iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VI **Month of publication:** June 2020

DOI: http://doi.org/10.22214/ijraset.2020.6410

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

Framing Bioclimatic Building Design Guidelines for Hot and Dry Climate: Case of Jaipur City

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Abstract: The city of Jaipur predominantly has hot and dry climate. Climate responsive architecture techniques of Jaipur are a result of optimisation of materials and construction technologies that have evolved over time and are still in an evolving stage. Contemporary architects in Jaipur nowadays pay very little attention to climatic consideration which is leading to reduced thermal comfort and higher energy consumption. The following research is an attempt to frame bioclimatic design guidelines for the city of Jaipur, which can act as a first stage design tool for architects, helping them to provide better thermal comfort and making buildings less resource and energy intensive. This has been facilitated by providing them with a set of passive strategies, incorporating vernacular features. Bioclimatic chart, mahoney table and psychometric chart have been used to frame the design guidelines. The guidelines have been validated using a case analysis.
Keywords: climate, thermal comfort, energy efficiency, vernacular architecture, building material

I. INTRODUCTION

Climate of a place is an aggregation of various factors happening over time. Majorly atmospheric environment, its physical state and geographical location defines the climate of a location [1]. While designing a building thermal comfort of humans needs to be kept in mind and the indoor spaces should be designed accordingly [1] [2]. Thermal comfort is a subjective terminology and can be defined as the satisfaction of human body and mind in a particular thermal environment [3] [4]. Many techniques are being used to evaluate thermal comfort such as bioclimatic chart, psychometric chart. These charts give us an idea about what conditions are required to achieve thermal comfort, e.g. whether cooling or heating is required etc. However, they do not give us any design strategies which we can directly apply in our built form.

Sustainability of a building can be understood by the local architecture i.e. vernacular architecture of that particular place. Vernacular architecture provides us an insight about how to design in the best possible way utilizing limited resources to achieve maximum thermal comfort. Also how these practices are evolving with time and being applied in contemporary era needs to be studied in detail [5]. Architects are using HVAC system (Heating Ventilation and Air Conditioning) to provide for heating and cooling in the building. These should be considered as secondary measures, first measure should always be about how to make that building climate responsive so that all these energy loads can be reduced taking in consideration human thermal comfort. Nowadays, architects are ignoring these fundamentals.

According to NBC (National Building Code) [6], Jaipur lies in hot and dry climatic zone. Hot and dry climate is predominantly characterized by extreme summers recording very high temperatures which are out of human comfort zone. Inferences from various climate analysis tools recommend usage of material having high thermal mass and focusing on keeping a low window wall ration in the building. Contemporary architects do not pay respect to these measures and they are designing building with huge window wall ratio and using materials having lower thermal mass which leads to significant heat gain. Ultimately its affect can be seen on the overall energy consumption of building.

We can take inspiration from vernacular architecture and how it has evolved to address the growing human needs, changing climate so as to achieve energy efficient buildings.

II. CLIMATE OF JAIPUR

We have considered the case of Jaipur, a city located in Rajasthan. The geographic location is 26.9° North and 75.8° East. The city is located at an altitude of 431m. It sprawls over an area of 467 sq. km [7].

Jaipur has a hot and dry climate, extremely hot summers and short, mild to warm winters. The mean monthly maximum temperature in summers is around 35°C. The maximum temperature in summers reaches around 48°C. Mean monthly maximum temperatures in winters is around 15°C and minimum temperature reaches around -2.2°C. Only for the months of March and November the temperature lies in comfort zone.

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Diurnal variations reach around 25°C which is quiet high. Days are recorded as very hot in summers and nights as extremely cold in winters. Monsoon ranges from July to September. Annual precipitation is around 630 millimeters. Approximately 460 kWh/m^2 per hour is the annual average direct solar radiation received. Annual mean sky cover is approximately 28% which leads to more direct solar radiation throughout the year.

III. PARAMETERS USED TO FRAME DESIGN GUIDELINES

Thermal comfort is necessary to achieve for the satisfaction of mind. It is defined as the condition of thermal environment which affects human comfort. There are large variations between metabolic rates of individuals and therefore it becomes difficult to satisfy the needs all the humans present in a given space [8]. All climatic parameters, some of them have been specified above combine to form the design guidelines required to achieve thermal comfort. In the following study, bioclimatic chart [9], psychometric chart [10] and Mahoney table [1] have been analysed to arrive at the comfort conditions of Jaipur and formulate building design guidelines.

A. Bioclimatic Chart

Bioclimatic Chart effectively analyses the thermal comfort by providing a relationship between temperature and humidity, which leads to a series of design strategies required for achieving thermal comfort conditions [9]. Climatic data of Jaipur has been plotted month wise on the chart to analyse the comfort condition and derive how we can achieve the passive thermal comfort strategies. The chart for a month is plotted by taking mean monthly minimum Dry Bulb Temperature (X-Axis) and AM (Ante Meridian) relative humidity (Y-Axis) and connecting this point to mean monthly maxima Dry Bulb Temperature (X-Axis) and PM (Post Meridian) relative humidity point [11] [9].

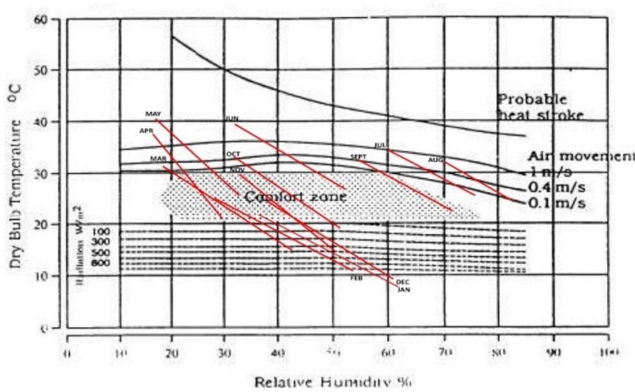

Figure 1: Bioclimatic chart for city of Jaipur

Table 1: Inferences of bioclimatic chart

	COMFORT	RADIATION NEEDED	SHADING NEEDED	AIR MOVEMENT NEEDED
JAN	10%	79%	21%	
FEB	35%	53%	45%	
MAR	53%	32%	74%	11%
APR	52%		100%	46%
MAY	30%		100%	70%
JUN	30%		100%	71%
JUL			100%	100%
AUG			100%	100%
SEP	77%		100%	23%
OCT	71%		91%	22%
NOV	63%	28%	72%	
DEC	28%	63%	35%	

The chart is clearly stating the nights of April, May and June, the month September, October and November and days of December, January and February are thermally comfortable. With a wind of 1m/s to 2m/s and properly designed shading devices we can make the months from April to September thermally comfortable. But it has to be kept in mind that in the month of December, January and February there is a requirement of solar Radiation inside the built form to keep the spaces thermally comfortable. Hence, it using these parameters the opening locations and shading device designs can be decided.
The Bioclimatic Chart analysis is limited to passive strategies in relation to wind movement and solar radiation only. To further analyse the indoor thermal comfort psychometric chart will be required.

