

Ventilation of the roof or ceiling air space (Roof No.8) had very little advantage over unventilated roof (No.9) the difference is 0.5 °C lower in maximum internal air temperature and also lower by 3 °C at internal surface temperature. Both rooms had same diurnal range and time of peak.

Ventilation of the roof of hollow files, air space proved little advantage over unventilated one (Roof No.6). Due to convection these observed a quick heat lose at night and by closing at day time the air acts as insulation.

III. <u>Effect of Surface Treatment</u> :

A considerable reduction internal air temperature and external surface temperature when a white-wash applied to the external surface of roofs and also improved the diurnal range and delay in time of peak temperatures. A great improvement is observed when it was applied to bare concrete slab and modified traditional room (See Figure No.). The main draw back is the problem of maintenance of whiteness of the surface.

When a layer of white gravel (5 cms) is applied on top of bare concrete slab showed very little effect on the thermal performance of roof and the time of peak temperatures were delayed an hour. An addition of 25 mm more white gravel showed a considerable effect by achieving a lower temperature, minimum diurnal range, and delay the time of maximum temperature readings. Its main disadvantage is its weight.

Reference : Mukhtar, Y.A., Roofs in hot-dry climates, with special reference to Northern Sudan. Building in Hot climates, Building Research Establishment, U.K. 1980.

TABLE No. <u>The external and internal surface temperatures of different roofs along with internal air temperature (1 m below ceiling).</u>

R. No.	Roof Section	Max. Temp. (°C) *	**	***	Min. Temp. (°C) *	**	***
1.	Bare concrete	60	52	47	25	27	34.5
2.	Bare Concrete(white washed)	55	47	44	24	26.5	34
3.	Insulated concrete	75	37	41	21.5	33	37
4.	'Khafgi' finish	66	40	42	23	32	36
5.	Shaded	35	36	41	30	29	36
6.	Hollow tile	62	41	43	24	30	37
7.	Jack arch	68	43	43	22	32	36
8.	Corrugated steel **(Vent.)**	72	37	41	25	32	36
9.	Corrugated steel **(Unvent.)**	76	37	41	25	33	37
10.	Modified traditional	47	48	44	29	30	36

External air temperature 42.5°C (Max.) and 28°C (min)

* External surface temperature of the roof.

** Internal surface temperature of the roof.

*** Internal air temperature, 1 m below the ceiling

(Ref. : Ahmad, Building in Hot Climates).

The observed no special advantage by putting white cement tiles over the Roof No.3, than that of same roof white washed.

Thermal Performance of Reed Shaded Concrete Roof and the Exposed Concrete Roof in Arid Summer Conditions :

An experiment carried out in University of Khartoum (Sudan), in an existing building (Figure-1) on a typical summer day i.e. May 21.

The reading were taken when doors kept closed practically all days and open for the rest of the time. The roof is shaded 2/3 portion of the surface and rest is unshaded i.e. exposed to sun. The reed panels are locally available and found fairly standard and its cost is also low.

Comparison between Unshaded and Shaded Roof : (Surface is of light colour)

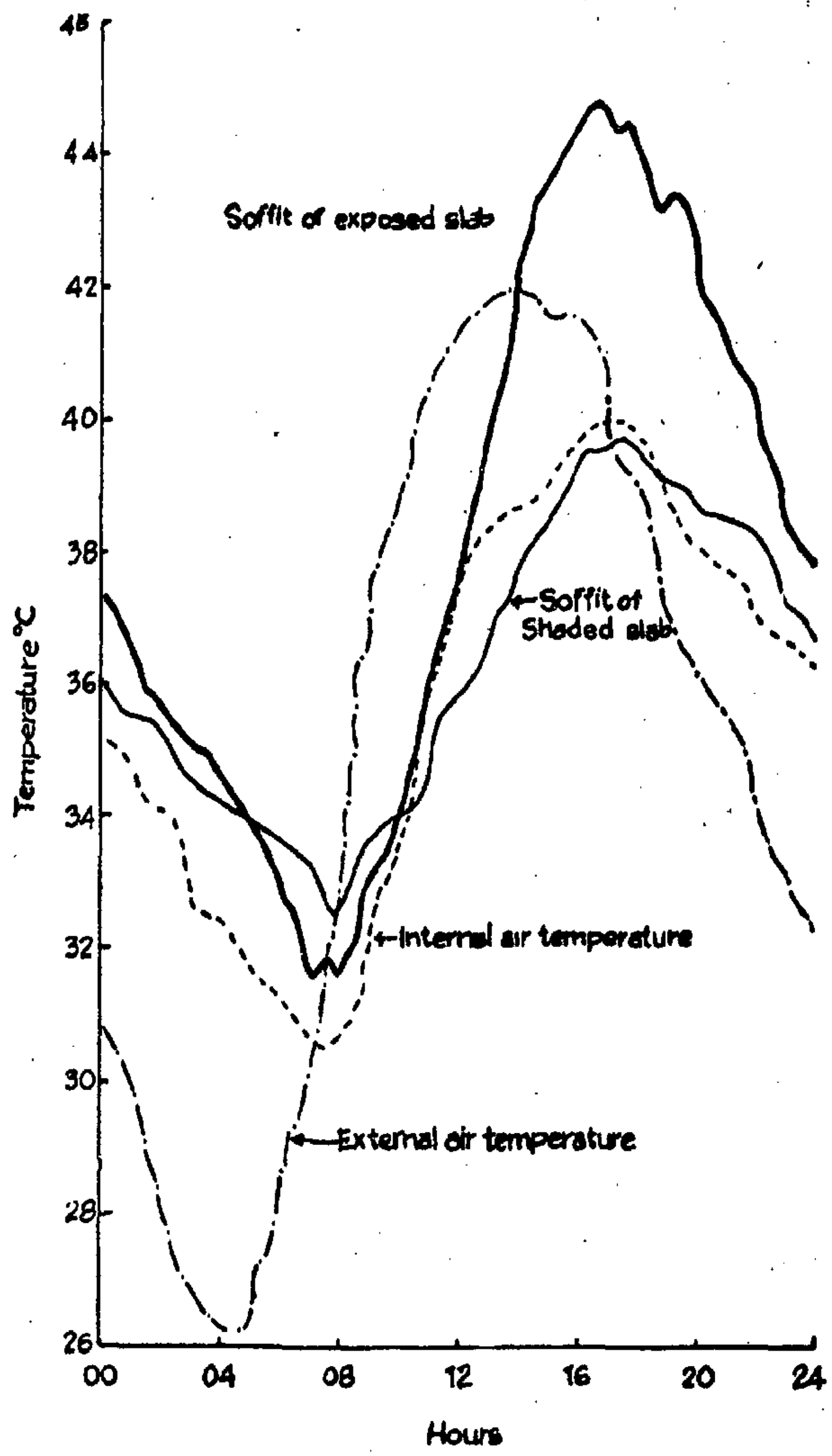
Unshaded	Shaded
1. A rapid rise in ceiling temperature from 31.5°C (07.00 hrs) to max.44.7 (16.30 hrs.) which is 4.8°C greater than ambient temperature.	A steady rise in ceiling temp. from 32.5°C (7.30 hrs) to max. 39.6°C (17.30 hrs) the difference is 5.1°C at 17.30 hrs. Because after sunset the shading device obstruct to heat loss in two ways : it obstruct the longwave radiation acting as opaque barrier and by restricting air movement it obstructs the convective heat loss.

Reference : Adil Mustafa Ahmad, The thermal performance of concrete roofs and reed shading panels under arid summer conditions. Building in hot climates, Building Research Establishment, U.K. 1980.

Unshaded	Shaded
2. Ceiling temp. is alway above the inside air temp. except at 11.00 when it equal(touches).	During most of the daytime internal surface temp. below the shaded part is below the inside air temp. and for all the nighttime it is above it by maximum 2°C.
3. Outside air temp. is exceeds the ceiling temp. only between 7.00 hrs to 13.00 hrs, after that it drops considerably. Minimum occurs at 4.00 hrs (8°C lower than ceiling temp.).At this time convective cooling is effective.	The outside air temp. rises above this ceiling temp. from 07.00 hrs to 17.00 hrs(max. difference is 6.5 °C), rest of the time it is well below it (max. difference is 8°C at 04.00 hrs.).
4. Its time lag is 4.5 hrs.	The time lag is increased to about 5.5 hrs.

Conclusions :

This experiments shows that how a concrete roof surface temperature is reduced to a minimum by applying different insula tions and shading by light reflecting material on top of the roof. To achieve at a low cost, locally available material are used for shading and insulation. Sometimes a single or a combination of methods should be adopted to achieve comfort conditions. In those methods applying white wash to the external surface of the roof, Ventilating the roof when external temperature is lower than internal. It is better to allow shaded roof, to be opened to the sky during the night time. By minimising the temperature difference



Soffit of exposed slab
Soffit of Shaded slab
Internal air temperature
External air temperature
Temperature °C
45
44
42
40
38
36
34
32
30
28
26
00
04
08
12
16
20
24
Hours

between indoor and outdoor air, the life period of material above the roof also get increased. The material which is to be applied on top of the roof should have some thermal insulation, otherwise it may not possess good results.

6.1.2 (II) WALLS :

The walls plays important role in the building envelope in controlling high temperature differential and high solar radiation, glare controls dust and hot winds. It should have capacity to store the nighttime coolness in it.

The walls of daytime living areas should be made of heat storing material, while walls of rooms like bedrooms, wall material can be of light heat capacity.

There are number of wall design are proposed for both for passive heating and cooling purposes. But most of the walls are first designed for heating then by doing little modification to the previous one. But the results in cooling are not as encouraging as in the case of heating. The different methods which are now in practice are massive wall (traditional), trombe walls, water walls, cavity walls, etc. In India the massive walls are in practice in the rural areas, and in some special occasions the cavity walls were also used.

Walls can be treated externally to achieve good thermal performance, like applying insulation and by different surface treatments etc.

(i) Trombe Wall

This wall is actually got popular while using it for passive heating purposes. Then it is modified to suite for getting benefit out of it for cooling. Actually trombe wall consists of a massive wall and a glazing/insulation with an air gap in between. In heating purposes heat is traped by using glass in mass wall, but in cooling purposes, heat is not allowed to fall on the wall and in case any heat transfer takes place from external insulating shutter, it is absorbed by the mass wall and stored in it (heat transfer won't takes place into the building). The gap between the external building envelope and mass wall is used for convective ventilation. In case of heating the mass wall will be provided with two openings at the top and bottom, to circulate hot air with he building constantly. But for cooling purposes, the external insulating shutter will be provided a ventilation at the top and the massive wall will have opening at the bottom. When air in the gap is not heated up it looses its density and goes out through the ventilation on top and the gap is replace by the air from the room. Here special arrangements should be made in the way, from which the external air is coming in to the building, to fill the air gap created by stack effect in the gap.

While during the evenings and nightsthe mass wall will be exposed to the environment by opening the insulation shutters. Then the mass wall will loss all that heat, which it stored during the daytime and get cooled still, will can be used in the day time for daytime cooling.

Water Wall (Drum Wall) :

This wall is also called 'water trombe wall' it works on the same principle of mass trombe wall which is explained earlier. Here the water tank (water wall) works the same as mass wall. In this process, water wall get more cooled during the nights and can be effectively used for daytime cooling. The drum should be painted with white colour on the external side when it is used for cooling purposes.

Massive Walls :

In hot-dry climates, larger the daily variations in outdoor air temperature with intense solar radiation will create uncomfortable condition inside the building. That is why in our traditional buildings we observe massive building structure. One of the functional requirement is to control and prevent heat from transferring into indoor space. The massive walls will have good insulation value, high heat storage capacity, greater time-log, and fairly good value, which are well suited for hot climates. The massive walled house will be relatively cooler than ordinary thick walled house. The massive walls will take more time to heat and similarly more time to cool down. By the time heat is about get inside surface of the wall, the outdoor temperature should be reducing (evenings) so that heat tries to travel back to the atmosphere.

Cavity Wall :

Air space between two walls will offer another barrier, besides the walls,to the passage of heat. The optimum width of the cavity in a wall is 50 mm. If it is less than that strong convection currents can takes place in it and it's effectiveness will be reduced. Suppose if the width is more than that, also looses its resistance. As the distance is increased the inner wall tends to behave like ordinary single wall in heat transfer.

Cavity works as insulator when it is unventilated. The two walls in the cavity wall are can be of different thickness, thin wall (light weight) is preferably the outer skin. It also observed that ventilation in day time is undesirable and in the nights it gives cooling effect to the building.

In case openings are provided, they should be on same side. To enhance the thermal resistivity the cavity can be filled with an insulating material.

Conclusions :

There is some technical data available on cavity wall and its thermal performance in C.B.R.I., but the rest do not possess enough data which can be used by architects in their practice.

6.1.3 III. OPENINGS :

Generally in hot-dry climates the openings are closed during the day time and are opened in evening till mornings. Thermal conditions in this climate indicates that, window size should be minimum . and will be sufficient to give enough lighting during the daytime. The opening of window shutter will encourage heat loss from the building envelope which is gained during the daytime. It is better to have big windows, which should be tightly closed during day-time and open it to sky during evening and night to quicken the process of cooling, the indoor environment.

If the window is big, the problems like shading and infiltration takes place to transfer heat from outside to inside, if the window is small enough, these problems are limited. Air movement inside the building, when desired, will have considerable effect due to the placement of window orientation, position and size of a window in a room and projections above the window. Some times it is effected by the surroundings also. These things are clearly explained Appendix No.

Due to influence of Western architecture in our country, made buildings with large windows and full glazed curtain wall, without looking into the climatic demands of a building.

In some cases, this can be controlled by reducing the solar light and heat through the openings . The building having large opening needs a special kind of sun protection. There are number of sun shading devices varying from simple curtains to automatically operated blinds.

The building oreintation and type of sun protection will depend on the climatic condition of that particular place. A typical house in hot-dry climates is required to be protected from direct sun. According to our traditional architecture, we came to know the importance of shaded courtyards, verandah around the building and their necessity at present. The amount of sunshine can be minimise through careful study of sun's movement.

Sun shades can be classified into two groups, like fixed and movable devices for fixed shade, it should clear that on what time and period the sun should be shaded. It is slightly expensive and needs little maintenance(There is a chance, when you require more lighting in the room, one would feel slightly dark interior, when you do not require sun protection). But in case of movable devices it requires certain amount of maintenance annually. It can be said that these devices are more effective than fixed, both in preventing direct solar radiation and encouraging longwave radiation during the evening and night. The effectiveness of shading devices, when it is internally placed, is limited and may lead to additional expenditure

The size and the type of sun shading device will depend on the orientation of wall in which it is installed. Generally sun shading device is placed near the window, but in tropical climates, the entire facade is required to shade, this can be done by using grills. There should be some gap between the shading device, and the building envelope, so as to enable the air can pass through grills or blends and do not allow a stagnated hot air at the building surface. This will excert a cooling effect on the facade.

While choosing the material for shading is to be considered thermal conductivity which will have great effect on the design itself. The shading device can be painted keeping the need of heat by reflection and absorption.

Shading can be done by the vegetation different ways with different kinds i.e. trees, creepers, shrubs etc.

<u>Shutters of the Openings</u> :

The material used for shutter either window or door, should have enough insulating value to prevent heat from transferring from outside to inside the building. These shutters play important role in preventing infiltration of heat. But their construction detailing should be good and it also depends on the workmanship. This infiltration occures due to bad workmanship in most of the times rather than bad designing. The intensity of infiltration will also depends on the temperature difference between indoor and outdoor environment. If the difference is more, the intensity of infiltration will also be more effective. Usually heat transfer in terms of convection takes place in infiltration.

6.1.4 IV. FLOORING :

In hot-dry climates, generally floors are raised by one to two feet high above the ground level. In case any cavity in underspace of floor is advisable to close in this climates, otherwise the floor will get heated by the ambient hot air. The floors which are laid directly on the floor will have considerable effect on foot comfort, during the summer day time.

It was observed that concrete floors are much cooler than timber, at about 5°C, when the indoor temperature is at 35 °C. Floors also get heat from the vertical building envelope as well as from ground itself, but major heat gained is due to roof radiation.

It was observed from the case studies that flooring done with concrete is cooler than Shabad stone flooring.

A careful detailing is to be given to the flooring so as to prevent heat flow from outside to the flooring. The foundation can be of in different layers instead of thick mass.

6.1.5 THERMAL PERFORMANCE :

To have comfort condition inside a building, it is necessary to prevent the penetration of solar radiation and minimise the flow of heat into the building. This could be accomplished by the proper choice of building materials. In order to choose the correct combination of building materials from thermal considerations the thermal performance characteristics must be known.

Due to the large diurnal swings of temperature a high solar radiation, the thermal problems of a building, get more complicated. Here both roof and walls play major role and a proper selection of these cross sections should be received attention in the design stage itself. A building not only should possess the protection from sun and rain, stability and durability but also should have comfort conditions indoors. In hot-dry climate the thermal capacity of a section is more reliable than light-weight constructions in case of thermal performance. That is why, the traditional buildings are better than present light-weight and sandwitch constructions in their thermal performance. So as you increase the thickness of a material you get better thermal performance.

T.P.I. is a method adopted by CBRI for finding out the thermal performance rating for different roof and wall sections. Thermal performance Index (T.P.I.) is nothing but the enlarged form of internal surface temperature is equal to 100 T.P.I., i.e. $1^{\circ}C$ is equivalent 12.5 of

T.P.I., for the temperatures above 30°C (assumed base temperature). If one know the T.P.I., can find out the internal surface temperature and the vise-versa.

For thermal comfort should ensure lower internal surface temperature to minimize the radiant heat load to the occupants. Higher the ceiling temperatures also contribue indirectly in raising the indoor temperature. That is why inside surface temperature is taken as a criteria for thermal performance rating of roofs and walls.

TABLE - 1 Basis for Thermal Performance Rating of Roofs

(Unconditioned Buildings)

S. No.	Peak Degree Hours(P.D.H.) Deg.C. above 30°C	Thermal performance Index (T.P.I.)	CLASS	Quality of performance	Remarks
1.	< 6°C	<75	A	Good	Preferable where bette standards are aimed at
2.	>6°<10°C	>75<125	B	Fair	Acceptable though not adequate.
3.	>10°<14°C	>125<175	C	Poor	Unsatisfactory. Requires moderate treatment to upgrade to B.
4.	>14°<18°C	>175<225	D	Very poor	Very unsatisfactory
5.	>18°C	>225	E	Extremely poor	Requires high degree of insulation to upgrade to B.

.B. : P.D.H. 8°C corresponds to 100 in T.P.I.

In traditional roof constructions, lime concrete and mud phuska, which are believed to act as thermal insulation, are common. There are number of roof and wall section given in the following tables, which are mostly of local materials. The thermal performance of a wall or roof can be improved in several ways viz., white washing, shading and insulation treatments. The effective treatment also depends on the type and thicknews of the basic structural element. Though fresh white wash brings the T.P.I. to practically half of its untreated value but its effect won't long last due to dust collection, etc.

The thermal performance index for a particular section depends on many factors, such as place, orientation, surface colour and indoor air temperature. For different places the T.P.I. value increases or decreases depending upon climate and location.

TABLE No. : THERMAL PERFORMANCE INDEX (T.P.I.) AND CLASSIFICATION OF FLAT ROOFS (HOT DRY CLIMATE)*

S. No.	Basic Str.Elem.	Insulative/Water proofing	T.P.I.	Class	Type of construction	Recommonded T.P.I.
1.	10 cm R.C.C. Slab	Mud Phuska/Bricktile(5cm) (5cm)	122	B	Proposed	100
2.	- do -	Mud Phuska/Bricktile(5cm) (7.5 cm)	110	B	''	
3.	- do -	White wash	125	B	''	
4.	- do -	Shaded	105	B	''	
5.	- do -	-/9 cm lime conc.	134	C	''	
6.	- do -	-/-	220	D	Existing	
7.	- do -	-/Tarfelt	225	E	Not applicable	

NOTE : A-Good; B-Fair; C-Poor; D-Very Poor; E-Extremely Poor (Roof are internally plastered).