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B. Psychometric Chart

Psychometric chart helps us to study the relationship between various parameters such as dry bulb temperature, wet bulb temperature, relative humidity, absolute humidity and vapour pressure of moist air. Psychometric chart has a representation of these zones which are defined using the properties of air and recommend the design strategies that could achieve thermal comfort [10].
These zones have been represented in figure 2.

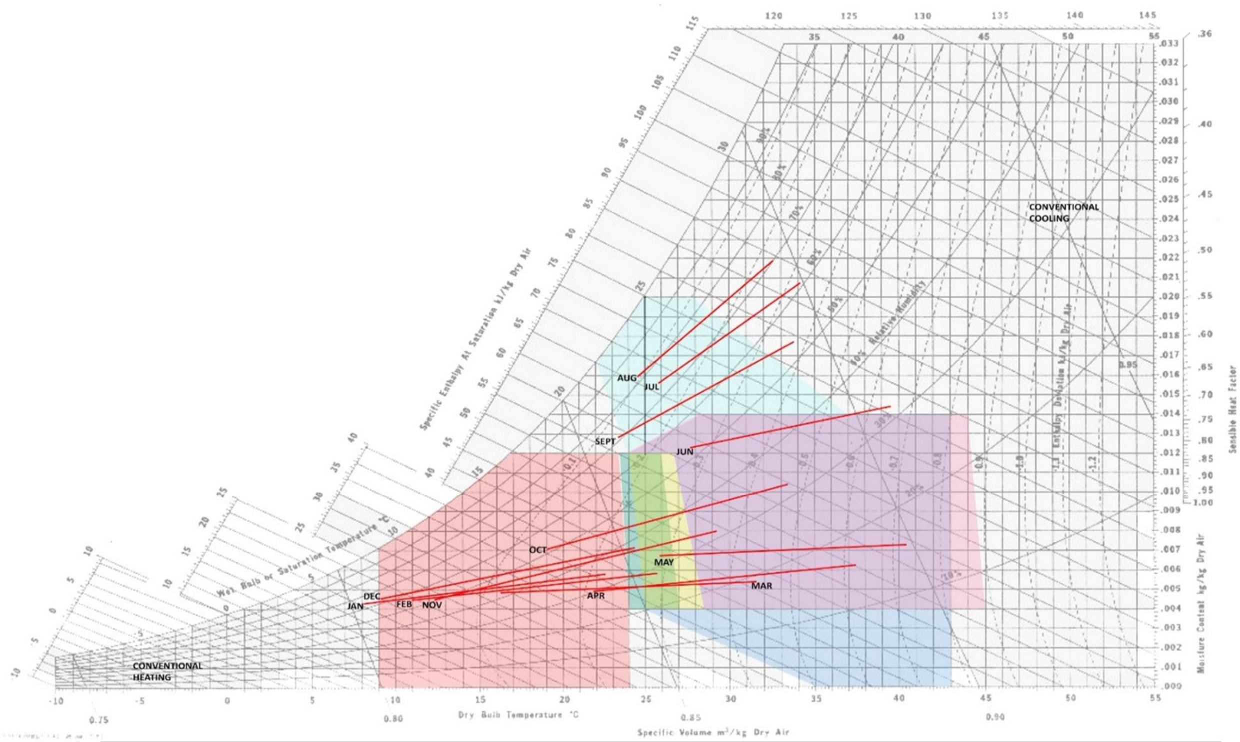

Figure 2: Psychometric chart for city of Jaipur

Table 2: Inferences from psychometric chart

	COMFORT	EVAPORATIVE COOLING	HIGH THERMAL MASS	VENTILATION	SHADING OF WINDOWS	PASSIVE SOLAR HEAT GAIN	CONVECTIONAL HEATING OR COOLING
JAN						94%	6%
FEB	6%				5%	89%	
MAR	22%	63%	63%		43%	49%	
APR	26%	59%	59%		80%	14%	
MAY	14%	86%	86%		100%		
JUN		82%	82%		100%		21%
JUL				53%	100%		47%
AUG				55%	95%		45%
SEP				86%	85%		15%
OCT	26%	42%	42%		59%	31%	
NOV	23%	11%	11%		25%	66%	
DEC	4%					95%	

Similar to bioclimatic chart, in psychometric chart also we try to map the climatic data. Table 2 gives us an insight about the percentage hours on monthly basis which require the specified design strategy to be incorporated. The table has similar design strategies listed as in Figure 2.

Passive heating is required for the months of December and January as can be clearly inferred from the table. Ventilation is required almost throughout the year but the windows should be well shaded because of high outdoor temperature. Shading of windows is highly recommended during the months of April to September to reduce the amount of solar radiation coming inside the built form. Materials with high thermal mass are required to increase the time lag both in winters and summers. Conventional cooling and heating is required almost throughout the year because of harsh summers and winters.

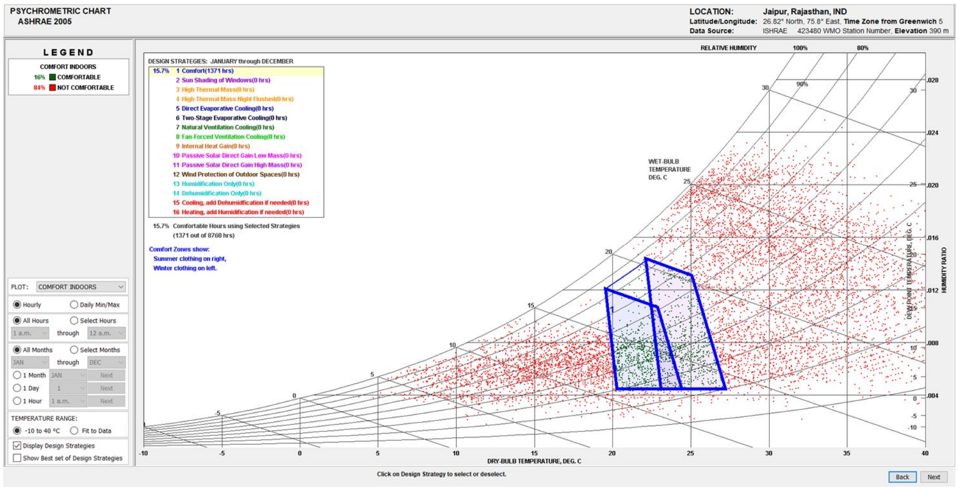

Figure 3: Psychometric chart without applying any design strategies (Source: Climate consultant)

After analyzing Figure 3 we can see that only for 15.7% hours of the whole year thermal comfort conditions can be achieved without applying passive design strategies.

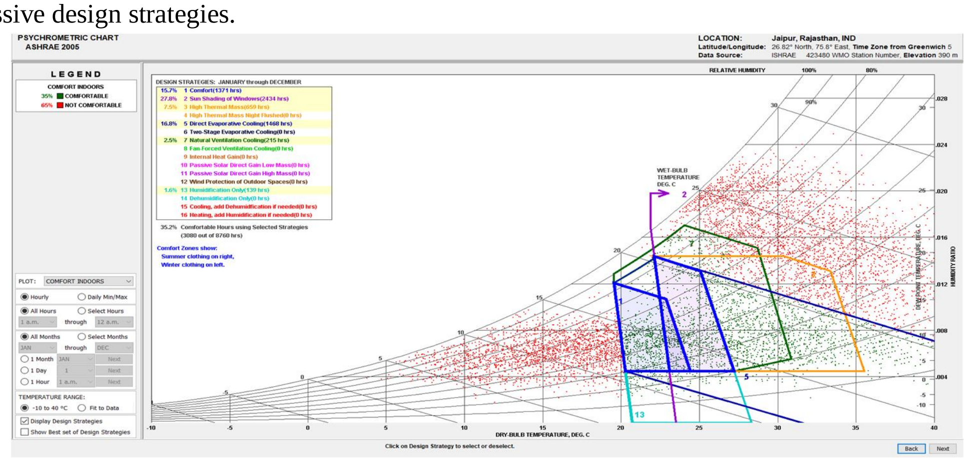

Figure 4: Psychometric chart after applying suitable passive design strategies (Source: Climate consultant)

After analyzing Figure 4 we can infer that even after applying suitable passive design strategies such as sun shading of windows, using materials having high thermal mass, providing natural ventilation to facilitate cooling, providing evaporative cooling and humidification only for 35.2% hours of the whole year thermal comfort conditions can be achieved. For rest of the hours we will need to employ some kind of HVAC systems in our building to achieve thermal comfort.

Table 3: Comfort hours month wise

	Comfortable	Total No. of hours	Comfortable with passive design strategies	%
January	115	744	638	85.8
February	197	672	610	90.8
March	291	744	738	99.2
April	163	720	645	89.6
May	15	744	124	16.7
June	0	720	27	3.8
July	0	744	10	1.3
August	0	744	12	1.6
September	36	720	137	19
October	188	744	507	68.1
November	254	720	703	97.6
December	163	744	616	82.8

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From table 3 we can infer that months ranging from May to September are highly comfortable even after applying passive design strategies. Some kind of artificial cooling needs to be provided.

C. Mahoney Table

From the above charts we have been able to define what all months are comfortable and not comfortable throughout the year and what things are necessary to achieve that thermal comfort. However, we could not arrive at some specific design strategies using the above charts.

To arrive at the design strategies which are suitable for the city of Jaipur, Mahoney table has been used. The table also helps us in making a decision between two conflicting requirements. This table also takes into consideration the severity of various climatic factors [1].

It comprises of various tables including the climatic data, diagnosis of climate, design recommendations etc. [1].

Temperature, humidity, rainfall and wind with other climatic data is present in Table 4. Temperature and humidity diagnosis has been represented in Table 5. Table 6 and 7 provide us with design recommendations.

Table 4: Data input

LOCATION	JAIPUR, RAJASTHAN, INDIA
LONGITUDE	75°48'E
LATITUDE	26°55'N
ALTITUDE	431 M

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.		
													HIGH	AMT
MEAN MONTHLY MAX. DBT° C	22.5	25.7	31.5	37.2	40.5	39.4	34.1	32.4	33.8	33.6	29.2	24.5	40.5	24.2
MEAN MONTHLY MIN. DBT° C	8.2	11	16.2	21.8	25.9	27.9	25.8	24.6	23.3	19.1	13.5	9.3	7.8	32.7
RANGE	14.3	14.7	15.3	15.4	14.6	11.5	8.3	7.8	10.5	14.5	15.7	15.2	LOW	AMR

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
MEAN MONTHLY MAX A.M.	63	54	42	30	32	52	75	82	72	51	50	61
MEAN MONTHLY MIN P.M.	35	28	19	16	17	32	61	70	55	32	33	38
AVERAGE	49	41	30.5	23	24.5	42	68	76	63.5	41.5	41.5	49.5
HUMIDITY GROUP	2	2	2	1	1	2	3	4	3	2	2	2

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	
MEAN MONTHLY RAINFALL, MM	5.5	4.9	4.2	8.2	18.7	68.8	220.8	194.8	71.4	20.1	5.3	3.8	626.5

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
WIND, PREVAILING	E	E	NW	WNW	WNW	WNW	WNW	W	WNW	NW	NW	NW
WIND, SECONDARY	SE	NW	E	NW	NW,W	W	W	WNW	W	WNW	E	E

Table 5: Temperature and humidity diagnosis

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.		
MEAN MONTHLY MAX. DBT° C	22.5	25.7	31.5	37.2	40.5	39.4	34.1	32.4	33.8	33.6	29.2	24.5	24.2	AMT
DAY COMFORT : UPPER	31	31	31	34	34	31	29	27	29	31	31	31		
DAY COMFORT :LOWER	25	25	25	26	26	25	23	22	23	25	25	25		
MEAN MONTHLY MIN. DBT° C	8.2	11	16.2	21.8	25.9	27.9	25.8	24.6	23.3	19.1	13.5	9.3		
NIGHT COMFORT : UPPER	24	24	24	25	25	24	23	21	23	24	24	24		
NIGHT COMFORT : LOWER	17	17	17	17	17	17	17	17	17	17	17	17		
THERMAL STRESS : DAY	C	O	H	H	H	H	H	H	H	H	O	C		
THERMAL STRESS :NIGHT	C	C	C	O	H	H	H	H	H	O	C	C		

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.		
HUMIDITY : H1							/	/					2	TOTAL
HUMIDITY : H2													0	
HUMIDITY : H3							/						1	
ARID : A1	/	/	/	/	/	/			/	/	/	/	10	
ARID : A2				/	/	/				/			4	
ARID : A3	/											/	2	

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Table 6: List of recommended specifications