* Khammam

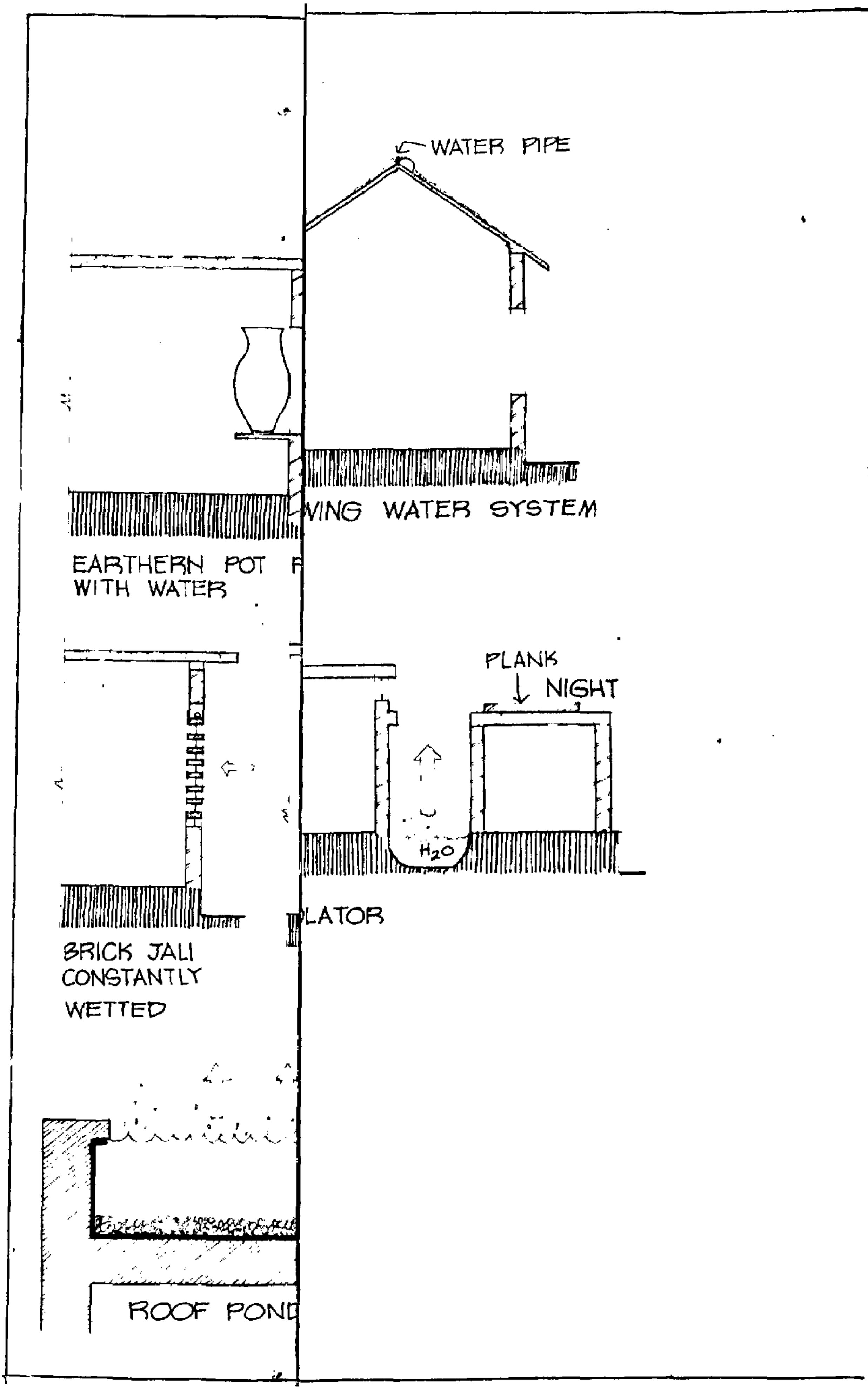
Table No. : THERMAL PERFORMANCE INDEX (T.P.I.) AND CLASSIFICATION OF WALLS (HOT DRY CLIMATE)*

Sl. No.	Basic Str.Ele.	Exterior	T.P.I.	Class	Type of Const.	Recommended T.P.I.
1.	34.5 cm Solid brick	1.25 cm plaster	64	A	Existing	125
2.	46.0 cm Solid brick	''	61	A	Proposed	
3.	23.0 cm Solid brick	''	96	B	Proposed	
4.	23.0 cm Solid brick	''	93	B	''	
5.	28.0 cm Cavity Wall	''	78	B	''	
6.	20.0 cm (Soil Fill)	''	99	B	''	
7.	23.0 cm (Solid brick	7.5 cm Sand stone	76	B	''	
8.	30.5 cm Rubble masonry	7.5 cm sand stone	89	B	''	
9.	38.0 cm Granite	''	99	B	''	
10.	30.0 cm granite	''	121	B	''	
11.	15 cm Granite+5.0 cm air space+15 cm granite	-	82	B	''	
12.	20 cm granite	-	167	C	-	
13.	15 cm granite	-	201	D	Not advisable	
14.	10 cm granite.	-	248	E	Not advisable	

NOTE : A-Good; B-Fair; C-Poor; D-Very Poor; E-Extremely Poor Brick Walls are internally plastered

* KHAMMAM.

Evaporative Cooling



6.2 EVAPORATIVE COOLING :

Introduction:

Evaporative cooling is the cheap and best method of cooling with the less efforts as far as hot-dry climate is concerned. The evaporative cooling functions through a process known as adiabatic process. Evaporative cooling units work on the principle of passing air over a constantly wetted surface, thereby increasing relative humidity and decreases the dry bulb temperature of the air. Evaporation process can be achieved by allowing air to pass over an open pond or thin film or flow, of water over a surface (let us say roof).

It can be observed in the summer that a mat, which is weaved with some plant's roots, hung infront of the openings of the buildings, in the path of the natural air flow and kept it damp. The matting humidifies and cools the air as well as filters out the dust. In countries like Egypt, they use a large porous earthernware pots filled with water which seeps through the walls of the pot moistening the outside air and cools when it passing over it. Similarly windscoops are used to cool indoor environment. It is similar to the design of a chimney but functions in a reverse way (Fig.). The windscoops catches the prevailing wind by diverting air on a porous water pot subsequently to the surface of a wet charcoal on to which water drips. It ultimately results in the reduction of the temperature of the air. It was observed that this process reduced the indoor temperature by 7* to $10^{\circ}C$**. Sometimes air which is coming through windscoops is directed towards deep walls, air is cooled when it passes through absorptive reed mats suspended with their bottom edge in water.

The farmers in South Africa, make a wall of 4" thickness with pieces of coke which is guided by two chicken wire meshes on either side. A water supply pipe, having ~~holes at regular intervals~~ which is conneeted to a raised storage tank is placed above it. This makes the wall continuously damp and the air which is coming through it will get cooled. In the similar fashion architects at Esrel made wall with brick jally. Rest remains the same.

A spray pond is more effective than a still pool of the same size and has the additional advantage that, it not only cools the air but also washes it from dust particles.

6.2.1 <u>Evapo-transpiration</u> :

Vegetation is an excellent natural humidifier. Like human beings, vegetation also maintain certain constant body temperature. To keep that temp. they lose moisture by evaporation to surrouddings. In the day time trees have a

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* Varshney B.S., evaporative cooling, Course-cum-workshop on solar architecture, CBRI, India.

** Hassan Fathy, Architecture for the poor, The University of Chicago Press, London, 1973.

greater cooling effect because the rate of evaporation in day time is more. Air passing over leaves will not only get cooled but also freshened. Broad leafed plants are better humidifiers than other type of plants. The plants or creepers grown in the way of incoming air, reduces the temperature to certain extent. Similarly the indoor plants reduce the room temperature to a little extent but there should not have excess number of plants in a room, which may cause raise in room temperature, and also injurious to health especially in sleeping beneath them in night times.

6.2.2 Roof Surface Evaporation :

It is a well known fact that roof in tropical climates receive greatest amount of the solar radiation than other surfaces of the building envelope.

The conventional methods of reduction of heat flux into a building through the roof are : by increasing the thickness, provision of insulation, false-ceiling, by reflective surface treatment and by shading. An unconventional and highly effective method to the problem in hot dry climates is 'open evaporation of water from roof surface.' It satisfies the demands like effectiveness, economical practicality and indegenous and implementation. The roof surface evaporation process can be divided into two parts: Open pond and spray of water on roof. It was observed that both the methods were highly effective in reducing the heat flux through all types of roofs.

Roof Spraying System :

In this system, water sprayer is put for constant wetting the surface of the roof, thereby encouraging the rate of evaporation at the top of the roof slab, so as to decrease the temperature of the ceiling.

It is effective and as well as economic to cool a building by using the process of evaporation at roof surface especially in the tropical climates where roof receives more heat than other building envelope.

Before, installation of roof spraying system, the roof surface should be treated with waterproofing material. And the material which is spread over the roof should be able to absorb sufficient amount of water and allow quick evaporation. CBRI Roorkee suggested a number of materials which can be used for this purpose, which are easily available and durability is also good. For example : 2.5 cm brick ballast and gunny bags. The same institute developed a system that sprinkles water in its movement i.e. rotation.

This spray with uniform and constant wetting arrangement and cover a large area. Here, chief regulating factors are sprayer's angle and on water pressure. In the peak hours of solar radiation the rate of evaporation will move. The total consumption of water per square meter is 9.0 litres in 24 hours.

Due to high rate of evaporation during day-time, better comfort conditions are achieved in the indoor environment. It was observed that, it can maintain a surface temperature of about 28°C on the roof. Another significant reduction is upto about 8°C in untreated building is recorded* (Graph No.).

Roof Pond :

The roof pond system requires a water body on the roof which is protected from direct solar radiation by exterior movable insulation. These movable shutters will control the rate of evaporation of water during the summer daytime. The movable shutters are put on the top of the roof pond at day-time and will be removed in the evening till the morning. By exposing roof pond to the atmosphere it looses the gained heat during the daytime and also this water mass can draw the unwanted heat from the building which is heated during the daytime by different building envelopes other than roof. Similarly in the day time, as the water is a good thermal regulator, water absorbs heat from ambient air and it stores the heat (this amount of heat is very little as the top of the water is already covered with movable shutters). If the shutters are not perfectly closed there is a chance to water to get evaporated. This loss can be controlled by some sort

*Building Digest 124

of cover, provided for water mass. Of course as water gets evaporated its temperature will drop but due to scarcity of water in hot-dry climates this should be avoided. It was observed that there was no significant change in the ceiling temperature when the depth of the roof pond was increased from 0.05 to 0.15 m., the maximum difference is 3°C.

This system can be effectively used for passive heating purposes also.

The cooling of the roof, the air above the roof also gets cooled and being heavier than the hot air, slides down the walls of the building, much of this chilled air drifts in the building due to unfiltration and ventilation*. It was observed that due to the roof spray, the peak roof temperature had been decreased from 55°C to 28°C as compared to reduction from 55°C to 32°C in case of roof pond. The drop in ceiling surface temperature is 15°C and 13°C respectively. Similarly indoor air temperature suffered a drop in case roof spray is 3.5 and 3°C in case of roof pond. This is due to more effective evaporation of water at the roof surface. It is found effective with lightly constructed, poorly insulated roofs (Graph No.).

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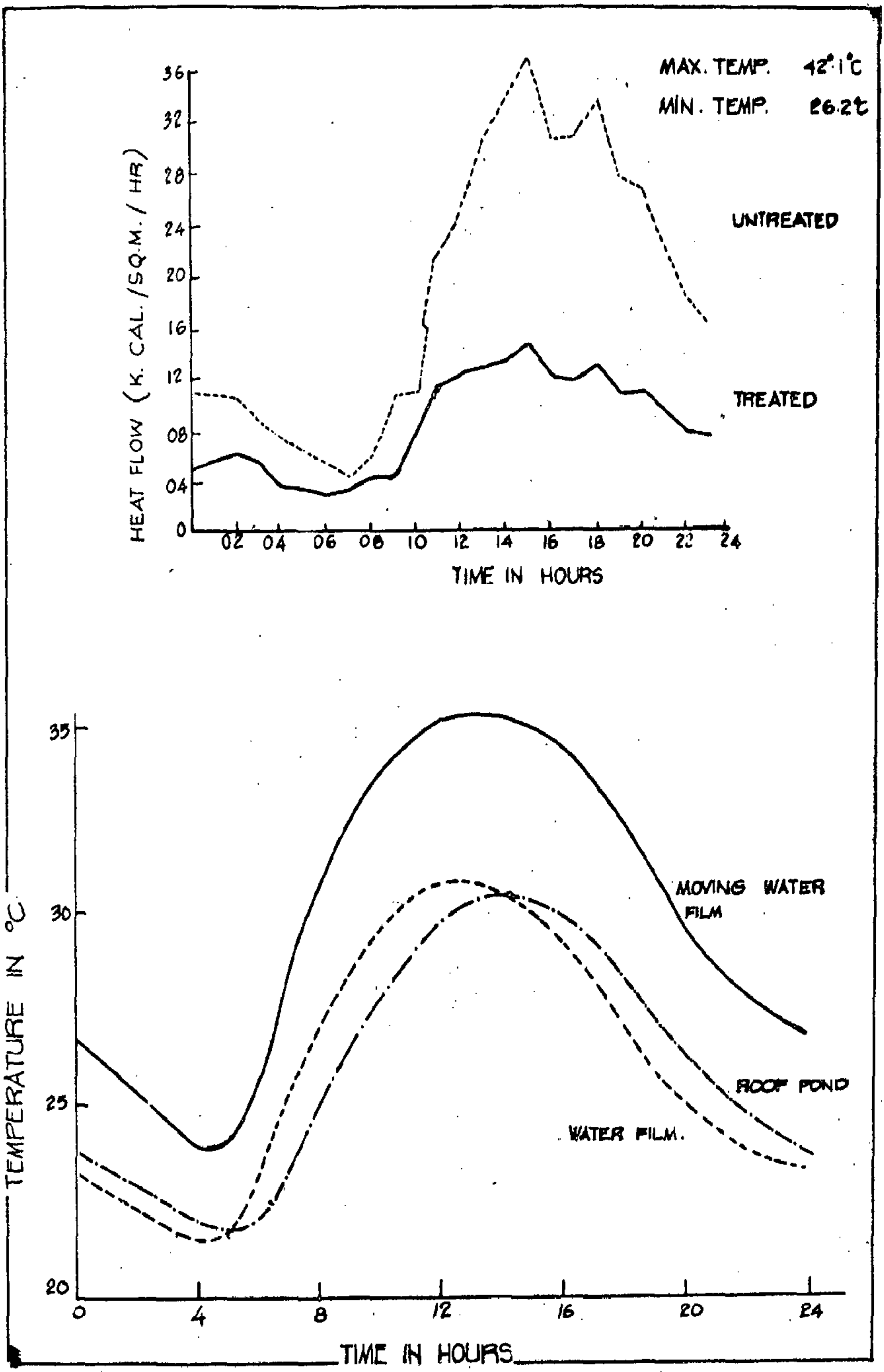
*State of Art, Passive Solar Building, I.I.T., Delhi, HAUZ KHAS.


MAX. TEMP. 42.1°C
MIN. TEMP. 26.2°C
UNTREATED
TREATED
HEAT FLOW (K. CAL. /SQ.M. / HR)
0
04
08
12
16
20
24
28
32
36
02
04
06
08
10
12
14
16
18
20
22
24
TIME IN HOURS
MOVING WATER FILM
ROOF POND
WATER FILM.
TEMPERATURE IN °C
20
25
30
35
0
4
8
12
16
20
24
TIME IN HOURS

6.3 EARTH COOLING

1. <u>Introduction</u> :

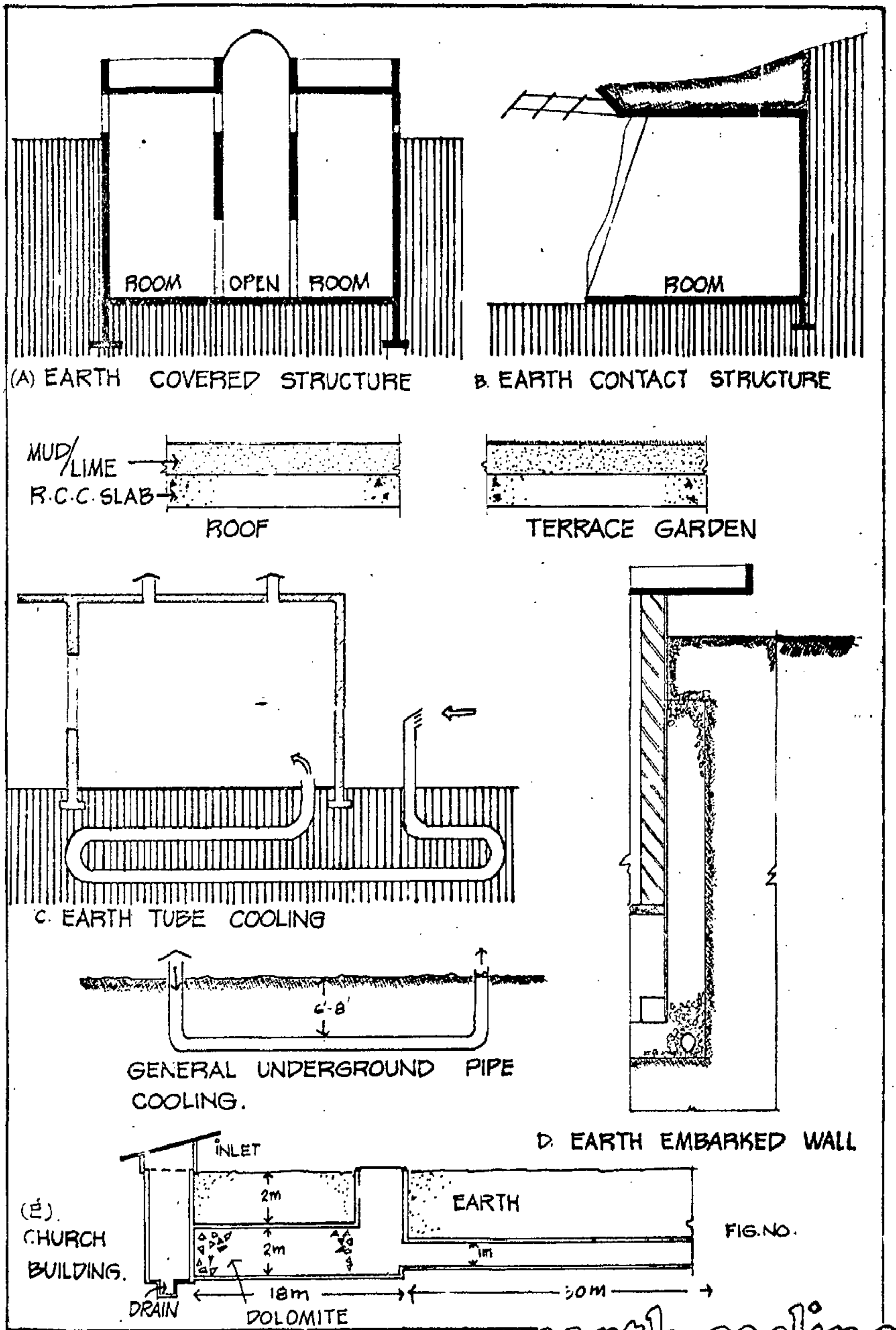
The field of passive cooling techniques has received a great deal of attention over past few years with much of this work being directed toward prediction and evaluation methods for energy conservation. The idea of making use of the earth's natural stored coolness has become increasing popular under energy conservation of techniques. Many countries are installing, testing and making use of earth as a natural space conditioning agent. This rediscovered truth is now-a-days branching in different way to achieve the goal.

The different types of earth cooling techniques can broadly be divided into 3 parts :

(i) Underground structures
(ii) Earth covered building surfaces
(iii) Earth cooling pipes

6.3.1 (2) <u>Underground Structures</u> :

The increased interest in building houses partially or entirely underground has prompted many questions about the physical and sociological factors associated with such housing. There is no reliable information available regarding, how much heat is lost to the soil ? One of the reasons for this may be due to extreme variability of soils with regard to texture, moisture and compaction.



earth cooling

It is well known fact, that the earth's temperature will be almost constant at certain depth. It is generally lying between 6' - 8' from the ground level. The earth will act as barrier to heat which is coming from ambient ground temperature to the building. Generally, the underground rooms will be cooler than rooms above ground level (Fig. No.).

Underground structures are very common requirement in most of the houses till the initial stages of nineteenth century. We can still observe these in some old buildings. They use to provide at least one room in cellar in a house. As the modern trend is advancing towards development, this system is completely getting vanished. But recent necessity of conservation of energy movement, which again lime lighting the importance of earth cooling in every Seminar both at national and international levels.

At present, the existing underground rooms in old buildings, the people are using it as a store room. Actually if one can observe the fact, that these rooms are well ventilated and relatively cooler than ground floor rooms. But because, the ventilators are closed and lot of unwanted goods are stored inside, we feel suffocation because there is no air movement inside.

In this type of rooms the openings which are left out for ventilation plays an important role in controlling the indoor temperature. The openings should be small and should be located on windward side. It gives better results when the underground room is narrow and elongated in the direction of wind. The incoming ambient air will get underground tunnel effect, which ultimately reduces the indoor temperature by loosing temperature to surrounding walls.

There will be lot of difference in indoor temperatures, between ventilated and unventilated Cellar rooms. The difference that found out was as much as 7°C and more which created a good and important position in passive cooling techniques. The thermal comfort inside will be maintained throughout the day and will be almost constant. This is because earth acts as barrier for thermal balance.

6.3.2 (3) Earth covered structures :

In rural areas, we can observe that the most of the houses are constructed of mud. In some houses roof also made out of thick mud slab. There the indoor environment will be very comfortable when compared to our present buildings. The thick mud layer will have high time lag than that of ordinary brick wall of 30 cm thick (Fig. No.).

In modern times, may be due to sanitary problem, the people instead of going deep into earth, they are constructing their houses as usual with a thick mud layer above the slab and started growing ground covers on it. Because slab will absorb more radiation than the walls. The thick soil above the slab will act as an insulator besides this the ground cover above it, will enhance the effect of cooling in the indoor environment. It maintains relatively constant temperature throughout the day (Fig. No.   ). It was observed that a slab of 10 cm is covered with 10 cm mud layer, which reduced the ceiling temperature by 10°C.

Experiments were carried out in U.S. Dept. of Agriculture on earth embarked wall, produced some interesting information regarding this method (Fig No.   ).

The temperature reading taken adjacent to house walls in different regions shows considerable variation. The variation was greater near the surface level and decreases with depth below grade.

It is observed through experiments heat loss through the embarked wall section was greater in December than February and also house temperatures were lower in June than in September.