			0-10			✓	1	Orientation north and south(long axis east +west
			11,12		5-12			
					0-4		2	Compact courtyard planning
								Spacing
11,12							3	Open spacing for breeze penetration
2-10						✓	4	As 3,but protection from hot and cold wind
0,1							5	Compact layout of estates
								Air movement
3-12							6	Rooms single banked,permanent provisions for air movement
1,2			0-5					
			6-12			✓	7	Double banked room, temporary provisions for air movement
0	2-12							
	0,1						8	No air movement required
								Openings
			0,1		0		9	Large openings ,40-80%
			11,12		0,1		10	Very small openings , 10-20%
Any other conditions						✓	11	Medium openings, 20-40%
								Walls
			0-2				12	Light walls,short time lag
			3-12			✓	13	Heavy external and internal walls
								Roofs
			0-5				14	Light,insulated roofs
			6-12			✓	15	Heavy external and internal walls
								Out-door sleeping
				2-12		✓	16	Space for out door sleeping required
								Rain protection
		3-12					17	Protection from heavy rain necessary

Table 7: List of detailed specifications

								Size of openings
			0,1		0		1	Large openings,40-80%
					1 to 12		2	Medium openings, 25-40%
			2-5					
			6-10			✓	3	Small openings,15-25%
			11,12		0-3		4	Very small openings,10-20%
					4 to 12		5	Medium openings, 25-40%
								Position of openings
3-12						✓	6	In north soth wall at body height on windward side
1-2								
						✓	7	As above, opening also in internal walls
0	2-12							
								Protection of openings
					0-2	✓	8	Exclude direct sunlight
		2-12					9	Provide protection from rain
								Walls and floors
			0-2				10	Light ,low thermal capacity
			3-12			✓	11	Heavy, over 8 hr time lag
								Roofs
10-12			0-2				12	Light,reflective surface,cavity
			3-12				13	Tight, well insulated
0-9			0-5					
			6-12			✓	14	Heavy, over 8hr time lag
								External features
				1-12		✓	15	Space for our seating
		1-12				✓	16	Adequate rainwater, drainage

By following the recommendations listed in Table 6 and 7, we can achieve thermal comfort. These strategies have been summarized in Table 8 by grouping them appropriately under different heads.

1. Layout	North-South Orientation
2. Spacing	Open spaces need to be provided for appropriate ventilation, but due consideration need to be given to living space (protecting it from direct hot and cold winds).
3. Air Movement	Double banked rooms, temporary provision for air movement.
4. Openings	WWR: 20-40% in North and South Walls, windows should be provided along windward side. Internal walls should also be provided with openings. Direct sunlight should be excluded.
5. Walls	Walls both internal and external with high thermal mass, heavy roofs, having time lag of 8 hours.
6. Roofs	Roofs with high thermal mass, heavy roofs, having time lag of 8 hours.
7. Outdoor Sleeping	Provision of space for outdoor sleeping and seating.
8. Rain Protection	Appropriate measures for protection from rain should be taken, drainage should be well designed.

Table 8: Design Recommendations

These methods provide us with primary recommendations. We further need to learn from vernacular architecture to achieve climate responsive design [12].

IV. JAIPUR: VERNACULAR ARCHITECTURE

Vernacular architecture of a place is a result of numerous factors which have evolved over time such as optimum usage of local materials, activities happening in a dwelling throughout the day, climatic conditions and the overall social organization of the settlement [13].

Solar radiation is a major issue in Jaipur. So all the units in a settlement should be oriented in a way so as to reduce the amount of solar heat gains. There is a need to provide appropriate ventilation measures in summers and protections from cold winds in winter. Settlements are usually compact and are designed in such a way so as to provide mutual shading among buildings.

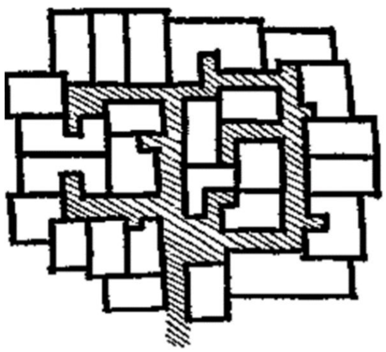

Figure 5: Typical settlement (Source: Slideshare- Vernacular architecture in hot and dry climate)

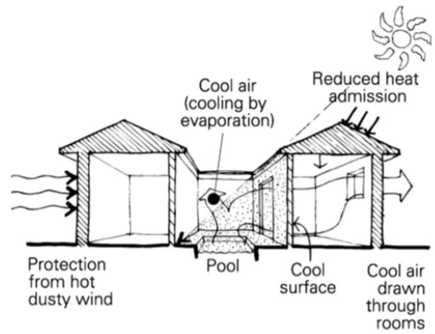

Figure 6: Courtyard design with evaporative cooling (Source: Slideshare- Vernacular architecture in hot and dry climate)

A. Design

Compact forms should be chosen to reduce surface areas of heat gain. Shading devices should be designed in such a way so as to cut the summer sun but allow the winter sun. Movable shading devices should be installed.

Main walls and windows should be facing the side in direction of the wind so that there could be a maximum amount of cross-ventilation in the room.

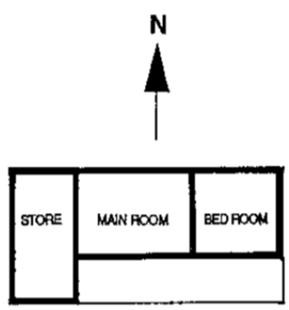

Figure 7: Orientation of different rooms (Source: Slideshare- Vernacular architecture in hot and dry climate)

Bedrooms are usually placed on the eastern side and living rooms on the north and south side. This is done keeping in mind the orientation of sun and wind direction.

Walls present in daytime living areas (North and South) should be of high thermal mass i.e they should be able to store the heat and have considerable time lag. Shading measures need to be provided on eastern and western walls. Cavity walls can be a suitable solution.

Cross ventilation and natural light are a necessary part of any building. North façade can be provided with more number of windows as it receives least radiation when compared to all other facades. Shading devices need to be incorporated. Overhangs, trees with good amount of foliage particularly deciduous trees can be used for the same. Minimum amount of openings should be provided on east and west walls to reduce heat gain.

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V. BUILDING MATERIALS

The Mahoney's Table of Jaipur recommends that there should be high thermal mass for roof and walls with over an 8 hour time lag. However thick walls and roofs are not a feasible option because of land shortage and cost constraints. We need to depend on secondary measures to account for the same. Usage of insulating materials in wall and roof surfaces is a suitable solution. Some insulating materials such as polyurethane foam, rockwool, glass fibre etc. can be used [8]. The details of ECBC are given in table 9 [14].