The heat transfer through the uninsulated crawl space portion of the foundation wall was greater than through the insulated portion of the wall being as much as 10 times that through insulated portion of the wall.

The temperature differentials measured indicated that the potential for heat decreases with depth below grade. If it is required to maintain a nearly uniform heat loss at all depths, wall insulation would vary as a function of depth.

During the summer, soil temperatures have remained very close to the human comfort zone and heat transfer to the house has been small.

6.3.3(4) Underground pipe system :

As the temperature of soil at about 6' or more below the surface of the earth stays fairly constant through the year and is very closely approximated by the annual average air temperature. If a pipe is buried underground at this depth atmospheric air is passed or circulated through it, the air will lose or gain heat depending upon whether it is summer or winter. This method of environmental control is practical, economical and energy efficient. Experiments were carried out in environmental study laboratory in State University. Four pipes were burried 6' to 8' deep. Two pipes were made out of corrugated galvanized steel with diameters 18" and 12" and lengths of 60' and 80' respectively. The other pipes were of plastic each 12" and 8" diameter and a length of 80' each.

(i) Ambient and exit air temperatures at different times during a continuous operation for 12" plastic pipe when air flow is kept constant at 56.39 x 10^3 ft^3/hr.

Table - I

Time after start	Ambient temp. (°F)	Exit temp.(°F)	Difference (°F)
1/2	84.0	71.2	12.8
1	87.0	69.0	18.0
2	89.0	75.0	14.0
2.1/2	93.0	78.2	14.8
7	85.6	84.2	11.4
18	88.8	70.0	12.8

(ii) Temperature of air through 12'' plastic and 18'' galvanised steel pipe

Table - II

Material	Ambient air temp. (°F)	Air temp. (°F)	Difference (°F)
Galvanized steel	89	75	14
Plastic	87	74	13

*Flow Rate = 56.5 x 10^3 ft^3/hr.

It is evident from this table that material of the pipe has very little effect on heat transfer because the thicknesses are very small (1/16 to 1/8).

(iii) Effect of pipe diameter on air temperature difference. Material used was galvanized iron sheet and air flow rate is 42.39×10^3 ft^3/hr.

Table - III

Diameter	Ambient temp. (°F)	Exit temp. (°F)	Difference (°F)
18''	89.2	80.2	9.0
12''	90.0	74.6	15.4

* Flow rate = 42.39×10^3 ft^3/hr.

* material - Galvanized steel.

We can observe from this table that 12'' pipe is more effective in heat transfer from the air than 18'' pipe.

(iv) Effect of flow rate on air temperature difference, material used is plastic, diameter is 12''.

Table - IV

Ambient temp. (°F)	Exit temp. (°F)	Diff. (°F)	Flow rate ($ft^3/hr.$)
82.6	70.2	12.4	5.88×10^3
83.6	75.4	8.2	$4(.03 \times 10^3)$

*Material - plastic

This table is clearly showing that if air flow is increased the air temperature difference is decreasing.

It is also observed during the experiments that heat transfer and hence the temperature difference becomes very small after a length of 50 feet. It is also stated that, it is better to use more than one pipe of length 50 feet in parallel than using one long pipe of equivalent length. The distance between the parallel pipe may be of 4 to 5 times the pipe diameter.

Table - v

Distance from inlet	Temp. ^oC DB	Temp. ^oC WB
Ambient	35	31.6
3 m	30	-
6	26	-
9	25	-
12	24	-
30	23	-
60	20.5	-
90	18.3	-
120	18.3	-

* Air velocity = 3.48 m/S

Another experiment was carried out in a Church building located in Normal, Illinois. This system consists of two cast-in-place concrete tanks which is 2 m x 2 m in cross section. The effective length of earth cooling tank is approximately 18 m. The tank is filled with 82 m tons of dolomite rock. Dolomite was used since it is locally available material and does not readily support biological growth. In order to wash the dust that is formed on dolomite, water is sprayed on it periodically. The tank is burried approximately 2 m below ground level (Fig. No.).

In operation, ambient air is shown through the dolomite while cooling the air approximately 11°C. The tanks are slightly slope away from the Church, thus condensated drains to a sump. After exiting the cooling tanks, the conditioned air is brought into the building, through underground course to tubes which are approximately 1 m in diameter by 30 m long. An ordinary forced air distribution system is used to distribute conditioned air throughout the building. It was recorded that the indoor temperature is 26.5°C when ambient temp. is at 32.2°C.

6.3.4 General Considerations :

For underground structure, especially where water table is near to ground level, the problem of water seepage into the room is very common. So, necessary precautions should be taken for waterproofing the external wall of the Cellar room.

Similarly in the case of terrace garden, the roof should be properly waterproofed and proper slope should be maintained to drain out the excess water from the slab. Another important thing one should note is that the structure should be designed such a way keeping in the load of soil above the slab.

The material used for underground piping depends upon the moisture content of the soil. If the soil has low moisture, we can use porous material like clay and if the soil contains high moisture content the material used for underground pipe should be nonporous material like PVC, Conc. pipes. And in underground structure system if the inside quantity of heat is more than outside, it has to be exhausted by mechanical means, because heat would not get transfer to outside through earth barrier. The soil in which the structure is built should provide good load bearing strength, good drainage characteristics and a sufficient distance from ground water table. Care must be taken so that no adjacent structure should shade the site.

The stresses produced on an earth - sheltered building greater than that of convention, above ground structures, so care should be taken while doing structural design, shear walls could be one solution and arches and shell shapes can transfer heavy loads very efficiently. A compromise between a large thermal mass and structural considerations can be made by using 1.5 to 20 ft of soil seems optimum.

An earth is a very poor insulator, it requires proper insulation under it to reduce the steady state conductive heat transfer.

Mechanical air-cooling is not required in a properly designed, earth-sheltered house, because the temperature of the surrounding earth is almost always cooler than in inside of the house, so if any excess heat, will flow from house to the surroundings, general fear of condensation and high relative humidity in fact would not exist as people think about it. By keeping good cross ventilation inside the building can control the excess humidity. Waterproofing should be of good material and laying should be perfect. The insulation is placed outside of the waterproofing system because most waterproofing systems need a smooth, dry and stable base like concrete structure.

It is surprising that the comparative cost of an earth-sheltered house and an above-grade house are as close as they are.

6.4 Justification of each technique :

As it is already discussed about some passive cooling techniques, and how far those techniques are successful to implement in Khammam conditions.

(i) Ventilative cooling :

In this Khammam climate daytime ventilation is not required but night time it is very essential. So, it is very important and easy way of cooling the building, just by allowing air to pass through the house. This system is not only applicable to new buildings in design stage but also effectively can be utilized in the existing buildings with less expenditure.

(ii) Solar Cooling :

This can be implemented to both in proposed building and existing building. It need some initial expenditure and regular maintenance. The material used at the outer skin, can be of asbestos painted white on the external side. But the one disadvantage is that the cavity can give room to the insects and lizards. Another thing is fixing of the thin external member to the main wall may need good workmanship and proper jointing.

North-sky radiation type can be implemented in proposed building with a little projection on the north-side.

(iii) Site Cooling :

It requires patience to get maximum benefit out of it. This method of cooling can be well implemented in large area plot rather than small, where its effect is limited. It will be further reduced while it is applied in the existing building, where the area is restricted and we have to consider the neighbours also, while implementing. If the surrounding surface area of the building is not heat storing or reflecting, it is well and good, otherwise we have to think other alternatives. Certainly if the surroundings are treated with some type of vegetation. One can achieve maximum benefit out of it. But water is not abandant during the summer, the used water in the house should be properly utilized.

(iv) Venturi Cooling :

This is almost not practicable in Khammam, where not even a single residential building is having domed roof. Its construction requires good workmanship and expensive also.

(v) Gain Prevention technique :

There are different ways to prevent heat gain to the different building envelope. The people know some techniques but those techniques also not effective in implementing and sometimes implementing one technique may not give good result. It is the combined effect of different building elements which are to be taken care in different ways.

This process requires some interest to be created in the people about the importance of gain prevention of heat, implementation won't take P much time and money, only this people have spare sometime to their house and their comfort condition, which is almost not existing in the people of Khammam.

There are number of simple ways to prevent Sun. But most of the information is confined to only libraries and no one is there to give good designs. By demonstration of these techniques are can be easily made popular in these areas.

(vi) Evaporative Cooling :

People are aware of the importance of water in cooling indoor environment. But they are not effectively utilizing it. This system can be used for both proposed and existing buildings. The building in proposal stage will have advantage over the existing buildings. Water should be properly utilized. This system is more effective in climates like Khammam.

(vii) Earth Cooling :

At present earth-sheltered structures are not important in Khammam. This system may be one of the best solution in achieving comfort condition inside the building, especially in a place like Khammam, where soil conditions are in favour of this type of constructions. As the soil has low moisture content in it, and fairly hard after 3' depth, no condensation takes places. In rainy season, the rains were not heavy, so waterproofing is also limited. Water table is about 15' to 20' from the ground level.

In this case initial cost will be more for excavation. The only question is whether it is sociologically accepted or not, it depends on the reaction of people after one building is built. At present people live in this type of climate are prefering this to ordinary building, in most of the countries are getting benefit out of it, so we also can expect same thing here also.

(viii) Sky Cooling :

This system, in fact unknowingly is in practice in the buildings of Khammam. Even this is not effectively used by other building elements like doors and windows except the roof and walls. Due to privacy, people do not open their opening shutter to allow the longwave radiation to sky, they keep the opening closed and sometime half closed. But radiation from roof and walls are effective, to get good cooling effect, the opening should be opened completely at least for sometime during the nights.

7.0 PROPOSAL FOR EXISTING :

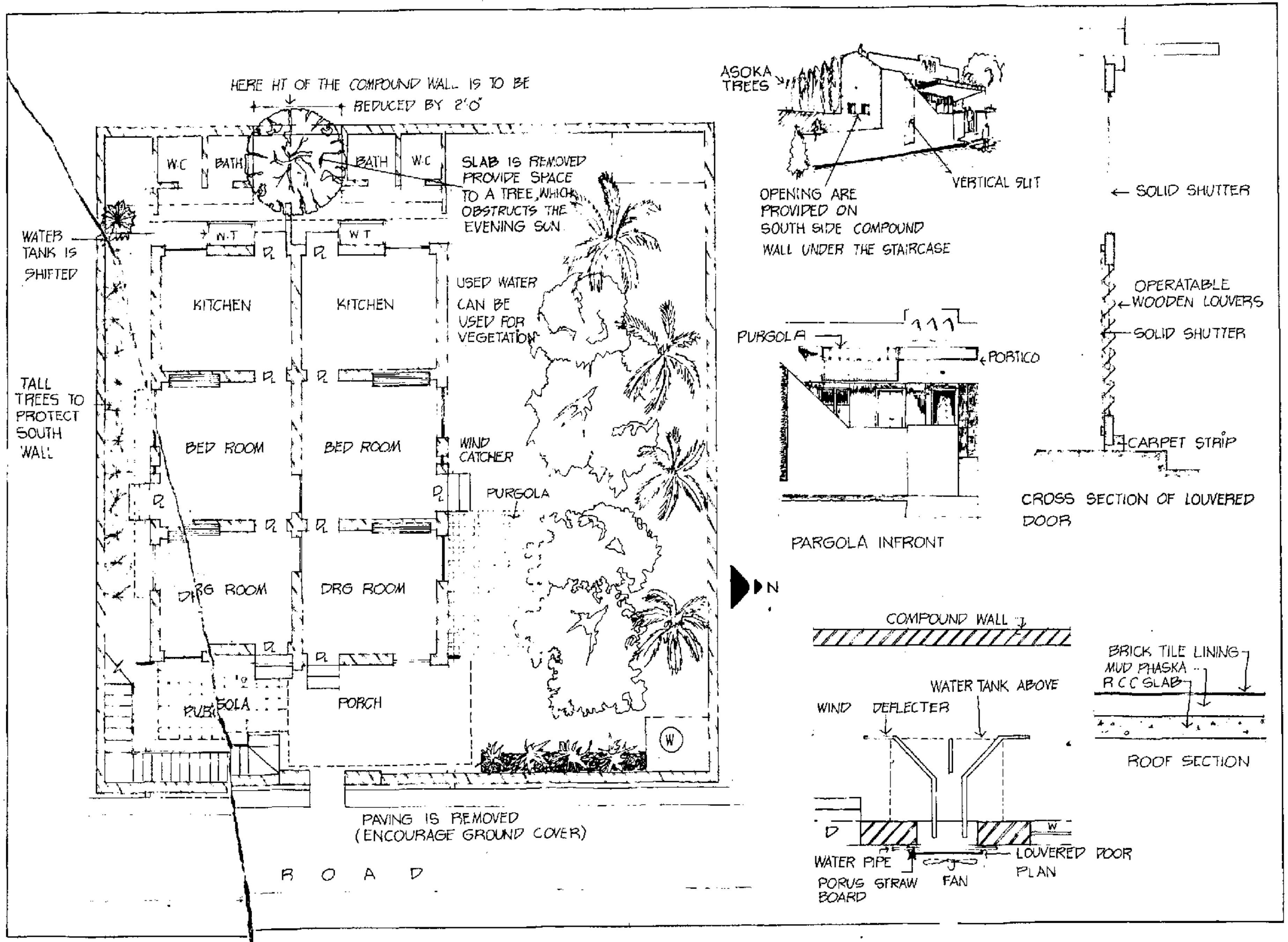
It is very tough job to give a good proposal to an existing building, rather than to a building which is at planning stage. While designing a new building, the architect will have liberty to do any thing to achieve comfort conditions inside the building, but where as for existing, he has to think twice or thrice before giving a solution. There should not have major changes in building.

This proposal is given to the building on which detailed case study is done.

As it is already mentioned that, stair-case (SE corner) and toilet block (west side) is obstructing the night time convective cooling effect. Now to get that cooling effect, there should have some arrangement in the staircase as well as toilet block, to allow some wind through it.

In the staircase a vertical slit in the wall (compound wall), which is facing East, can be provided of 1'-6'' width. The same technique cannot be applied on south wall of staircase, besause it is facing neighbouring plot. So in the south side under staircase three slits can be provided to get wind to building, at 4' height of 1'-0'' width and 2'-0'' height.

Similarly, the space between two toilet blocks in the western side can be modified to allow incoming wind. For the compound wall height at that place should be reduced to



Propesal for existing bldg.

4'-0'' and slab is cut to avail place for small tree.

Coming to building, as it is already said that, not even single room is having good cross ventilation. To enhance the cross ventilation, doors should have some opening in it. And it is observed that when all windows are opened the cross ventilation is not good. So a special arrangement is made to door. The bottom portion of door is to be arranged with two, shutter one is louvered and the other is thick. At the daytime the solid shutter is closed and during night this shutter is opend, with enough security measures the louvers are opened. This arrangement can definetely give good results in achieving night time cooling. As the 10 cm R.C.C. roof in this climate is very undesirable, so the roof should be protected from sun, by applying a layer of mud phaska on the top of the slab with clay tile lining over it. This arrangement can show considerable reduction in heat transfer from out side to inside.

The window should be properly shaded from direct sun. The window and door shutter should be sealed properly to prevent infiltration. The walls can be shaded by vegetation i.e., in south side row of ashoka trees can be planted, in the SW corner (space between building and toilet block) can have a medium size tree, in the place of water tank. Similarly in the western side, a medium size tree can be planted between two toilet blocks. The walls should be painted with white washed externally.

* The big ventilators in the front rooms can be minimized it's size to 3" x 1'-6".

* In the surroundings, paving should be removed except on the North eastern corner, where purgola is laid above (As the owner is a lecturer, he usually takes tution class outside in the evenings and mornings).

* The water tank on the ground can be placed near to the building to get humidified cool air.

* On the front portion of SE corner should have a purgola at portico level, over it creepers can be grown.

* The sunshade should be treated with creepers.

* Shading of windows can be with white canvas cloth, which can be opened to sky during evenings and nights for getting wind movement inside the building.

* The weight of the compound wall has different heights at different places, except in eastern side, its height is more than 8'-0" from the ground level and higher than sill height. So the height of the compound wall is reduced to atleast to the sill heights. In the western side wall which is reduced, should have some grill for security reasons.

* Using ceiling fan during daytime is not advisable, instead of that, table fan can be used to serve the purpose.

* To avoid glare, it is better to grow plants near to the building by utilising the used water from the house.

* Drying of wet cloths, the summers can be done inside the building, for that,a portion of the room is left out where dripped water do not possess any problem. This method can increase the humidity content in the room and there takes place a drop in room temperature.

7.1 PASSIVE COOLING TECHNIQUES FOR EXISTING BUILDINGS :

(i) A combination of induced ventilation and evaporative cooling can be provided in the bed room. A hole of 1'-0" x 1'-0" is made on wall. Some wind diverting arrangements should be made to catch wind, on the soutside surface of wall. This opening will have two shutters, one is louvered and the other is solid shutter. The window consists a porous straw board, which is constantly wetted by connecting it to a water tank (which is situated on the wind diverters) through a pipe. In case there is no wind, the table fan can be used in front to suck wind from outside through this openings (Fig.No.).

(ii) As already said roof should be treated with mud phuska with clay tile line over it.

(iii) The other techniques are indirectly coming into picture are : (a) gain prevention techniques (b) ventilative cooling (c) nocturanal cooling etc.

8.0 RECOMMENDATIONS :

Here are the recommendations for achieving comfort conditions inside a house in Khammam, in relation to existing conditions, of the town.

I. BUILDING ENVELOPE :

(i) Roof : (a) Roofs can be treated on their external member with mud phaska along with the brick tile lining over it.

(b) Roof can be shaded with red gram dry plants during summers, which can be used as firewood during winters.

(c) Roof can be treated with waste white ceramic tiles (or white washing), to encourage reflection of incoming solar radiation.

(ii) Walls :(a) Walls can be white washed externally, and with cool colours internally.

(b) Cavity wall, externally painted white.

(iii) Openings :

(a) Windows : The window to-gether with its control device as a complete unit, must satisfy the requirements of (i) ventilation and air movement, (ii) closure for exclusion of air at times,

(iii) Daylight admission and glare control, (iv) Solar exclusion, (v) insects pest and burglar proofing, (vi) view and visual effects.

The openings give the most complicated and difficult design task. Instead of trying to design a window that fulfils the above six functions, one might provide four sets of openings, one for daylight, a second for view, a third for air movement and fourth for ventilation with adequate protection against direct solar radiation, burglars and insects.

The gaps, which are encouraging the infiltration of heat, should be sealed properly at the window design stage itself.

The shading of windows according to orientation is as follows: North - Vertical shading, south - horizontal, E/W - egg-crete, NE/NW - Vertical, SE/SE - Eggcrete.

The shutter should be thick enough to resist to heat transfer from inside to outside, both in case of doors and windows.

(b) doors : door should have carpet strip with proper workmanship, to avoid infiltration heat.

(c) Ventilator : This size of the ventilator should be small and nearer to ceiling is preferred.

(iv) Flooring : Flooring pacca flooring with cement plastering on cement concrete bed.

(vi) Sunshade : Sunshade, the horizontal surface, is to be avoided. Some treatment should be made or creeper can be used to prevent heat gain.

II. Surroundings :

(i) paving should be avoided and surrounding should not possess glare to building.

(ii) Selection of vegetation can be of local

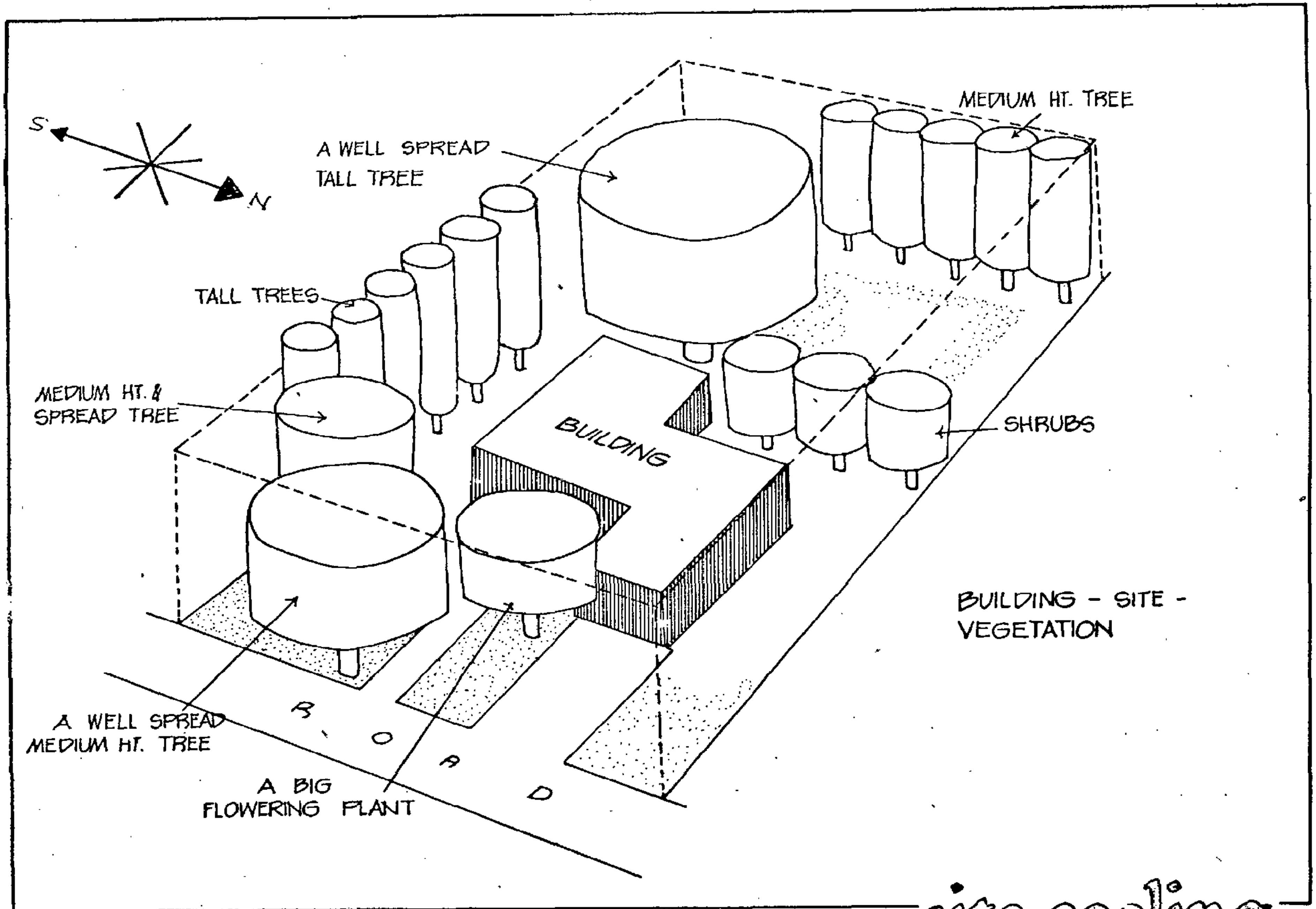
(iii) Location of trees to shade the building should be specified as mentioned earlier.

(iv) Water tank should be nearer to the building to improve building content thereby reducing ambient temperatures.

(v) As water is scarce in this place, waste water from kitchen and toilets should be properly utilized for growing vegetation around the house.

(vi) No obstruction should be theee, in the prevailing wind direction.

(vii) The canopy of the tree should not affect the incoming air, so its height should be more than lintel level.



site cooling

PASSIVE COOLING TECHNIQUES :

1. VENTILATIVE COOLING :

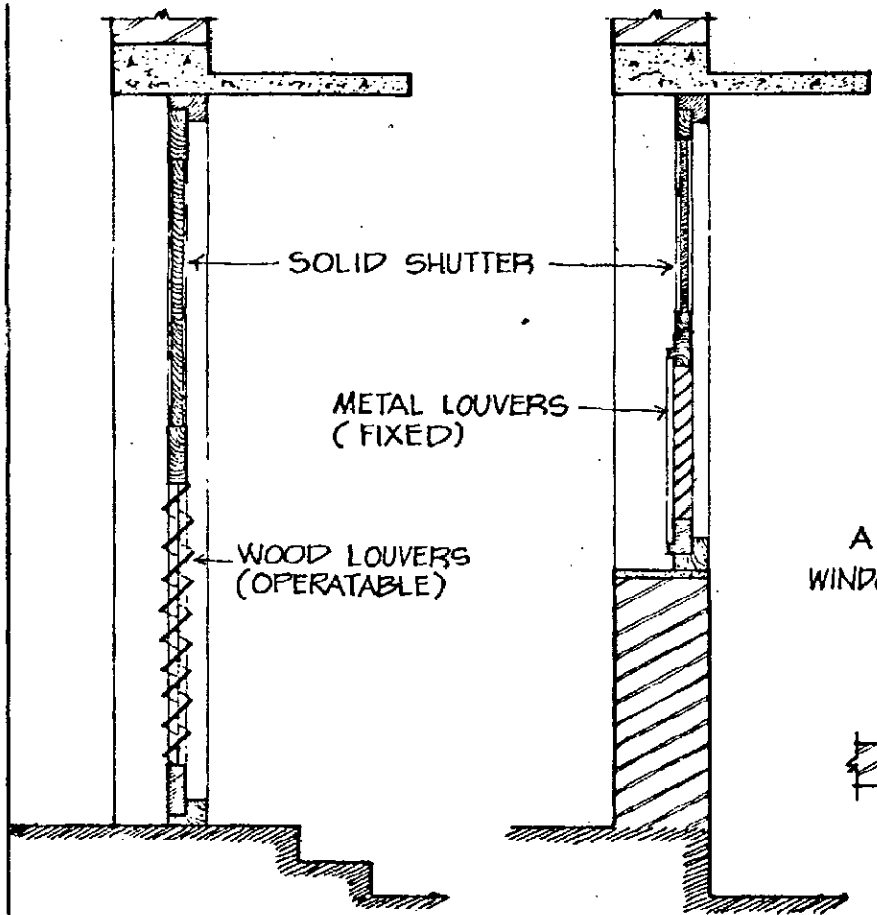
The places like Khammam needs ventilation into the houses during the night time. During this process the heat accumulated during daytime in the building is taken out and also takes the cool air from the surroundings to the inside of the building for physical comfort.

(a) Louvered Doors and Windows :

The lower portion of the door/window should allow air to pass through it. It also provides privacy also which is an essential requirement of the people. The Louvers can be closed when wind movement is not necessary. This device can solve the problem of cross ventilation. This system can be used for existing buildings also (See Fig. No.).

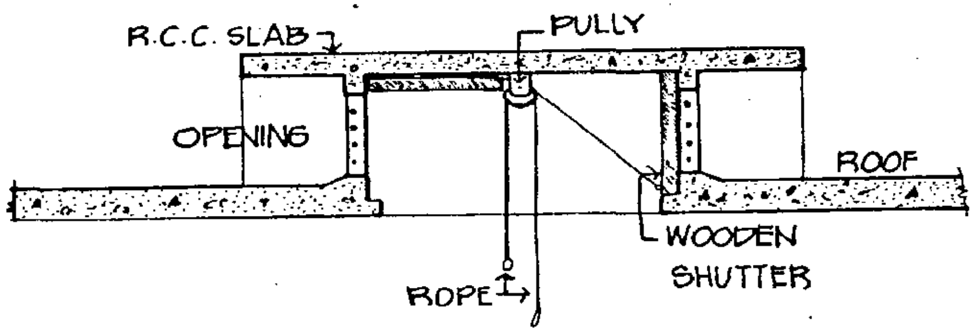
(b) Roof Projection :

By projecting a portion of the roof, we can achieve good cross ventilation and cool the indoor environment by removing hot air, which is accumulated at ceiling level. This system also consist of louvers, at the two sides of the opening. This system can be controlled by the two shutters which are tied to a rope through a pully (See Fig.No.).

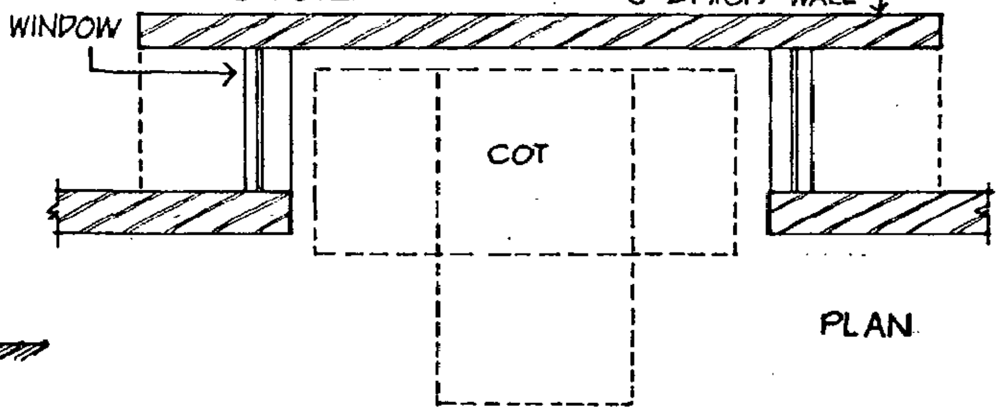


(B)

CROSS SECTION OF
(A) LOUVERED DOOR AND WINDOW



(C) PROJECTED ROOF PORTION SECTION



(D) A PORTION A ROOM IS PROJECTED

ventilative cooling

(c) Wall Projection :

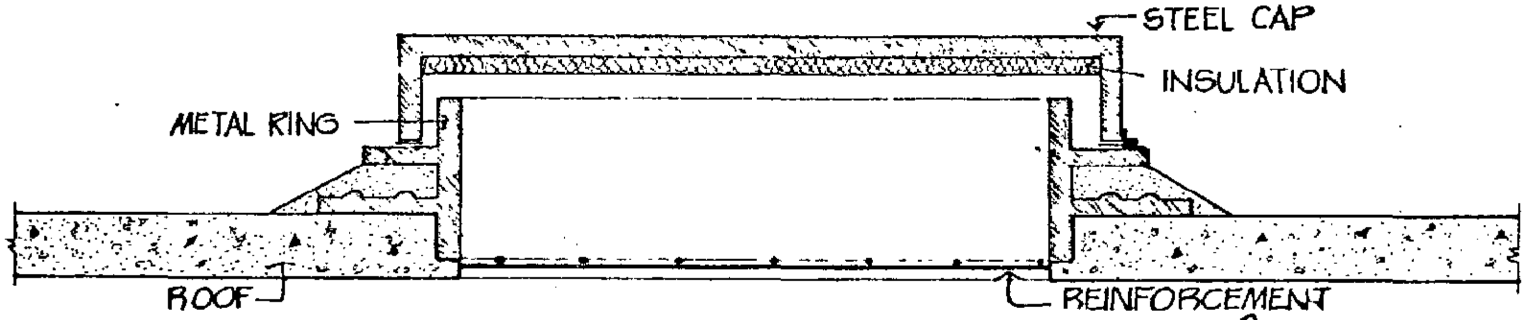
This system is similar to above said system, but here is a portion wall that is to be projected out to get good cool air movement during the night times. The projection can be of 6'-0" (a cot length) in length and at about 2'-6" in width. Two windows can be provided at two side, with proper shading can be closed during daytime. It not only provides air movement to that projected area, but also helps in providing good cross ventilation to the entire room (See Fig.No.).

2. VENTURI COOLING :

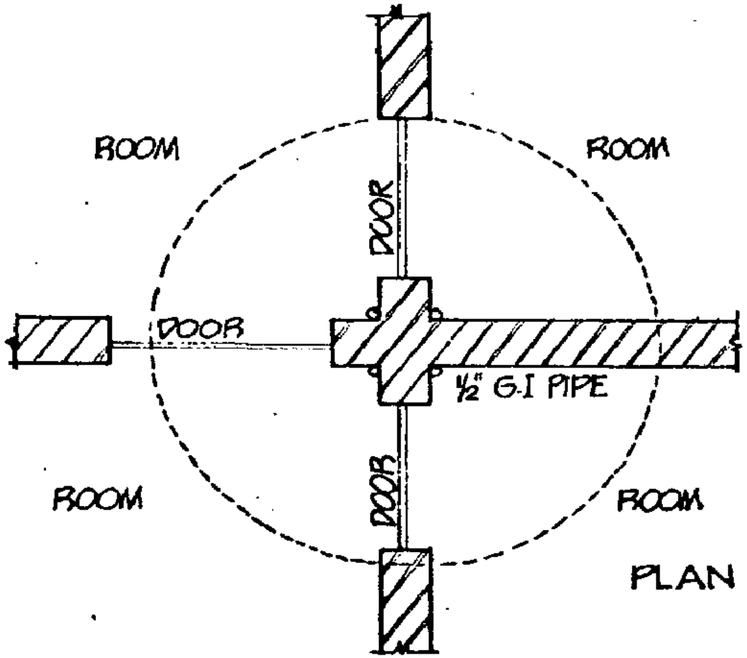
This system can be used/experimented by putting a half sphere shape structure above roof of the building. As in this process, at the apex of the half sphere air pressure will be minimum. So the pipe connected from different rooms, sucks the air from inside and takes it out. The diameter can be of 6'-0". The inside portion of the half sphere can be filled with poor cement mortar and covered with tiles plastered (smooth) externally.(See Fig. No.).

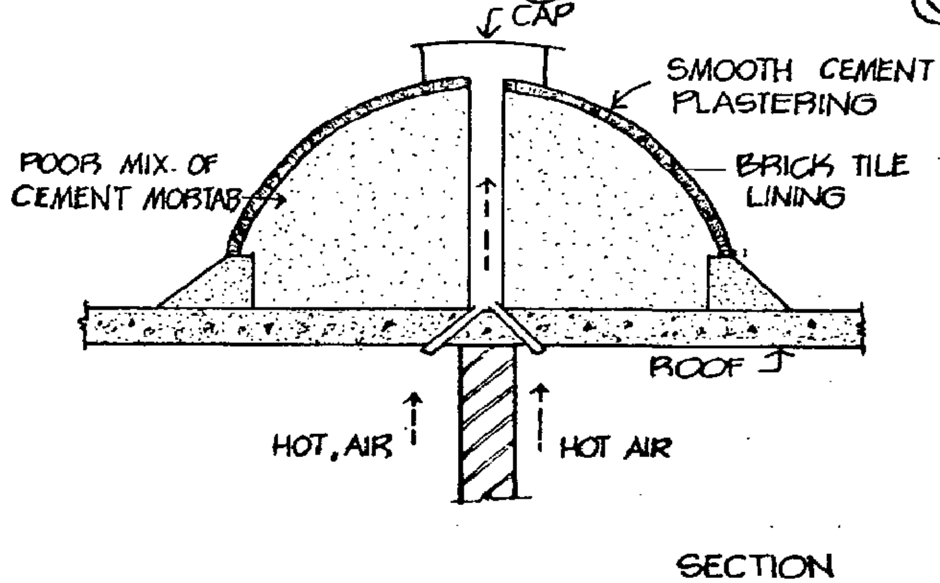
3. SKY COOLING :

In this system, a cut out is provided, at about 2'-0" dia, on the roof to accelerate the heat loss, both from the building internal envelope and from indoor air. Scientist believe that this process is very effective for achieving comfort condition inside the building in shorter span of time,



sky cooling





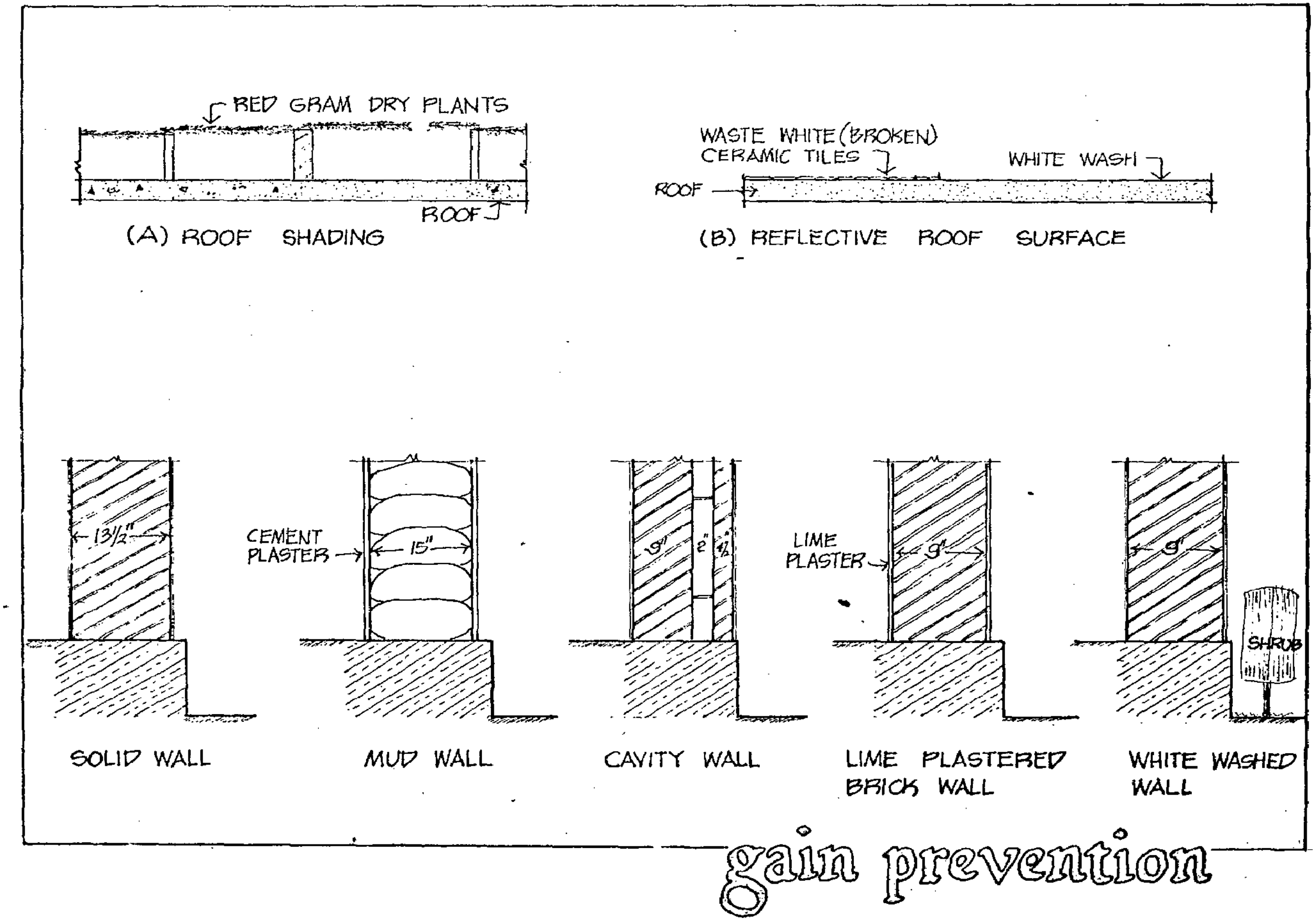
venturi cooling

after sun set. At day time the hole is closed with well insulated shutter and is opened during evening, night and morning hours (Fig.No.).

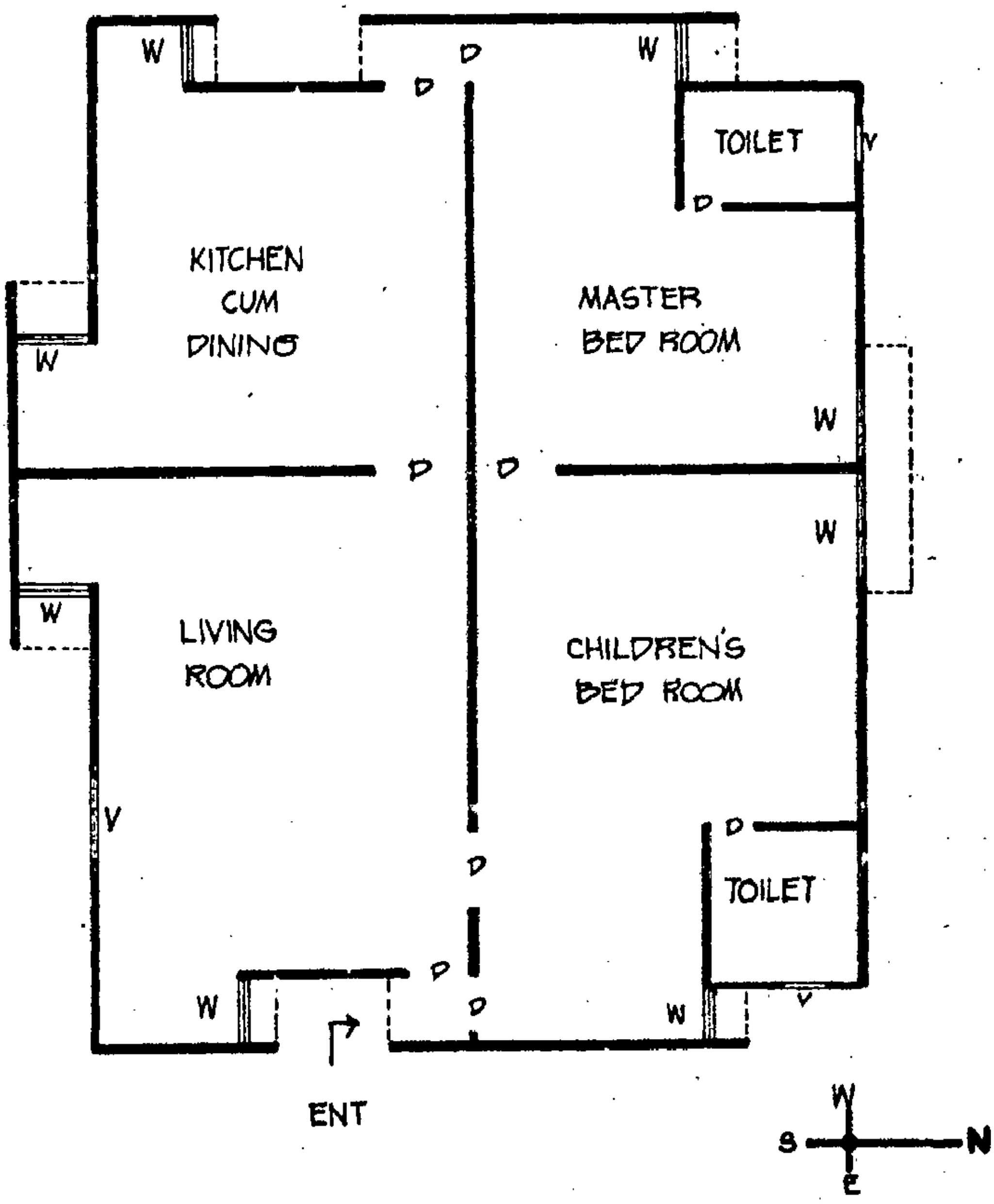
4. GAIN PREVENTION TECHNIQUES :

(a) Generally, roof gets heated first and it transfers heat to indoor environment in different way, in that one way is conduction of heat to the walls. The heat stored in the wall during daytime cannot go back in the same route during nights. It re-radiates that stored heat to the indoor environment. For taking out this stored heat will not be possible in a shorter period of span, it takes 4 to 5 hours at least. To avoid this if we can stop conduction of heat to the wall from roof by providing some insulation (wooden plank) can solve the problem at starting point itself (See Fig.No.).