Table 9: Prescribed requirements by ECBC for building envelope in hot and dry climate

	HOSPITALS, HOTELS, CALL CENTERS (24-HOURS)		OTHER BUILDING TYPES (DAYTIME)	
	MAXIMUM U-FACTOR OF OVERALL ASSEMBLY (W/M2-K)	MINIMUM R-VALUE OF INSULTION ALONE (M2-K/W)	MAXIMUM U-FACTOR OF OVERALL ASSEMBLY (W/M2-K)	MINIMUM R-VALUE OF INSULTION ALONE (M2-K/W)
OPAQUE WALLS	U-0.440	R-2.10	U-0.440	R-2.1
ROOF	U-0.261	R-3.5	U-0.409	R-2.1
		WWR≤40%	40%<WWR≤60%	
	MAXIMUM U-FACTOR (W/M2-K)	MAXIMUM SHGC	MAXIMUM SHGC	
VERTICAL FENESTRATION	3.3	0.25	0.2	

VI. SHADING DEVICES AND ISOPLETH

Thermal isopleth a line on a map connecting points having equal temperature incidence of a specified scale. With the help of mean monthly max DBT, RH PM% and WBT we can calculate ET max and with mean monthly min DBT, RH, AM% and WBT we can calculate ET min. With help of ETs we can calculate ET at each hour of the day in a month for all months and could develop the isopleth.

The area enclosed within 30 degrees C is thermally uncomfortable so it is then transferred to the solar chart.

		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
DATA	MEAN MAX. DBT° C	22.5	25.7	31.5	37.2	40.5	39.4	34.1	32.4	33.8	33.6	29.2	24.5
DATA	RH PM %	35	28	19	16	17	32	61	70	55	32	33	38
	WBT °C	13.3	14.4	16.2	18.8	21.1	25	27.5	27.6	26	20.8	17.9	15.4
	ET MAX. °C	19.2	21	24	26.7	28.3	29.8	29.6	29.1	28.8	26.4	23.8	20.8
DATA	MEAN MIN. DBT° C	8.2	11	16.2	21.8	25.9	27.9	25.8	24.6	23.3	19.1	13.5	9.3
DATA	RH AM %	63	54	42	30	32	52	75	82	72	51	50	61
	WBT °C	5.1	6.7	9.6	12	15.3	20.5	22.3	22.2	19.6	13.1	8.4	5.9
	ET MIN. °C	9.2	10.6	14.8	18.5	21.5	24.1	24	23.5	21.8	17.3	12.9	9.2

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
0000	11	12.5	17.5	20	23.8	25.1	25	24.6	23.2	19.2	14.9	11.7
0200	10	11.2	16.3	19	22	24.5	24.4	23.9	22.2	18	13.5	10.1
0400	8.5	9.8	14	17.8	21	23.6	23.5	23	21.4	16.8	12	8.5
0600	7.5	8.8	13.2	17	30.5	23.1	23	22.5	20.8	16	11	7.5
0800	9.2	10.6	14.8	18.5	21.5	24.1	24	23.5	21.8	17.3	12.9	9.2
1000	17.4	19	22.1	25.3	27.2	28.8	28.7	28.2	27.5	25	21.9	18.9
1200	22	24	26.2	29.1	30.3	31.3	31.2	31	30.8	29.2	26.9	24.1
1400	24.6	26.5	28.6	31.2	32.2	32.8	32.7	32.3	32.5	31.6	29.7	26.8
1600	23.2	25	27.2	30	31.1	32	31.9	31.6	31.5	30.2	28.1	25.2
1800	19.2	21	24	26.7	28.3	29.8	29.6	29.1	28.8	26.4	23.8	20.8
2000	15	16.5	19.9	23.1	25.5	27.2	27.1	26.8	25.8	22.6	19	16
2200	13	14.2	18	21.5	24.1	26	25.8	25.6	24.4	20.8	16.8	13.5

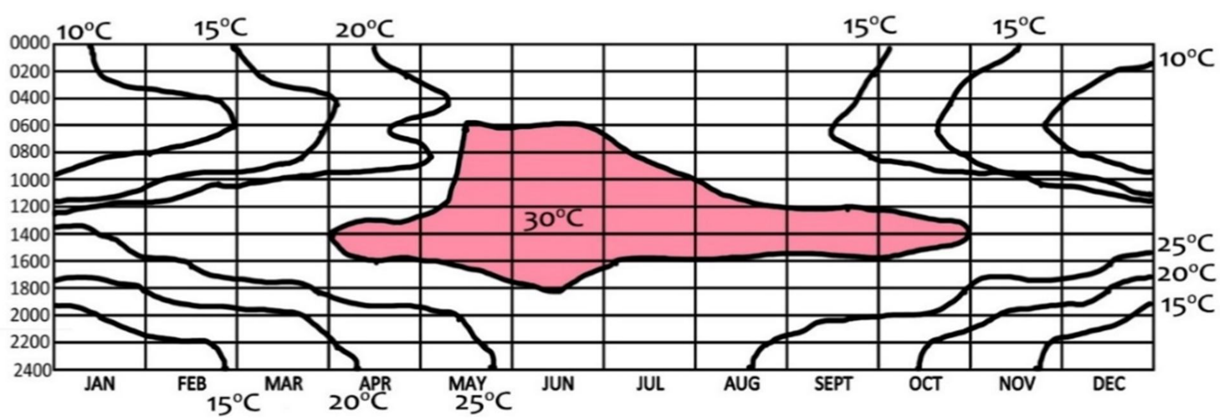

Figure 8: Isopleth for Jaipur

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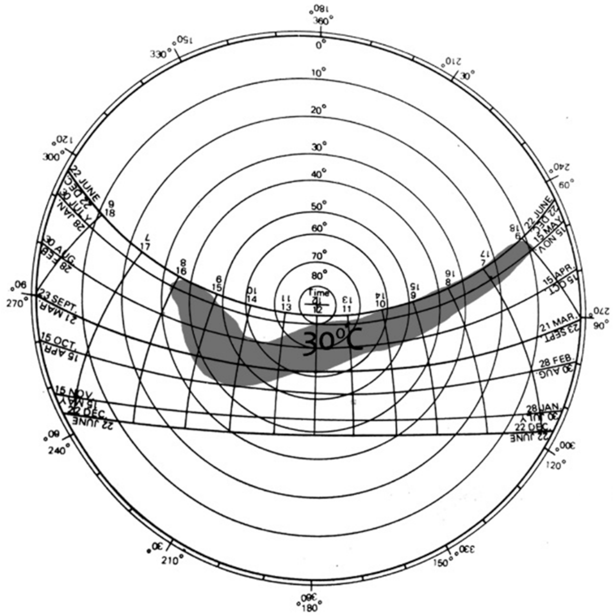