(b) It is better to have indirect window especially in the eastern and western side walls. As shown in the Fig.No. , the windows should hot directly face to neither of the two side; i.e. east and west. Similarly in the case of doors. In general plans, door are not properly shaded from sun, which ultimately creating discomfort to occupants, but in this indirect door system, the doors are fully well shaded from the sun.


RED GRAM DRY PLANTS
ROOF
(A) ROOF SHADING
WASTE WHITE (BROKEN) CERAMIC TILES
WHITE WASH
ROOF
(B) REFLECTIVE ROOF SURFACE
13½"
SOLID WALL
CEMENT PLASTER
15"
MUD WALL
9"
2"
4½
CAVITY WALL
LIME PLASTER
9"
LIME PLASTERED BRICK WALL
9"
SHRUB
WHITE WASHED WALL
gain prevention

• WINDOWS & DOORS ARE FULLY SHADED BY WALLS ITSELF



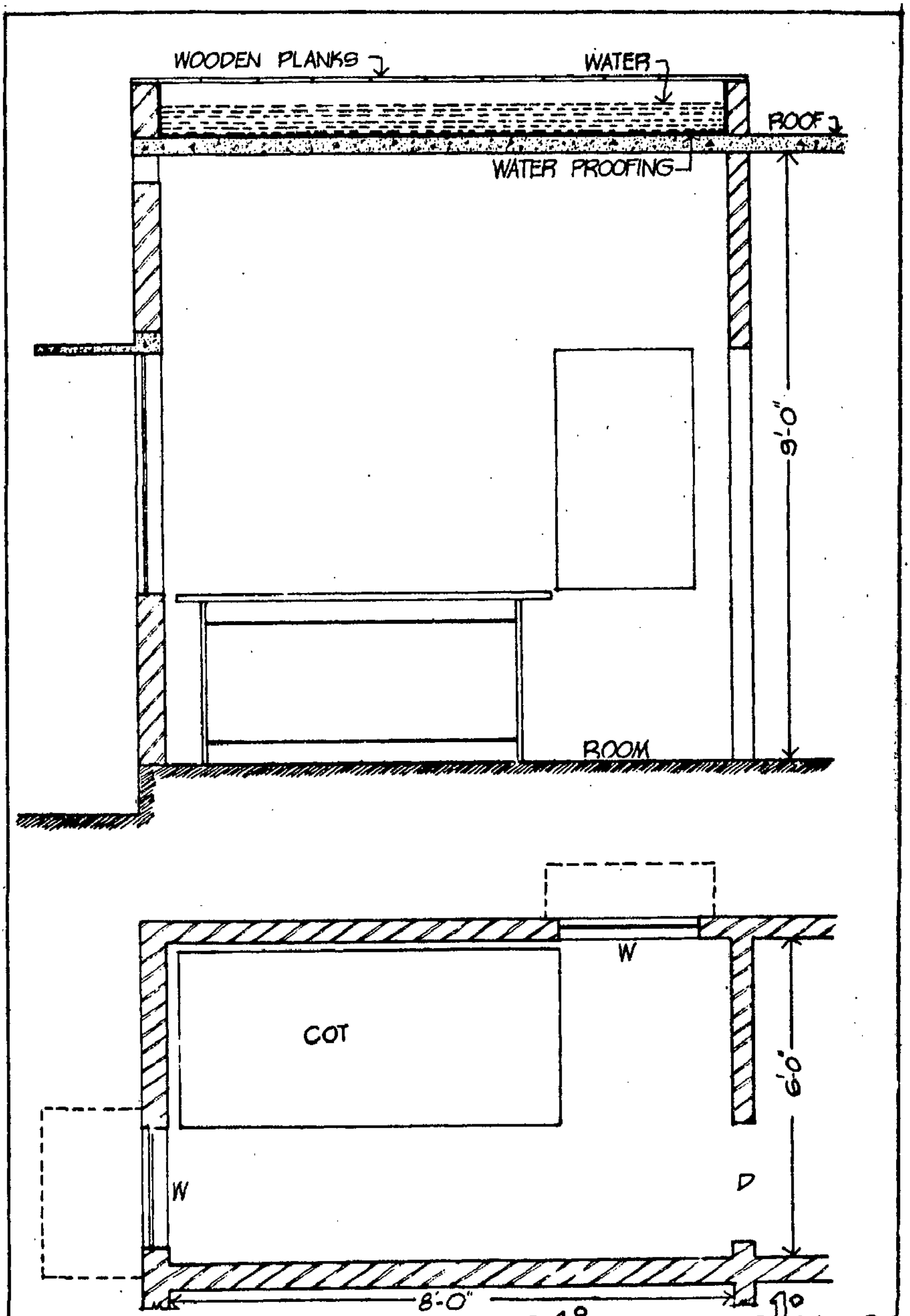
INDIRECT LOCATION OF DOORS & WINDOWS TO AVOID DIRECT SOLAR RADIATION FROM ENTERING INTO THE BUILDING.

5. EVAPORATIVE COOLING :

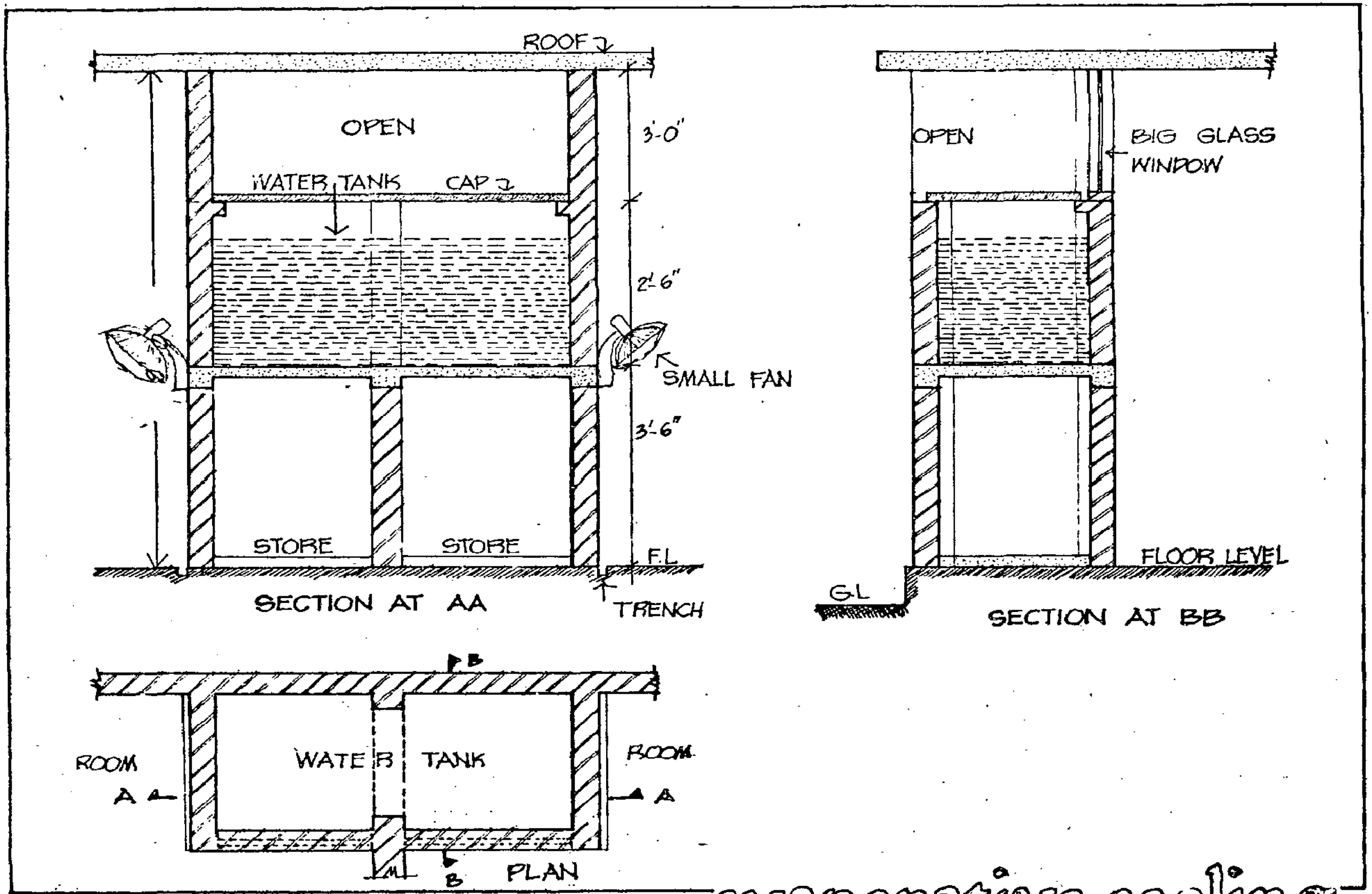
(a) The evaporative roof pond can be used on a small room, haviug minimum dimensions, like 6'x8', can be used for living and sleeping room. Usually during daytime ladies and small children stay in their houses. This system can give enough comfort during hot summers. Here water consumption is also minimum. In case water is not available for few day, the shade provided for roof pond can prevent solar radiation from falling on the roof which ultimately donot raise the indoor temperature.

(b) In this system a water tank is provided at a level of about 3'-0" and its height is 4'-0", having the dimension 2'x4'. This tank be placed between two rooms, with two small fans on either side of the tank. The walls which are facing room and be made some controllable arrangement to get seepage of water from the tank. The air in contact with this wet surface will naturally be cooler and it is taken out for circulation by the fans. Necessary arrangements shall be made to drain the water out. The water tank's cap can be opened from outside for regular maintenance(See Fig. No.).

(c) In this system entire wall height is made into three parts, the top one is a water tank middle one is a fixed glaze window for lighting and the bottom portion is having a small fan infront of which porus straw board is placed which is



evaporative cooling



evaporative cooling

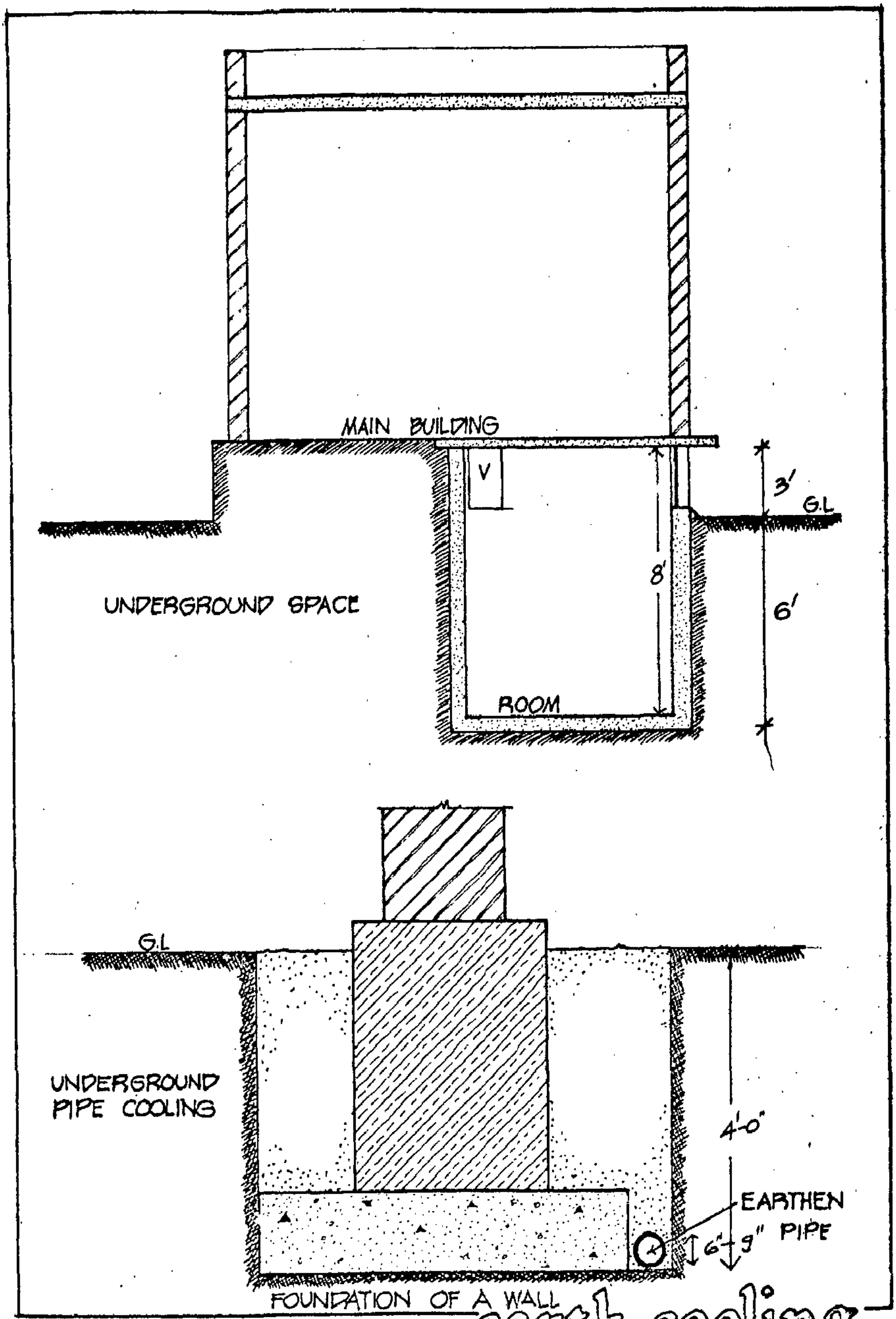
constantly wetted by the water from tank above. Here in this the window is divided into two for two purposes one is for lighting another is for cross ventilation. The used water in this system can be utilised to grow grass at the bottom which will be useful in case of water scarcity.

EARTH COOLING :

(a) Atleast a small room in the underground will give some sort of relief from the hot summer months. As the underground room temperature does not posses a wide difference between maximum and minimum temperatures.

(b) While constructing foundation a house if a earthen pipe is laid along the circumference of the building or compound wall, at a depth of about 4'-0" from ground level. The end point of this can be put in a living room with an exhaust fan in front. The starting part of this earthen pipe can at least 6" above the ground level well protected from rain, insects. The ambient hot air which is passing through the pipe will loose its heat to earth and ultimately get cooled when it reaches the end (room) (See Fig.No.).

(c) A room in the centre of the building which is surrounded by different rent rooms having low ceiling height than the rest of the room can possess good indoor comfort. The ventilation to this room can be given by arranging an earthen pipe passing



earth cooling

through the bottom portion of the surrounding room flooring which is let to outside at about 6" above ground level with a protection mesh cap. The other end of the pipe which is in the central room can have a small exhaust fan which drags air from outside to inside, through this pipe. The necessary arrangement should be made to get cool air inside the room.

Traditional Methods of Cooling :

Reintroduction of Verandah and courtyard houses is strongly recommended. A courtyard need not be a big one, a small one can also serve the purpose very efficiently. While at design stage of a building itself these two things must be kept in mind, before finalising the plan.

8.1 CONCLUSIONS :

Research in energy conservation in buildings is being conducted throughout the world. In that more emphasis is given to passive systems without using mechanical means. So lot of investigation and research is going on both traditional and proposed building designs. Some of the successful passive techniques are derived from traditional methods. Still some are unidentified.

Givoni feels 'that research in passive cooling techniques in hot-dry climates is almost has come to saturation point and he tells that only necessary modification can be done to the existing techniques to suite a particular climate'. At one end this saturation taking place but on the other end people are suffering from solar intensity due to unawareness of the existing passive cooling techniques. The two contradictory states clearly indicate that there lies a communication gap between research and implementation. People should be made to think interms of energy conservation and to get bettern environment inside the building. There are two methods to achieve the goal, one is by demonstration, another one is by showing documentary movies.

In some of the papers, the passive cooling techniques are shown and with complicated calculation along with it. But they are too technical to understand. In my opinion the suggested techniques should be simple, easy to understand and implement. Also they should be less costly and easy to maintain.

The following are some of the broad conclusions arrived at out of this study.

- A place's climatic character can be determined by two parameters i.e. air temperature and humidity but not rainfall.
- More emphasis is given to the roof and it's treatment than walls of the building envelopes, to reduce or to prevent heat transfer from outside to inside.
- The ceiling height can be 9'-0", there won't be any considerable advantage in increasing it's height further and it is costly too.
- The orientation can be of N-S, with well shaded windows. Main emphasis should be given to solar radiation rather than wind. Any way the windows are closed during daytime and opened during night time. So there will not be much of loss if wind direction is from SW or West.
- As surface area to floor area increases the heat gain also gets increased. So while at design stage itself care should be taken to minimise the exposed wall area and the space enclosed.
- For controlling the infiltration, avoid using too many shutters in a window with proper workmanship and minimise the heat transfer from outside to inside.

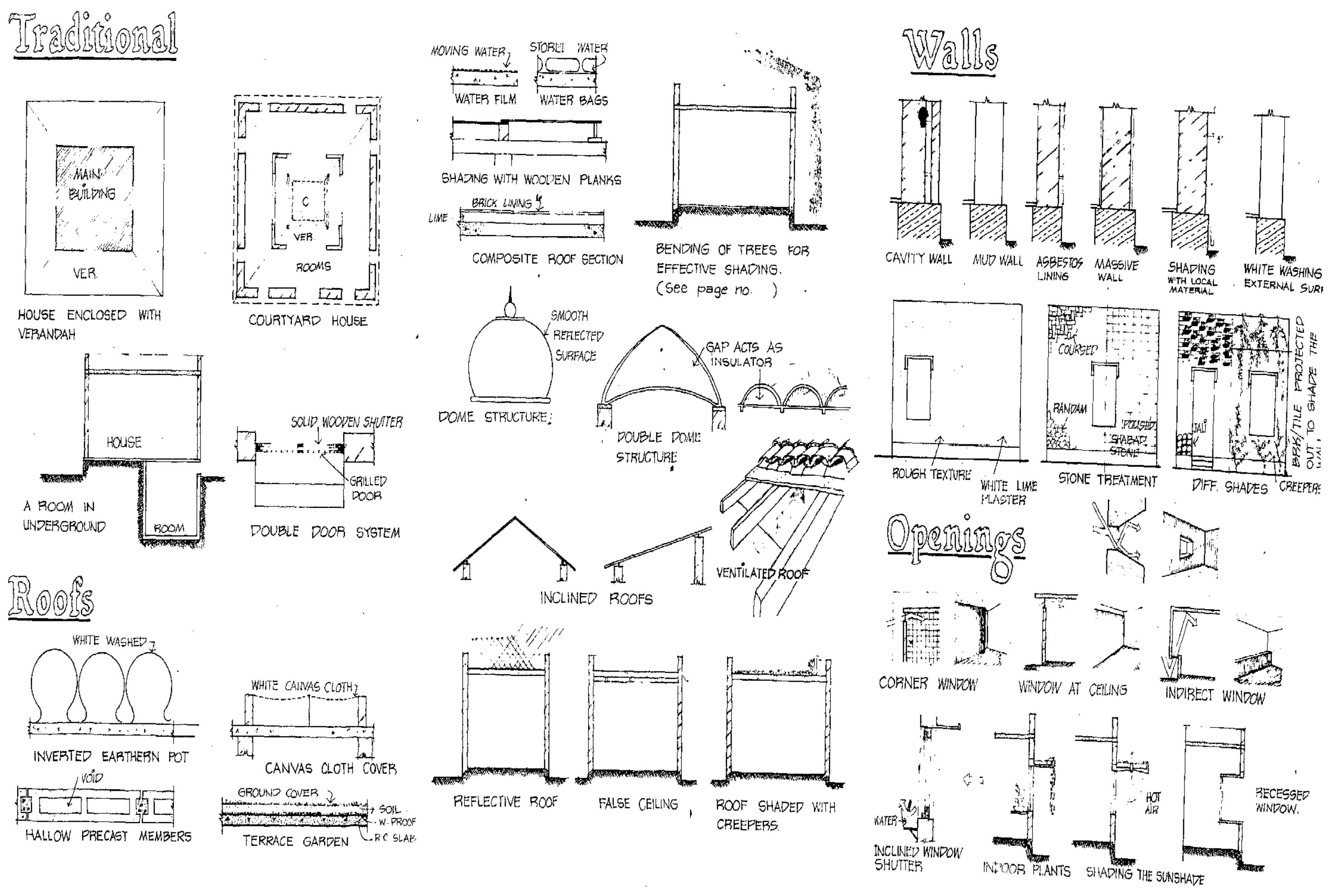
- Using indegeneous material alway better to that particular area to achieve comfort conditions inside the building. Imported material from different places may not be economical and suitable to that climate. The study also showing the importance of using lime and mud as a chief building material.

- Surface treatment has considerable effect on the indoor environment it can reduce or increase both ventilation rate and indoor temperature. Using white wash to the external envelope of the building will always good with respect to ventilation rate and for reducing indoor air temperature.