Figure 9: Sun path diagram with overlapped isopleth

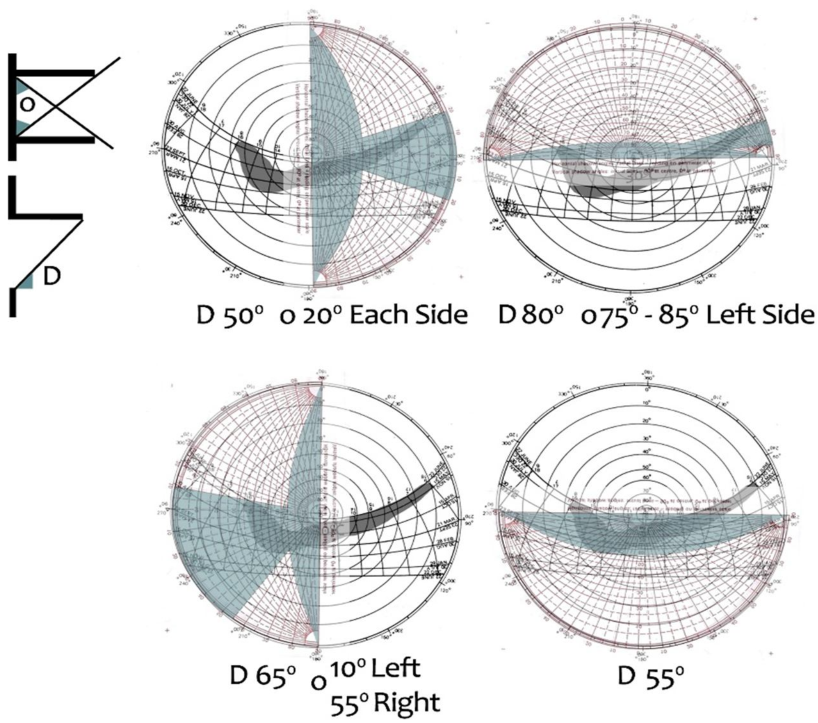

Figure 10: Shading devices for N, E, S and W direction openings for Jaipur

All the analysis done suggest that the windows should be shaded from solar radiation, but it should be taken care that only that part of sun should be shaded that is thermally uncomfortable. Sun Path diagram of Jaipur along with its Isopleth chart has been used to derive horizontal and vertical shading angles.

North side faces the sun at a very lower level in the morning and a bit in late afternoon, South sun has the maximum uncomfortable radiations, but the shading devices are only cutting the thermally uncomfortable radiations from the sun and letting the rest of radiation (especially in winters) to enter. West and East sides contain a combination of both horizontal as well as vertical shading devices as the harsh sun from the W is at the lower angle and produces a strong glare, while the E sun is also direct but is less harsh.

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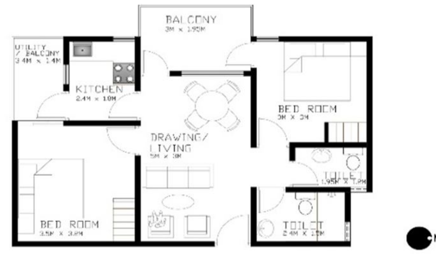
VII. CASE ANALYSIS

To verify the above guidelines simulations have been carried out for a residence using two cases:
1) *Case 1:* Standard residence design
2) *Case 2:* Residence design conforming to the guidelines stated above

Table 10: Specifications

	CASE 1	**CASE 2**
1. PLAN		
2. ORIENTATION	East and West (long axis north-south)	North and south (long axis east-west)
3. WALLS	Brick Wall: 230 mm	Cavity wall: 280 mm
4. ROOF	RCC roof: 150mm thick	RCC roof (150 mm) with mud phuska
5. WINDOW	Single glazing 6mm clear glass	Single glazing 6mm clear glass
6. WWR	6-15%	25-35%

Following simulations have been carried out for summer typical week (18 June – 24 June) and winter typical week (24 December – 30 December). Design Builder Software has been used to carry out the simulations.

A. Indoor Temperature

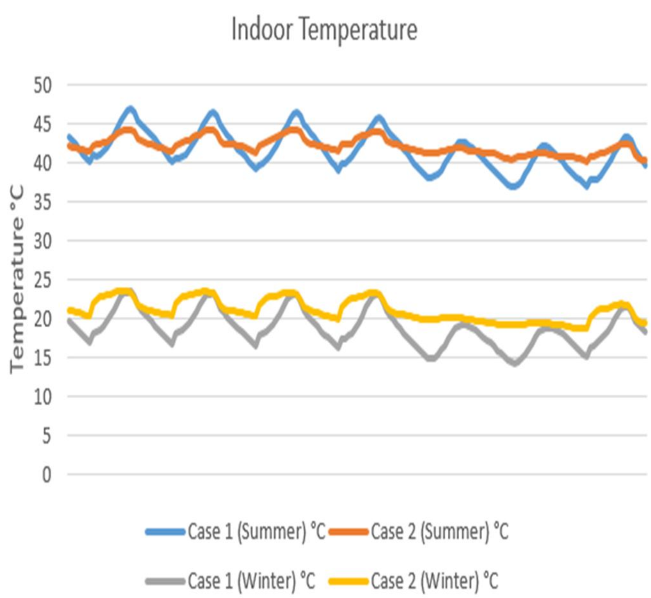


Figure 11: Indoor Temperature

From the above graph we can see that in case 1 during summers peak temperatures are reached in afternoon which cause major discomfort and also increase the overall cooling load whereas in case 2 no such peaks are observed. During winters in case 1 indoor temperatures go below 20°C which can cause discomfort and to overcome that heating system will need to be employed whereas in case 2 the temperature remains between 20-23°C.

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B. Heat Gain Through Walls

During summers heat gains in case 1 are comparatively less than case 2 whose direct effect can be seen on cooling loads in section 8.4. Also in winters there is comparatively lesser heat loss in case 2 when compared to case 1.

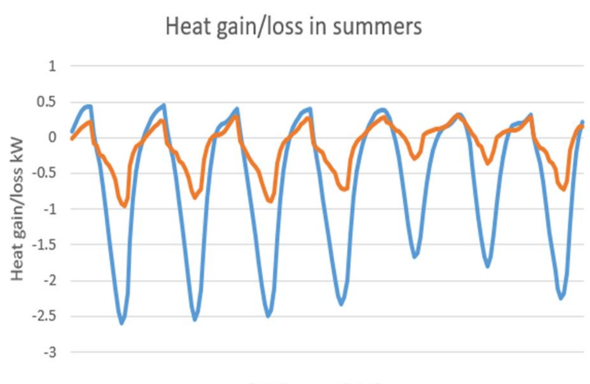


Figure 12: Heat gain through walls in summers

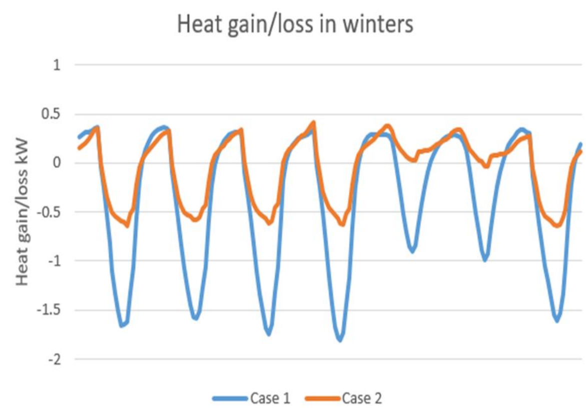


Figure 13: Heat gain through walls in winters

C. Heat Gain Through Roof

Significant difference between heat gain in summers between case 1 and case 2 can be seen. Case 2 has approximately 75% less heat gain when compared to case 1 during summers. Also in winters there is comparatively lesser heat loss in case 2 when compared to case 1.