- In our general living style colour has got great impact on psycholggical feeling of the people. Cool colour will give some sort of imaginary feeling of coolness. So using cool colour in the interior will give psychological relief in summer.

The passive cooling techniques which are discussed earlier are based on the availability of building material and from implementation point of view also. And in the recommendations it is suggested, some modified passive cooling techniques which can be implemented in both existing and proposed buildings.

One thing which is understood during this study is, it is not easy to estimate the indoor air temperature, when there applied one or more passive cooling techniques, because number of variable parameters are involved in these calculations. But it will definetely be better than previous building's in terms of indoor air temperature. Thus it can be conclusively looked upon that progressive research in near future may reduce gulf between formulation and implementation, and a pragmatic treatment to the passive cooling techniques as suggested may be established.



Traditional
MAIN BUILDING
VER.
HOUSE ENCLOSED WITH VERANDAH
C
VER.
ROOMS
COURTYARD HOUSE
HOUSE
ROOM
A ROOM IN UNDERGROUND
SOLID WOODEN SHUTTER
GRILLED DOOR
DOUBLE DOOR SYSTEM
Roofs
WHITE WASHED
INVERTED EARTHERN POT
VOID
HALLOW PRECAST MEMBERS
WHITE CANVAS CLOTH
CANVAS CLOTH COVER
GROUND COVER
SOIL
W. PROOF
R.C SLAB
TERRACE GARDEN
MOVING WATER
WATER FILM
STOREI WATER
WATER BAGS
SHADING WITH WOODEN PLANKS
BRICK LINING
LIME
COMPOSITE ROOF SECTION
BENDING OF TREES FOR EFFECTIVE SHADING.
(See page no.)
SMOOTH REFLECTED SURFACE
DOME STRUCTURE
GAP ACTS AS INSULATOR
DOUBLE DOME STRUCTURE
INCLINED ROOFS
VENTILATED ROOF
REFLECTIVE ROOF
FALSE CEILING
ROOF SHADED WITH CREEPERS.
Walls
CAVITY WALL
MUD WALL
ASBESTOS LINING
MASSIVE WALL
SHADING WITH LOCAL MATERIAL
WHITE WASHING EXTERNAL SURI
ROUGH TEXTURE
WHITE LIME PLASTER
COURSED
RANDAM
POLISHED SHABAD STONE
STONE TREATMENT
JALI
BRK/TILE PROJECTED OUT TO SHADE THE WALL
DIFF. SHADES
CREEPERS
Openings
CORNER WINDOW
WINDOW AT CEILING
INDIRECT WINDOW
WATER
INCLINED WINDOW SHUTTER
INDOOR PLANTS
HOT AIR
SHADING THE SUNSHADE
RECESSED WINDOW.

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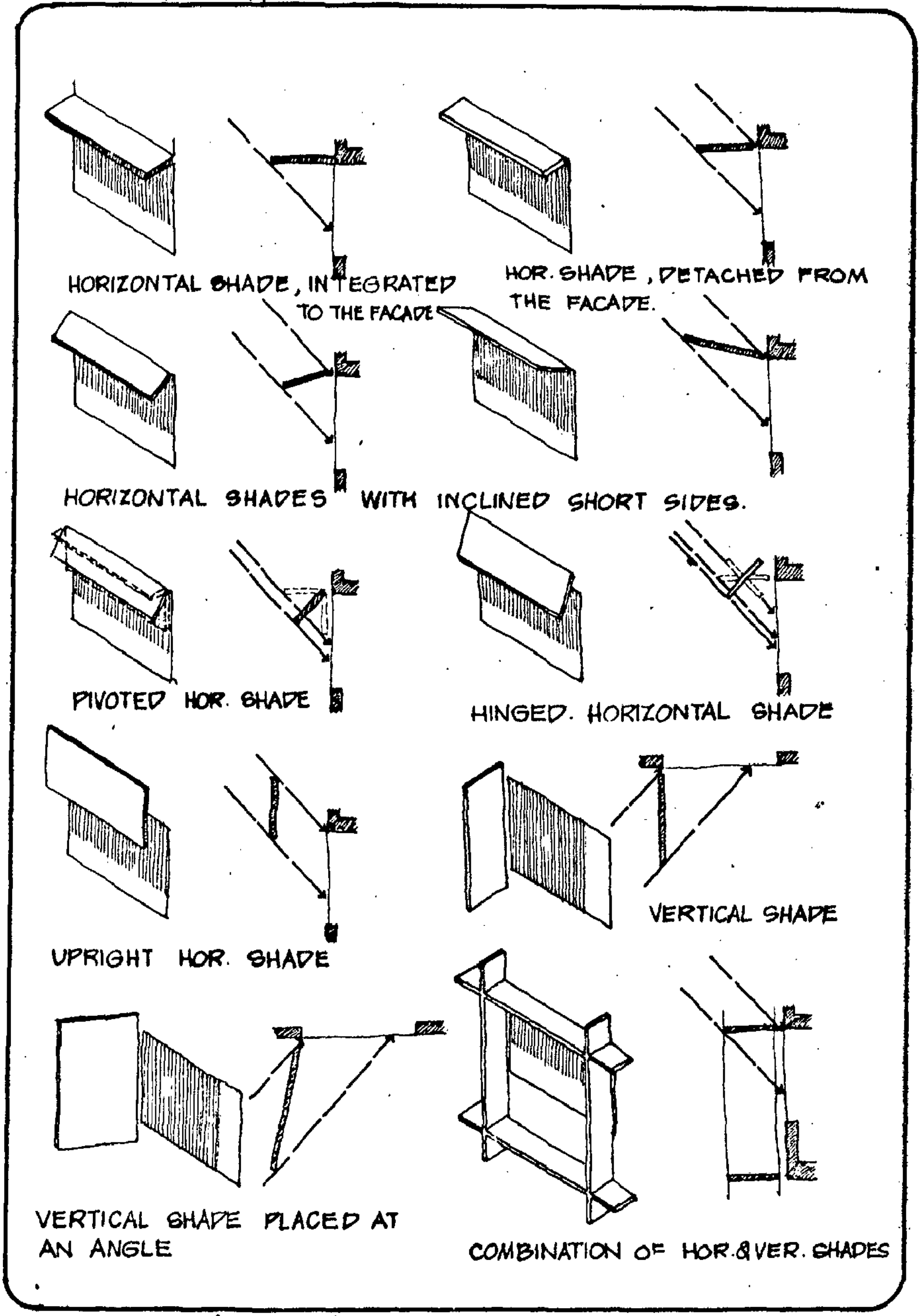
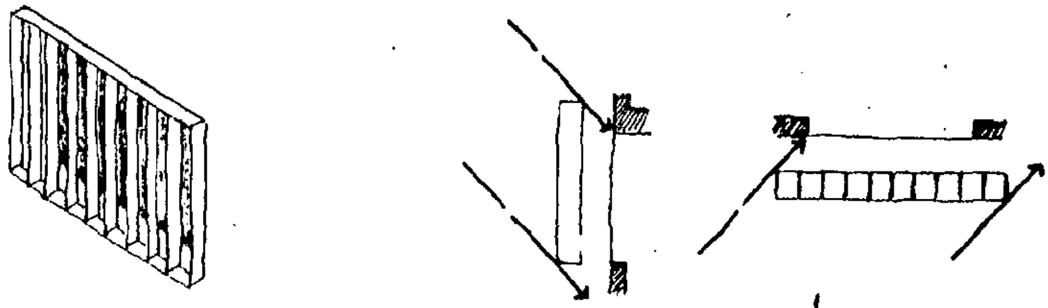
CBRI Building Digests :

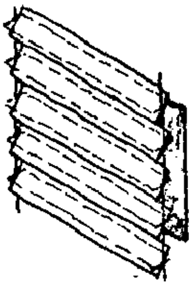
94, 101, 103, 108, 117, 119, 121, 124, 138, etc.


HORIZONTAL SHADE, INTEGRATED TO THE FACADE
HOR. SHADE, DETACHED FROM THE FACADE.
HORIZONTAL SHADES WITH INCLINED SHORT SIDES.
PIVOTED HOR. SHADE
HINGED. HORIZONTAL SHADE
UPRIGHT HOR. SHADE
VERTICAL SHADE
VERTICAL SHADE PLACED AT AN ANGLE
COMBINATION OF HOR.&VER. SHADES

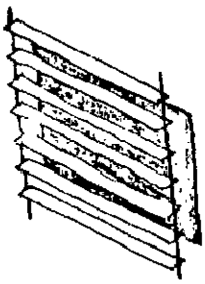
APPENDIX NO. 1B



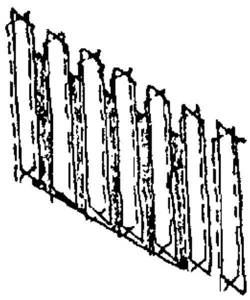
VERTICAL FIXED LOUVER, FRAMED, WITH FIXED/MOVABLE SLATS

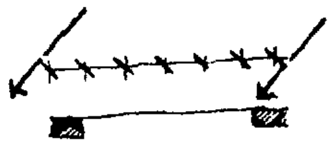


HINGED HORIZONTAL BLIND

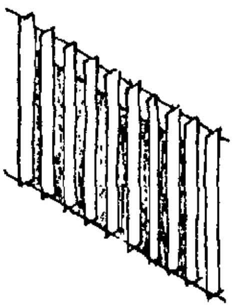


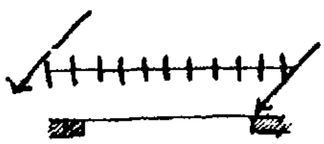
HOR. BLIND WITH ADJUST-ABLE LEVEL.





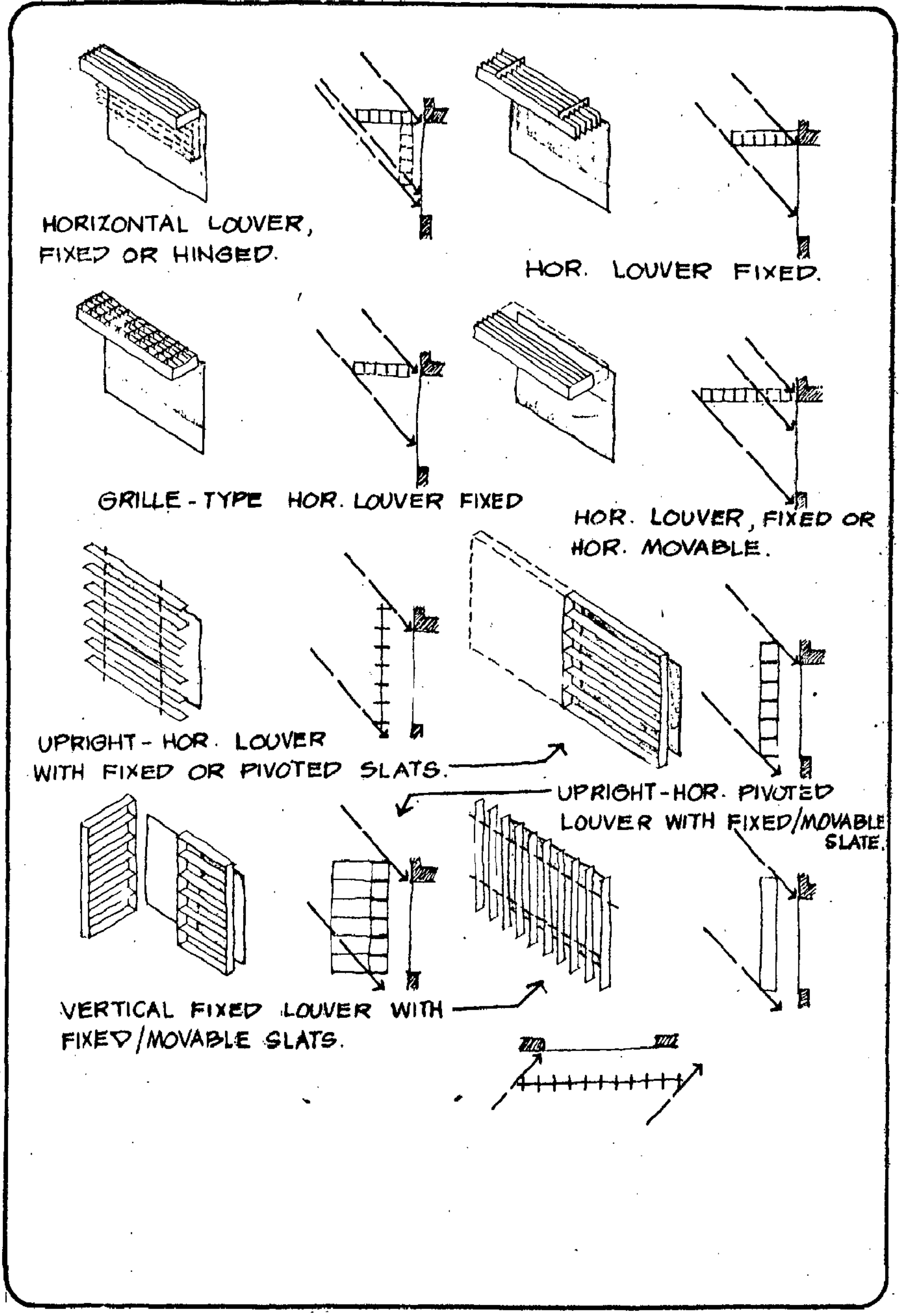
HINGED VERTICAL BLIND

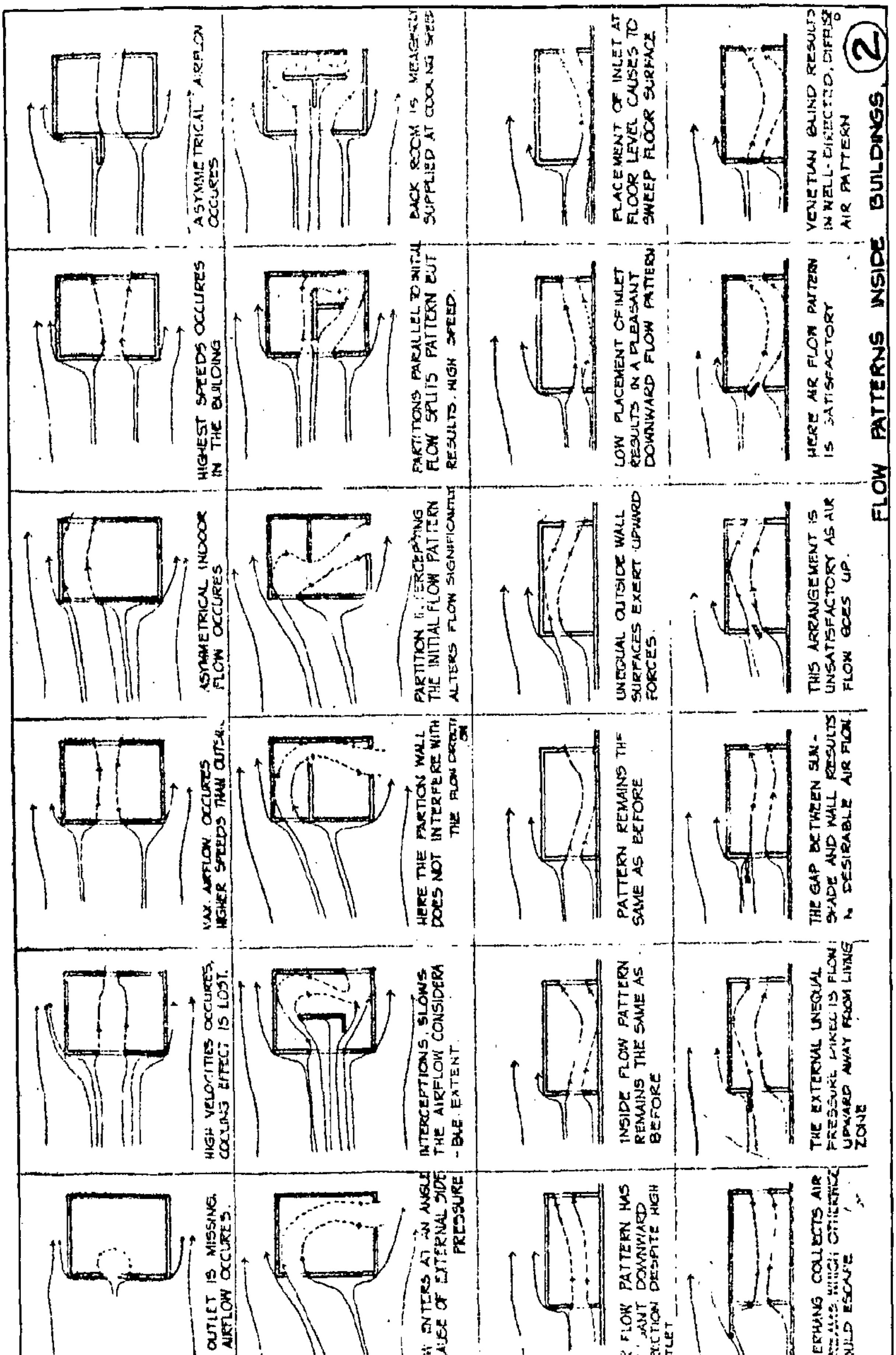




LATERALLY MOVABLE VERTICAL BLIND.

APPENDIX NO. 1C

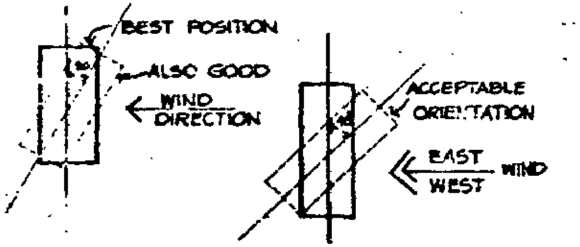



AS OUTLET IS MISSING NO AIRFLOW OCCURES.
HIGH VELOCITIES OCCURES, COOLING EFFECT IS LOST.
MAX. AIRFLOW OCCURES HIGHER SPEEDS THAN OUTSI.
ASYMMETRICAL INDOOR FLOW OCCURES
HIGHEST SPEEDS OCCURES IN THE BUILDING
ASYMMETRICAL AIRFLOW OCCURES
PRESSURE
INTERCEPTIONS, SLOWS THE AIRFLOW CONSIDERA -BLE EXTENT
HERE THE PARTION WALL DOES NOT INTERFERE WITH THE FLOW DIRECTI ON
THE INITIAL FLOW PATTERN ALTERS FLOW SIGNIFICANTLY
PARTITIONS PARALLEL TO INITIAL FLOW SPLITS PATTERN BUT RESULTS HIGH SPEED
SUPPLIED AT COOLING SPEED
AIR FLOW PATTERN HAS DOWNWARD DIRECTION DESPITE HIGH OUTLET
INSIDE FLOW PATTERN REMAINS THE SAME AS BEFORE
PATTERN REMAINS THE SAME AS BEFORE
UNEQUAL OUTSIDE WALL SURFACES EXERT UPWARD FORCES.
LOW PLACEMENT OF INLET RESULTS IN A PLEASANT DOWNWARD FLOW PATTERN
PLACEMENT OF INLET AT FLOOR LEVEL CAUSES TO SWEEP FLOOR SURFACE
OVERHANG COLLECTS AIR WOULD ESCAPE
THE EXTERNAL UNEQUAL UPWARD AWAY FROM LIVING ZONE
THE GAP BETWEEN SUN-SHADE AND WALL RESULTS IN DESIRABLE AIR FLOW
THIS ARRANGEMENT IS UNSATISFACTORY AS AIR FLOW GOES UP.
HERE AIR FLOW PATTERN IS SATISFACTORY
VENETIAN BLIND RESULTS AIR PATTERN
FLOW PATTERNS INSIDE BUILDINGS
2

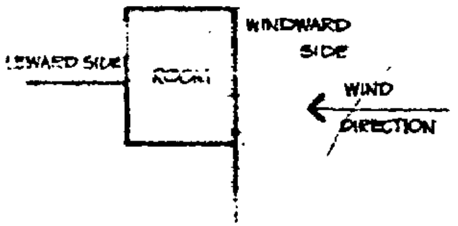
AIR MOTION IS AN IMPORTANT CONTRIBUTOR TO MAN'S THERMAL SENSATION THE LEVEL OF ACCEPTABLE AIR MOTION DEPENDS UPON CLIMATIC CONDITIONS. IN HOT CLIMATES, HIGH RATES OF AIR MOTION ARE DESIRA FOR COMFORT AND PRIME IMPORTANCE IS GIVEN TO GOOD VENTILATION IN DESIGN OF BLDGS.

GUIDELINES FOR DESIGNING AIRY BLDGS:

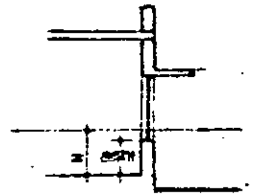
1. FOR ACHIEVING MAX. BENEFIT FROM NATURAL WIND, BUILDINGS NEED NOT NECESSARILY BE ORIENTED PERPENDICULAR TO THE PREVAILING OUTDOOR WIND; IT MAY BE ORIENTED AT ANY CONVENIENT ANGLE BETWEEN 0° AND 30° WITHOUT LOSING ANY BENEFICIAL ASPECT OF THE BREEZE. IF THE PREVAILING WIND IS FROM EAST OR WEST, BUILDINGS CAN BE ORIENTED AT 45° TO THE INCIDENT WIND FOR DIMINISHING THE SOLAR HEAT WITHOUT AFFECTING THE AIR MOTION INDOORS.