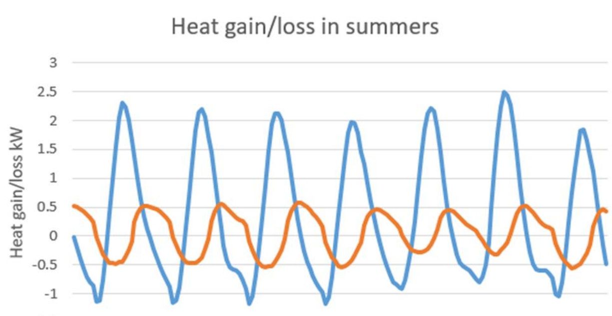


Figure 15: Heat gain through roof in summers

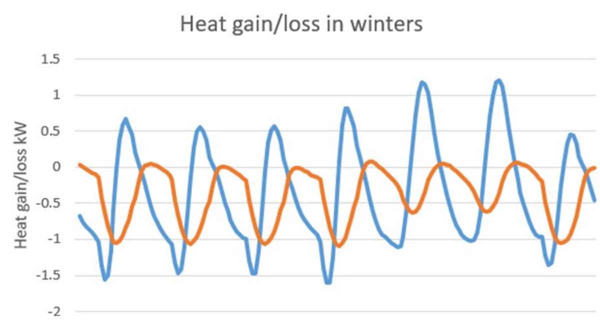


Figure 14: Heat gain through roof in winters

D. Cooling Loads

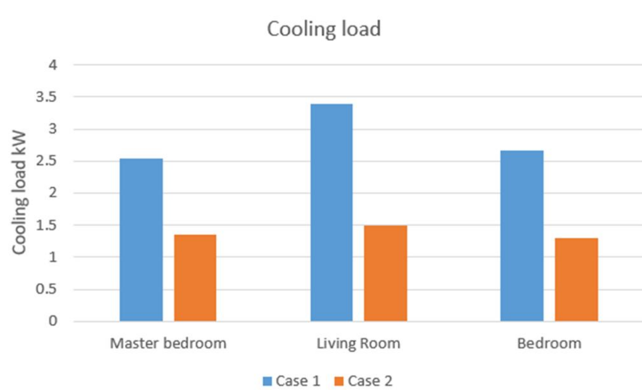


Figure 16: Cooling Loads

There is a reduction of approximately 50% in total cooling loads in case 2 when compared to case 1. Total cooling load in case 1 is approximately 8.61 kW and in case 2 is 4.14 kW.

E. Energy Performance Index (EPI)

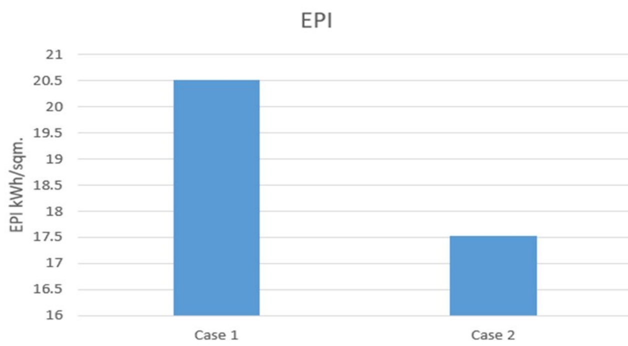


Figure 17: EPI

EPI in case 1 is 20.52 kWh/sqm. and in case 2 is 17.52 kWh/sqm. for a summer typical week. So a reduction of about 17.12% in EPI can be seen in case 2 when compared to case 1.

VIII. BIOCLIMATIC BUILDING DESIGN GUIDELINES

Climate responsive buildings has its own set of advantages in terms of reduced heating and cooling loads, reduced operational energy and overall energy consumption. It significantly improves the thermal comfort of occupant. Following sections discuss in detail the design guidelines framed on the basis of previous discussed sections.

A. Orientation

The analysis done in previous sections and case analysis suggest that heat gain should be reduced inside the building. Orientation should be north-south to reduce the heat gains i.e. longer axis should be east-west. However, appropriated shading devices as discussed in previous sections need to be provided.

B. Layout

Planning should be compact, minimizing surface area to volume ratio to reduce the heat gain. Doubly banked rooms should be provided. Courtyards can be provided in between to use during summer evenings and winter afternoons. Mutual shading between buildings can be done to cut harsh summer sun.

C. Shading of Window

Openings should be shaded from the month of March to October on the basis of results derived from bioclimatic and psychometric chart. Shading mask in different directions can be created using sun path diagram. Shading devices as prescribed in previous sections need to be incorporated. East and west can have design elements like jaalis, jharokhas etc. to cut the glare.

D. Openings

WWR should be kept between 20-40% to reduce the amount of heat gain. This will also ensure adequate amount of daylight inside the premises. Sun rays are horizontal in east and west directions which will be difficult to shade. So openings in north and south direction should be kept maximum.

E. Ventilation

Months ranging from June to September require ventilation because of high humidity as these months receive 80% of the precipitation. Air movement during these months will facilitate evaporative cooling and provide a cooling sensation. Openings should be provided in west and north-west direction keeping in mind wind direction during these months. Also cross ventilation should be provided.

F. Thermal Mass

Psychometric chart and mahoney's table recommends thick walls and roof with insulation which increases the time lag as it acts as thermal mass. High thermal mass reduce heat gain during daytime by storing the heat and dissipating the same at night. This helps in maintaining the indoor thermal comfort conditions. Methods such as roof pond etc. can be used. As discussed earlier contemporary buildings use thin walls and roofs so secondary measures such as providing adequate insulation need to be taken care of.

G. Passive Solar Heating

Months from November to February are relatively cold and passive solar heating is required during these months. Keeping in mind the direction of sun appropriate openings on southern façade can be provided with shading devices to facilitate heat gain during these months.