2. ATLEAST ONE WINDOW SHOULD BE PROVIDED ON THE WINDWARD WALL AND THE OTHER ON THE LEEWARD WALL



3. MAX. AIR MOVEMENT AT A PERTICULAR PLANE IS ACHIEVED BY KEEPING THE SILL HEIGHT AT 85% OF THE HEIGHT OF THE PLANE(H)



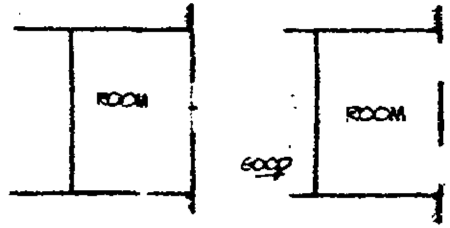
4. IN ROOMS OF NORMAL SIZE HAVING IDENTICAL WINDOWS ON OPPOSITE WALLS THE AVERAGE INDOOR AIR SPEED INCREASES RAPIDLY BY INCREASING THE WIDTH OF THE WINDOW UP TO ABOUT 2/3 OF THE WALL WIDTH; BEYOND THAT THE INCREASE IS IN MUCH SMALLER PROPORTION THAN THE INCREASE OF THE WINDOW WIDTH

5. THE AVERAGE INDOOR WIND SPEED IN THE WORK ZONE IS MAX. WHEN WINDOW HEIGHT IS 110 CMS. FURTHER INCREASE IN WINDOW HEIGHT PROMOTES AIR MOTION AT THE TOP LEVEL OF WINDOW, BUT DOES NOT CONTRIBUTE ADDITIONAL BENEFITS AS REGARDS AIR MOTION IN THE OCCUPANCY ZONE IN BUILDINGS.

6. FOR TOTAL FENESTRATION AREA (INLET + OUTLET) OF 20 TO 30% OF FLOOR AREA, THE AVERAGE INDOOR WIND VELOCITY. FURTHER INCREASE IN WINDOW SIZE INCREASE THE AVAILABLE VELOCITY BUT NOT IN THE SAME PROPORTION. THE MAX AVERAGE INDOOR WIND VELOCITY DOES NOT EXCEED 40% OF THE OUTDOOR VELOCITY

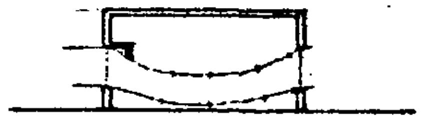
7. IN REGIONS HAVING FAIRLY CONSTANT WIND DIRECTION, THE SIZE OF THE INLET SHOULD BE KEPT WITHIN 30 TO 50% OF THE TOTAL AREA OF FENESTRATION AND BUILDING SHOULD BE ORIENTED PERPENDICULAR TO THE INCIDENT WIND. SINCE INLETS SMALLER THAN OUTLETS ARE MORE SENSITIVE TO CHANGE IN WIND DIRECTION, OPENINGS OF EQUAL SIZES ARE PREFERRED IN THE REGIONS HAVING FREQUENT CHANGES IN WIND DIRECTION.

8. INCASE OF A ROOM WITH ONLY ONE WALL EXPOSED TO OUTSIDE, PROVISION OF TWO WINDOWS IS PREFERRED TO THAT OF A SINGLE WINDOW.



9. WINDOWS LOCATED DIAGONALLY OPPOSITE TO EACH OTHER, WITH THE WINDWARD WINDOW NEAR THE UPSTREAM CONER, GIVE PERFORMANCE BETTER THAN OTHER WINDOW ARRANGEMENTS FOR MOST OF THE BLDG ORIENTATIONS

10. HORIZONTAL LOUVER (SUNSHADE) DEFLECTS THE INCIDENT WIND UPWARD AND REDUCES AIR MOTION IN THE ZONE OF OCCUPANCY. A GAP BETWEEN HORIZONTAL LOUVERS AND WALL PREVENTS UPWARD DEFLECTION OF AIR IN THE INTERIOR OF ROOMS.

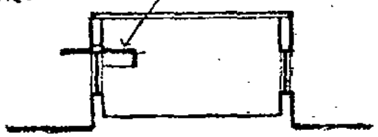


PROVISION OF L-TYPE LOUVERS INCREASES THE ROOM AIR MOTION PROVIDED THAT VERTICAL PROTECTION DOESNOT OBSTRUCT THE INCIDENT WIND.

INSIDE AIRFLOW - GUIDELINES (3)

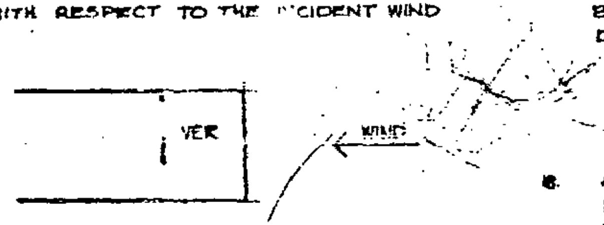
1. PROVISION OF HORIZONTAL SHASHES INCLINED AT AN ANGLE OF 45° IN APPROPRIATE DIRECTION HELPS TO PROMOTE THE AIR MOTION INSIDE ROOMS. SHASHES PROJECTING OUTWARD ARE MORE EFFECTIVE THAN PROJECTING INWARD.

2. AIR MOVEMENT AT WORKING PLANE 0.4m ABOVE THE FLOOR CAN BE ENHANCED BY 30% USING A PLEMET TYPE WIND DEFLECTOR.

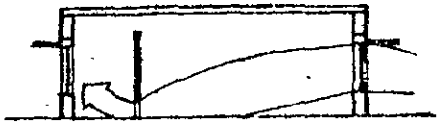


3. ROOF OVERHANGS HELP PROMOTING AIR MOTION IN THE WORKING ZONE INSIDE BUILDINGS

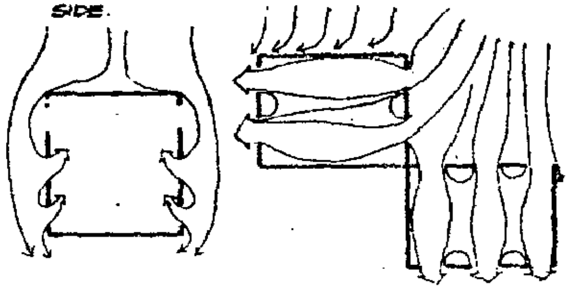
4. VERANDAH OPEN ON THREE SIDES IS TO BE PREFERRED SINCE IT CAUSES AN INCREASE IN THE ROOM AIR MOTION FOR MOST OF THE ORIENTATIONS OF BUILDING WITH RESPECT TO THE INCIDENT WIND



5. A PARTITION PLACED PARALLEL TO THE INCIDENT WIND, HAS LITTLE INFLUENCE ON THE PATTERN OF AIR FLOW; BUT WHEN LOCATED PERPENDICULAR TO THE MAIN-FLOW, THE SAME PARTITION CREATES A WIND SHADOW. PROVISION OF A PARTITION WITH SPACING OF 0.3M UNDERNEATH, HELPS MAKING AIR MOTION NEAR FLOOR LEVEL IN THE LEEWARD COMPARTMENT OF WIDE SPAN BUILDINGS.



6. AIR MOTION IN A BUILDING UNIT HAVING WINDOWS TANGENTIAL TO THE INCIDENT WIND IS ACCELERATED WHEN ANOTHER UNIT IS LOCATED AT END-ON POSITION ON DOWNSTREAM SIDE.



7. AIR MOTION IN TWO WINGS ORIENTED PARRALEL TO THE PREVAILING BREEZE IS PROMOTED BY CONNECTING THEM WITH A BLOCK ON THE DOWNSTREAM SIDE.

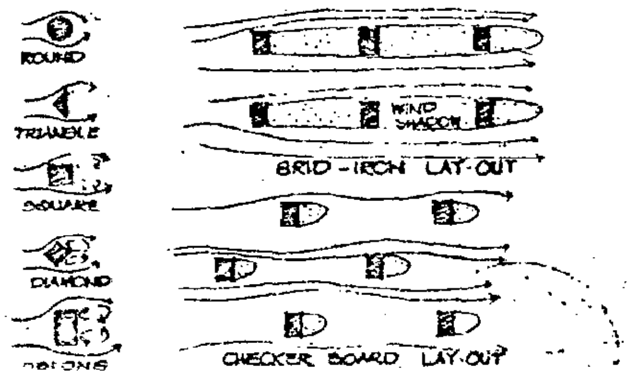
8. AIR MOTION IN A BUILDING IS LESS THAN THAT IN AN UNOBSTRUCTED BUILDING. TO MINIMISE SHIELDING EFFECT, THE DISTANCE BETWEEN THE TWO ROWS SHOULD BE ABOUT 8H FOR SEMIDETACHED HOUSES AND 10H FOR A LONG ROWS HOUSES. HOWEVER, THE SHIELDING EFFECT IS DIMINISHED BY RAISING THE HEIGHT OF THE SHIELDED BUILDING.

9. AIR MOTION IN A BUILDING IS NOT AFFECTED BY CONSTRUCTING ANOTHER BUILDING OF EQUAL OR SMALLER HEIGHT ON THE LEEWARD SIDE (A) BUT IT IS SLIGHTLY REDUCE IF LEEWARD BUILDING IS TALLER THAN THE WINDWARD BLOCK (B)

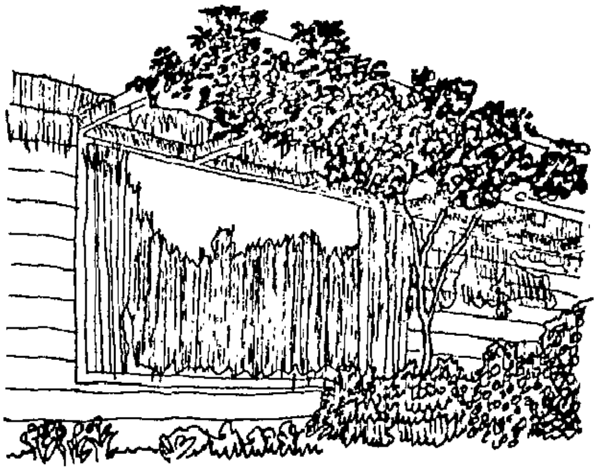
10. HEDGES AND SHRUBS DEFLECT THE AIR AWAY FROM THE INLET OPENING AND CAUSE A REDUCTION IN AIR MOTION INDOORS AIR MOTION IN THE LEEWARD PART OF THE BUILDING CAN BE ENHANCED BY PLANTING A LOW HEDGES AT A DISTANCE OF 2m FROM THE BUILDING

11. TREES WITH LARGE FOLIAGE MASS HAVING TRUNK BARE OF BRANCHES UP TO THE TOP LEVEL OF WINDOW, DEFLECT THE OUTDOOR WIND DOWNWARDS AND PROMOTES AIR MOTION IN THE OCCUPANCY ZONE INSIDE THE BUILDINGS.

12. VENTILATION CONDITIONS INDOORS CAN BE AMELIORATED BY CONSTRUCTING BUILDINGS ON EARTH MOUND HAVING A SLANT SURFACE WITH A SLOPE OF 10° ON UPSTREAM SIDE

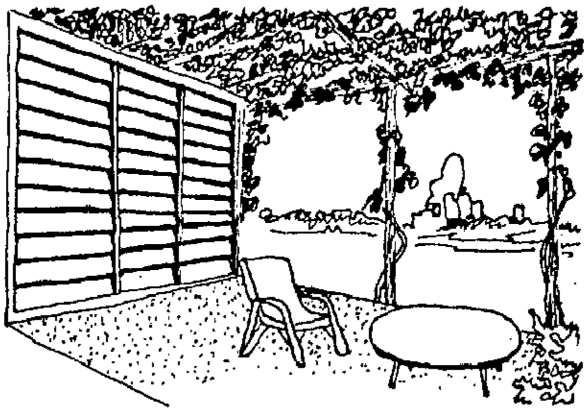


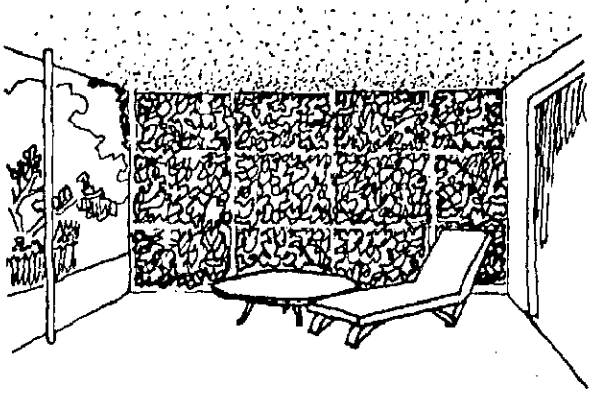
APPENDIX NO. 2A 4



A COOL GREEN AWNING OVER WINDOW OF A BED-ROOM, LIVING ROOM, OR A DINING ROOM IN SUMMER.

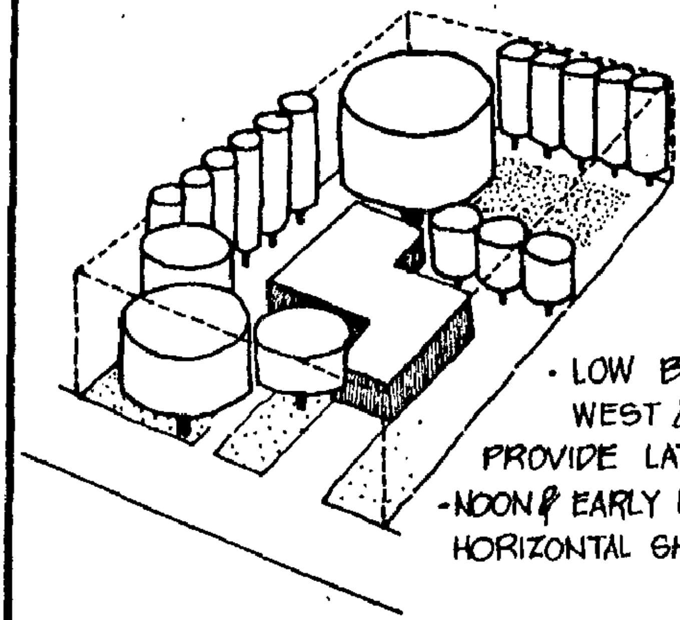
HEAVIER STRUCTURE, HEAVIER VINE GIVES THICK SHADE.





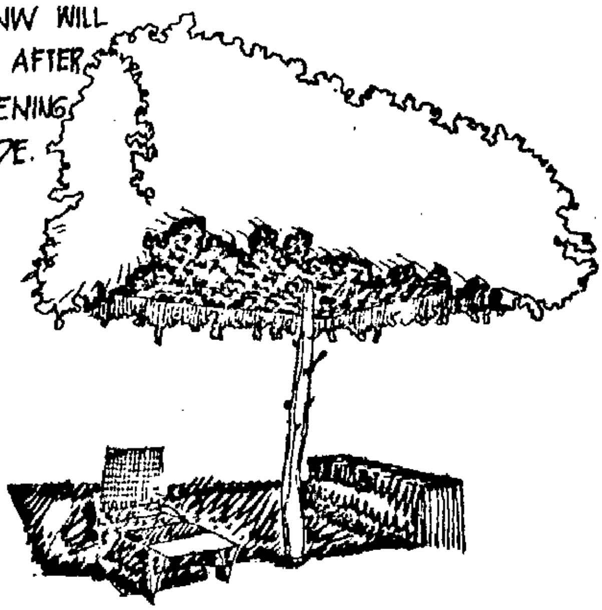
IT CUTS GLARE, WIND; INSULATE AGAINST SUMMER SUN. VINE CAN BE EVER-GREEN IF YOU DO NOT WANT WINTER SUN. GOOD AT PORCH OR TERRACE WALL.

APPENDIX NO. 2B4



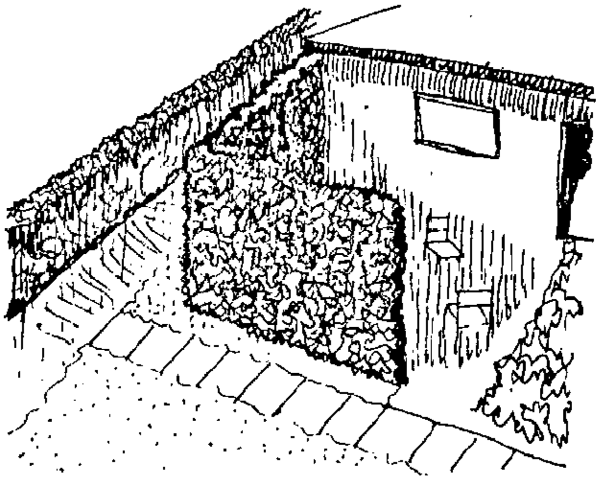
• BEST PLANTING FOR HOUSE SHADE IN A TYPICAL SITUATION ARE HIGH-BRANCHING DECIDUOUS TREES RELATIVELY CLOSE TO THE HOUSE ON THE EAST AND SOUTH, FOR VERTICAL SHADE MORNING AND AFTERNOON.

• LOW BRANCHING EVERGREEN TREES ON THE WEST & NW WILL PROVIDE LATE AFTER-NOON & EARLY EVENING HORIZONTAL SHADE.



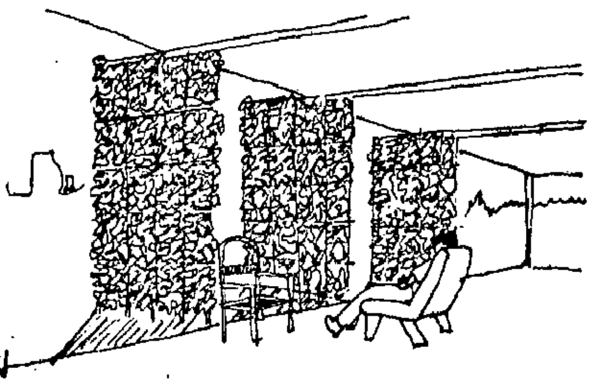
WITH A CAREFUL SUPPORT A TREE CAN BE SHAPED TO FORM AN ALMOST SOLID OVERHEAD CANOPY.

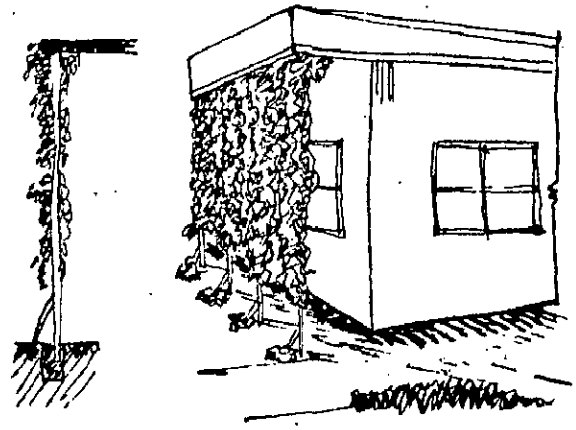
PORTABLE SUN CONTROL. BOXED BAMBOO, PLACED CLOSE TOGETHER CASTS FILTERED AFTERNOON SHADE ON WINDOW WALL.



IT STOPS GLARE IN THE MORNING AND AFTERNOON AND CUTS DIRECT SOLAR RADIATION IN LATE WESTERN SUN.

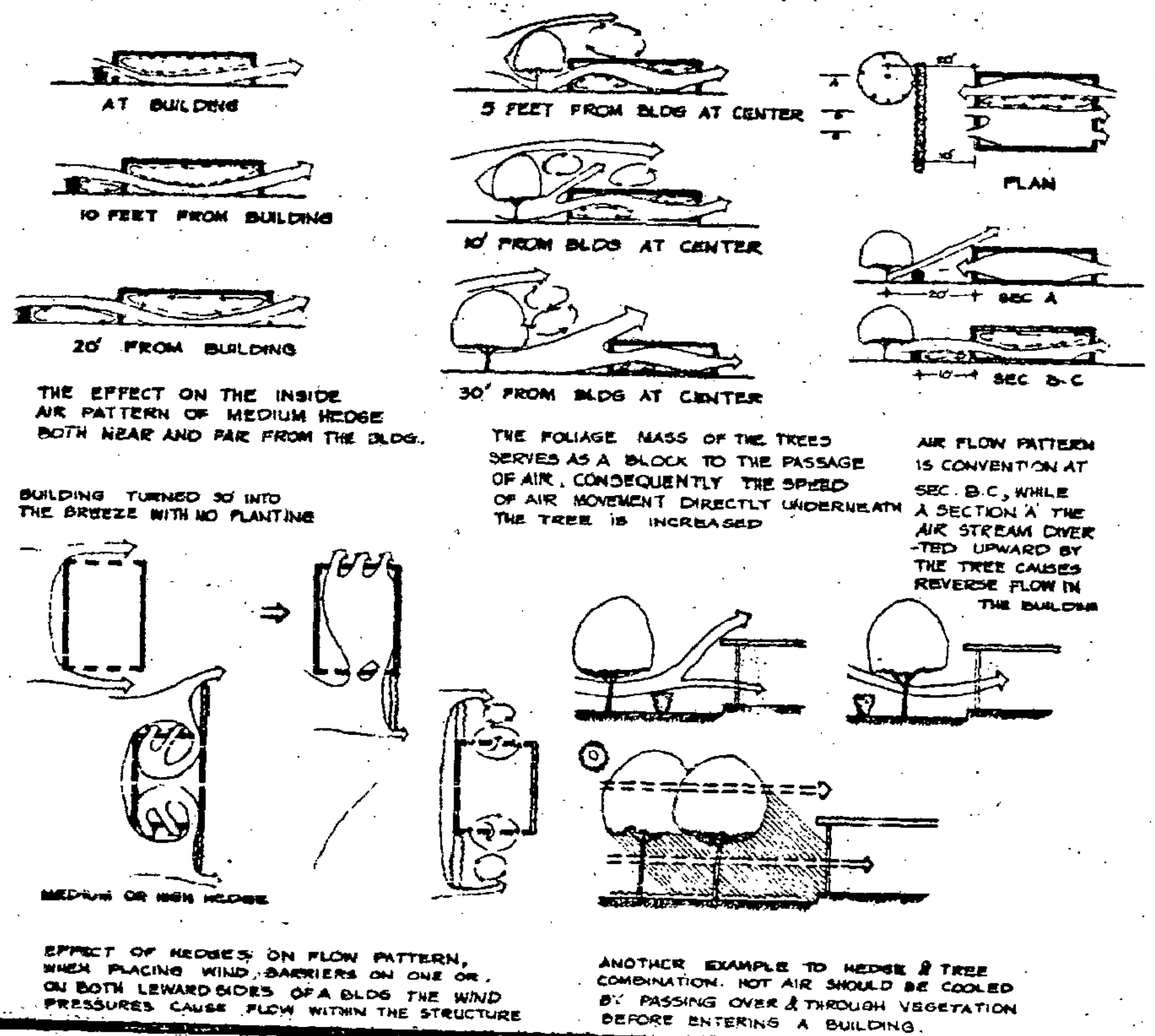
IT SHIELDS OUTDOOR LIVING AREA OR GLASS OPENING FROM THE DIRECT RAYS OF LOW, LATE AFTERNOON WESTERN SUN WITHOUT SHUTTING OUT LIGHT OR STOPPING AIR CIRCULATION





INSULATION AGAINST AFTERNOON SUN IN HOT SUMMER CLIMATE, BUT WITH SPACE BETWEEN BARRIER AND HOUSE WALL FOR AIR CIRCULATION.

APPENDIX NO. ...


AT BUILDING
10 FEET FROM BUILDING
20' FROM BUILDING
THE EFFECT ON THE INSIDE AIR PATTERN OF MEDIUM HEDGE BOTH NEAR AND FAR FROM THE BLDG.
5 FEET FROM BLDG AT CENTER
10' FROM BLDG AT CENTER
30' FROM BLDG AT CENTER
THE FOLIAGE MASS OF THE TREES SERVES AS A BLOCK TO THE PASSAGE OF AIR, CONSEQUENTLY THE SPEED OF AIR MOVEMENT DIRECTLY UNDERNEATH THE TREE IS INCREASED
PLAN
SEC A
SEC B-C
AIR FLOW PATTERN IS CONVENTION AT SEC. B.C, WHILE A SECTION 'A' THE AIR STREAM DIVER-TED UPWARD BY THE TREE CAUSES REVERSE FLOW IN THE BUILDING
BUILDING TURNED 30 INTO THE BREEZE WITH NO PLANTING
MEDIUM OR HIGH HEDGE
EFFECT OF HEDGES ON FLOW PATTERN, WHEN PLACING WIND BARRIERS ON ONE OR ON BOTH LEWARD SIDES OF A BLDG THE WIND PRESSURES CAUSE FLOW WITHIN THE STRUCTURE
ANOTHER EXAMPLE TO HEDGE & TREE COMBINATION. HOT AIR SHOULD BE COOLED BY PASSING OVER & THROUGH VEGETATION BEFORE ENTERING A BUILDING.

APPENDIX No. 5

The following are the reflection levels of certain building materials :

* White Cement - Fresh	50%
* White Cement - After a year	30%
* White Washed Surface	75%
* New Galvanised iron	30%
* Bare ground-dry	10-25%
* Bare ground-wet	9-18%
* Rock	12-15%
* Dry grass	32%
* Green fields	3-15%
* Green leaves	25-32%
* Brick(depends on colour)	23-48%
* Asphalt	15%
* Sand dry	18-30%
* Sand wet	9-18%
* Red clay tiles	40%
* Concrete tiles	35%
* Asbestos Cement-white	58%
* Copper-polished	82%
* Mortar Screed - Cement finish	27%

Ref. : 1. Konya Allan, Design Primer for hot climates.

2. Kukreja, Tropical Architecture.

APPENDIX NO. 6

Calculation of Thermal Performance Index of Roof and Wall Section of a Contemporary Building in Khammam :

The outdoor air temperature in peak summer will be 45^{o}, then the inside surface temperature of roof at that time will, atleast 10^{o}C more than the external air temperature (please see Table No. and Table No.). The internal surface temperature will be 55^{o}C.

The peak internal surface temperature = base temperature + peak degree hours

$55^{o}C = 30^{o}C + P.D.H.$

$\therefore$ P.D.H. = 25^{o}C

to get T.P.I. of the roof section will be 25 x 12.5 = 312.5 the recommended value for roof is 100 only. So it comes under class 'E' which is very unsatisfactory for this climate of Khammam.

Similarly when calculated the external wall section (13 1/2") which of brick with cement mortar, is came under Class 'A' i.e. it has good thermal performance. From this it is evident that main cause of discomfort is due to roof.

APPENDIX NO. 7

Designing a Shading Device :

Direct entry of solar radiation through window opening causes a large increase in the indoor temperature, there are number of methods to calculate the effective shading device. Here the design of the Sunshade to a particular size window, i.e. 4'x3', is taken as an example. The calculations are based on CBRI Building Digest 119. In this, there are three type of shading devices are used 1. Horizontal, 2. Vertical, and 3. Egg-crate (combination of 1 and 2). See Figure No. and Table No. to get clear idea about it.

The letter 'P' represents the outward projection of Louver perpendicular to wall. B is the angle of inclination of the louver away from the normal to the wall. Usually width of louver in inclination will be greater than P.

For B	0°	15°	30°	45°	60°
Width	P	1.04P	1.15P	1.41P	2P

Shading of Windows of different orientations :

While designing the sunshade, one has to decide how much period that sunshade should cut the direct sun in the year. Designer has choice of fixing the outward projection of louver according to the conveniences and elevation. Similarly in case of louver inclination.

TYPE – H

(FOR ALL FACADES EXCEPT N)

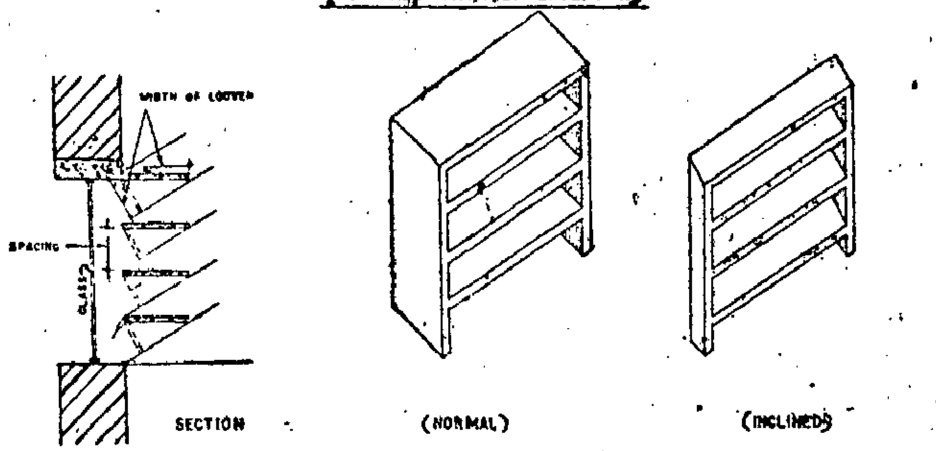
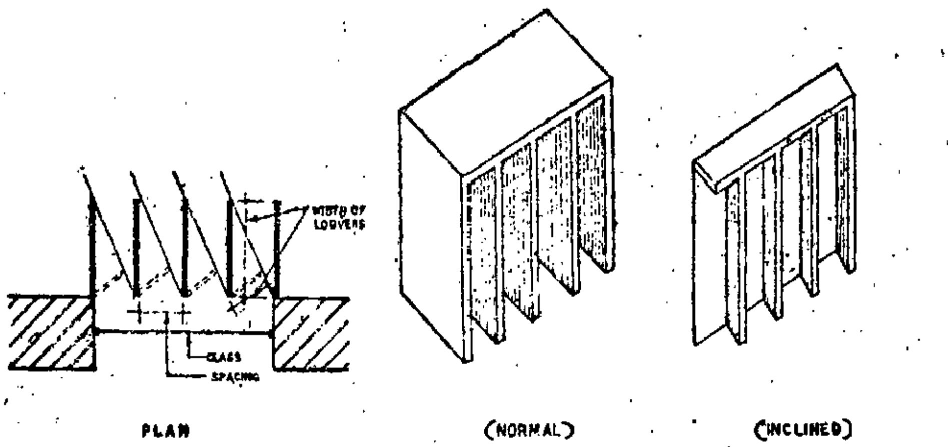


FIG. 1

TYPE – V

(FOR ALL FACADES EXCEPT S)

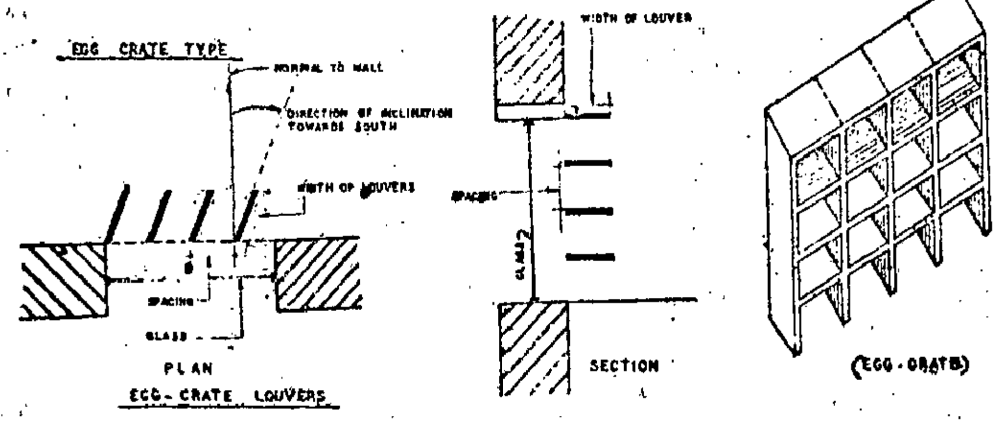


NOTE: SHOULD IT BE NECESSARY TO INCLINE THE VERTICAL MEMBERS THE LAST MEMBER AT THE EXTREMITY TOWARDS WHICH THEY MAY BE INCLINED, IS NOT NEEDED.

FIG. 2

TYPE – C

(FOR E, W, SE, SW, FACADES)



NOTE: THE LAST VERTICAL MEMBER AT THE SOUTHERN EXTREMITY IS NOT NEEDED

(a) <u>North</u> : Vertical member normal to the wall, capped by a horizontal member of the same projection are adequate.

Let us have the vertical louver which cuts off sun completely at all times, without louver inclination. Here we take two vertical members at extreme ends of the window.

2.15P = 90 cms (From table No.)

∴ P = 41.86 42 cms.

(b) <u>South</u> : One or more horizontal members (can be inclined) together with vertical members of the same outward projection at the extremities are needed.

Let us choose a louver without inclination which cuts off all summer sun after 15th March to 30th Sept.

2.75P = 120 cms (From Table)

P = 43.63 44 cms.

(c) <u>East/West</u> : These facades are very critical and are very essential to be shaded from sun. Here any one of the three types can be used. If the first two i.e. vertical and horizontal are used the louver inclination will be more with less spacing. So it is recommended to use both in combination. Horizontal members should have $B = 0^{\circ}$ where as vertical member should have $B = 30^{\circ}$ towards south from normal to the wall.

Here we are getting advantage of letting in winter sun during early mornings and during late evenings which also cuts of the summer sun from morning to evening.

take horizontal member first

$0.84P = 120$ (for one louver on top)

$P = 142$ (better have 2 louvers one in the middle)

$0.84P = 60$

$P = 71.42$ 72 cms.

Now for vertical member the required spacing 0.31P, here we know 'P' so the spacing $0.31 \times P = 0.31 \times 72$

22.5 cms.

(d) <u>North-East/North-West</u> :

For the orientations, either vertical or horizontal type can be used. The vertical members capped by a horizontal members of the same width will cut of all summer and winter sun completely.

Let us take vertical type with 30^{o} inclination towards north (with horizontal member on top).

$0.94P = 90$ cms.

$P = 95$ cms.

here 'P' is too large, so let us fix 'P' as 45 cm

Then the spacing will be $0.94 \times 45 = 47$ cms.

Here we have to consider the thickness of the louver as 5 cm, then each spacing will be $45+5 = 50$ cm. Then, number of spacing are 90/50 = 1.8 (It is not a whole number).

Let us make number of spacing as 2, then each spacing will be 45,

$\therefore P = \frac{(45-5^*)}{0.94}$ * Louver thickness

$= 42.5$ cm.

(e) South-East/South-West : These orientation are critical ones, here only egg-crate type of louvers should be used. In this horizontal member should have $B = 0^o$ and vertical 30^o inclined towards south. It permits sun winter sun upto mid-day on the south-east and during late afternoon on the south-west orientations. It intercepts all summer sun.

Here decide, intended outward projection (P) as 40 cm for horizontal member spacing

1 x P = 40 cm, when height is 120 cm.

$\therefore$ number of louvers $= \frac{120}{40} = 3$

For vertical members, the spacing

$= 1.15P = 1.15 \times 40 = 46$

$\therefore$ number of spacings $= \frac{90}{46}$ 2

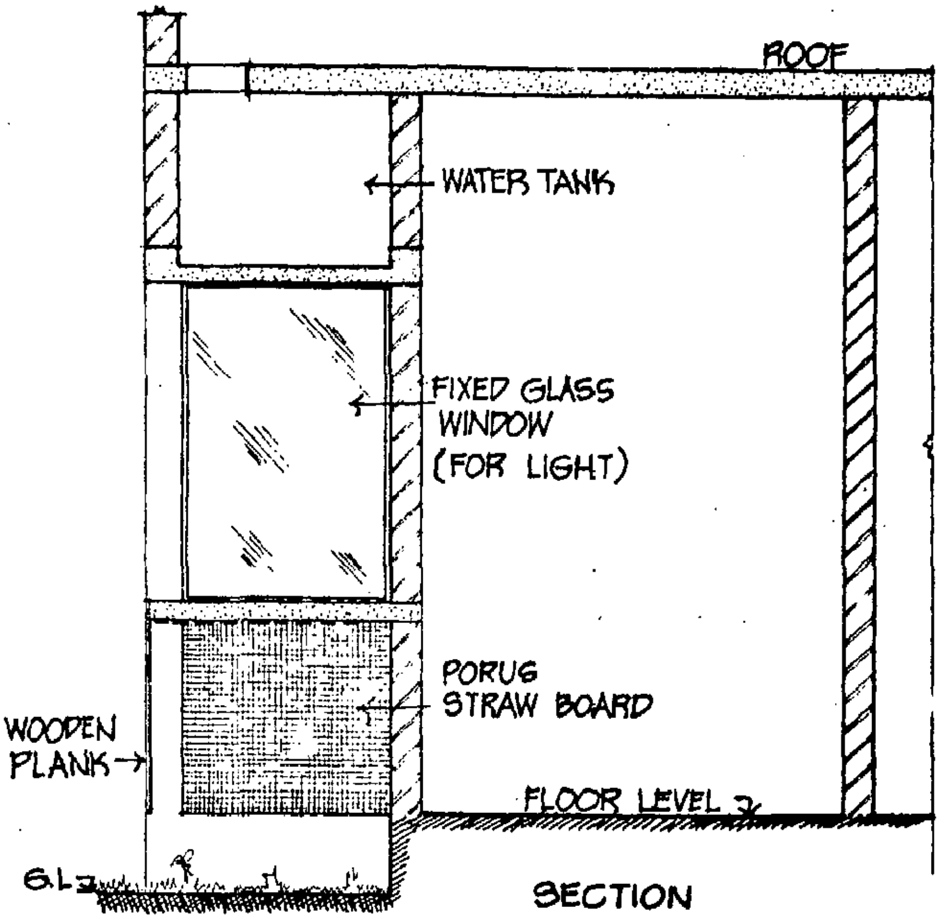
If the number of spacing are two, then number of louver will be three, but louver one the southern extremity of the window is not needed as it does not serve any useful purpose.

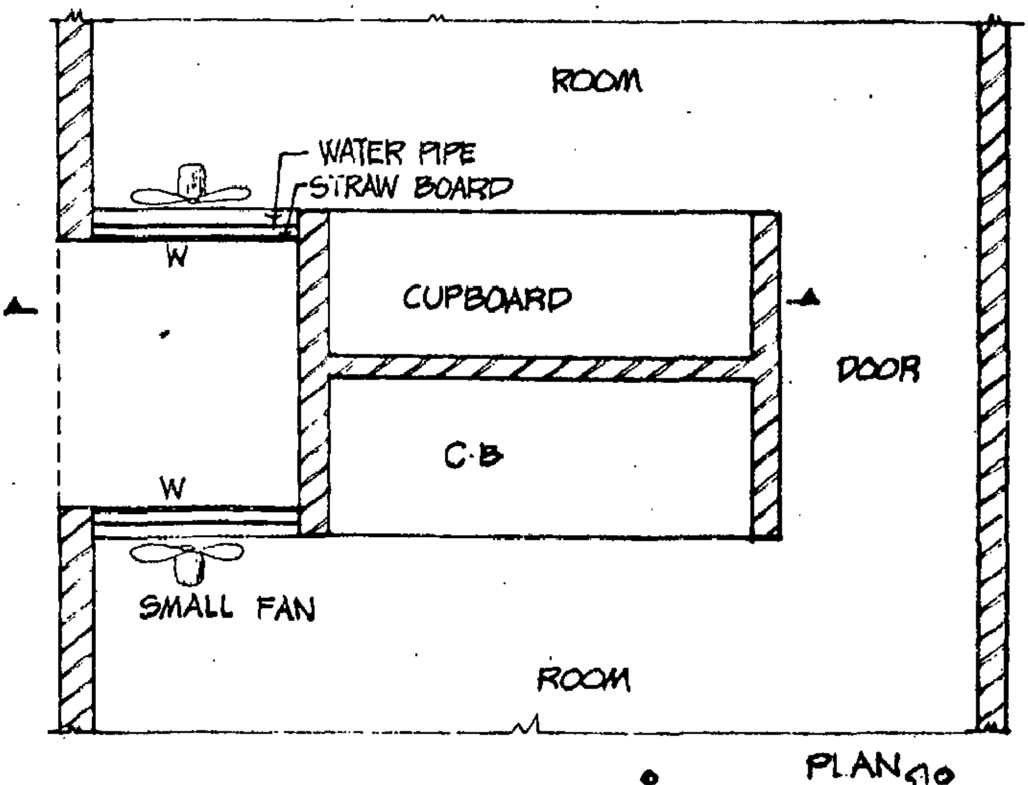
TABLE

Spacing Distances Between Vertical or Horizontal Members of Louver System
(SOUTHERN REGION)

	Type of Louver	ANGLE		OF	INCLINATION				
		B = 0°	B = 15°	B = 30°	B = 45°	B = 60°	Direction of Inclination	Performance	Recommended
A NORTH Alternative 1.	Type V	2.75 P		Inclining	not	desirable	—	Cuts off sun after 7 a.m. during June and completely in other months.	Either
2.	Type V	2.15 P	—	-do-	—	—	—	Cuts off completely at all times.	
B. SOUTH 1.	Type H	2.75 P	3 P	3.33 P	3.75 P	4.5 P	Downwards	Cuts off all summer sun after 15th March to 30th September.	Type H (B = 0)
C. EAST/WEST 1.	Type V	Inclining	not	desirable	.53 P	1.27 P	Inclined towards north away from the normal.	Cuts off both summer and winter sun.	
2.	Type H	.27 P	.54 P	.85 P	1.27 P	2 P	Downwards	Cuts off only after / a.m. in summer and winter.	Type C
3.	Type C Vertical member	—	—	0.31 P	0.73 P	1·46 P	Inclined towards south away from normal.	Completely cuts off only summer sun but allows winter sun to come partially.	Combination of V (B = 30°) and H (B = 0°)
	Horizontal member	.84 P	1.11 P	1.42 P	1.84 P	2.57 P	Downwards		
D. NORTH-EAST/NORTH-WEST 1.	Type V	.36 P	.63 P	.94 P	1.36 P	2.1 P	Inclined towards north away from normal.	Winter sun negligible on this facade and summer sun is completely cut off.	Type V (B = 30°)
2.	Type H	.36 P	.63 P	.94 P	1.36 P	2.1 P	Downwards	Cuts off only after 7 a.m.	
E. SOUTH-EAST/SOUTH-WEST 1.	Type C Vertical member	.58 P	.85 P	1.15 P	1.58 P	2.31 P	Southwards away from normal.	Completely cuts off all summer sun and allows winter morning sun partially.	Type C Combination of V (B = 30°) and H (B = 0°)
	Horizontal member	P	1.27 P	1.58 P	2 P	3.73 P	Downwards		

Note : In type C above, any combination of the angles of inclination of vertical and horizontal members can be made.





evaporative cooling