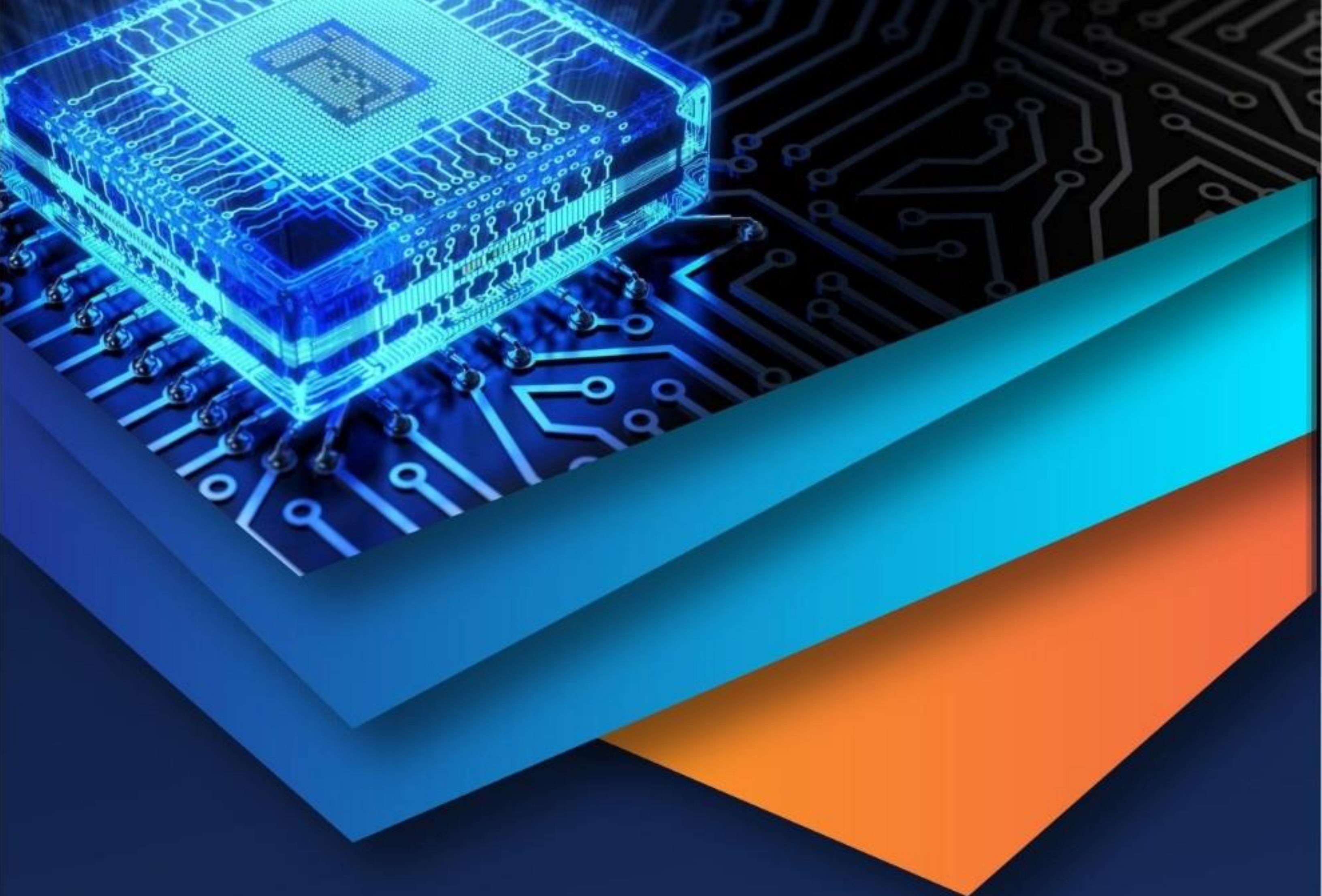
IX. CONCLUSION

Vernacular architecture of the place, mahoney table, Bioclimatic chart, psychometric chart, have been studied in detail to frame the bioclimatic building design guidelines for hot and dry climate considering the case of Jaipur city.

Design considerations discussed can help a designer in designing a building which is climatically responsive and can provide utmost thermal comfort to its occupants. They have been framed considering climate all throughout the year. These guidelines will also act as a driver in framing the conceptual and early stage design for any project. They will further ensure reduced cooling loads and energy consumption in a building. Furthermore, the methodology can be used for understanding by the architecture students to do analysis of climate for any place.

REFERENCES

[1] O. H. Koeinsberger, T. G. Ingersoll, A. Mayhew and S. V. Szokolay, Manual Of Tropical Housing & Building: Climatic Design, Chennai: Orient Longman Pvt. Limited, 1973.
[2] "ASHRAE 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings".
[3] K. Nkurikiyeyezu, "An efficient thermal comfort delivery in workplaces," in *PhD Forum on Pervasive Computing and Communications 2019*, 2019.
[4] S. V. Szokolay, Introduction to Architectural Science- The Basis of Sustainable Design, London and New York: Routledge Taylor & Francis Group, 2014.
[5] M. Vellinga, "Vernacular architecture and sustainability: Two or three lessons...," *Vernacular Architecture: Towards a Sustainable Future - Mileto, vegas, Garcia Soriano & Cristini*, 2015.
[6] Bureau of Indian Standards, "National Building Code of India 2016, Volume 2," 2016.
[7] A. Krishan, N. Baker, S. Yannas and S. Szokolay, Climate Responsive Architecture: A design handbook of energy efficient buildings, Tata McGraw-Hill Education, 2001.
[8] "Bioclimatic Building Design Guidelines for Lucknow City: Use of Various Climate Analysis Method," *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, vol. 5, no. 11, pp. 330-341, 2017.
[9] V. Olgyay, Design with Climate: Bioclimatic Approach to Architectural Regionalism, New Jersey: Princeton University Press, 1962.
[10] B. Givoni, Man, Climate and Architecture, New York: Van Nostrand Reinhold, 1976.
[11] K. Kant, A. Kumar and S. C. Mullick, "Space Conditioning using evaporative cooling for summers in Delhi," *Building and Environment*, 2001
[12] A. T. Nguyen, N. S. H. Truong, D. Rockwood and A. D. Tran Le, "Studies on sustainble features of vernacular architecture in different regions across the worls: A comprehensive synthesis and evaluation," *Frontiers of Architectural Research*, 2019.
[13] A. G. Noble, Traditional Buildings: A Global Survey of Structural Forms and Cultural Functions, New York: I.B Tauris and Co. Ltd, 2007
[14] Bureau of Energy Efficiency, "ECBC: Energy Conservation Building Code," 2017.



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