Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

Bio Climatic Design Strategies for Buildings in Varanasi, India

Mansi Kanojia, Mitali Kanojia
Student, School of Architecture and town Planning, Lucknow, India
Master of Art – MA, Political Science and IR, Conflict Management and Sustainable Development Lucknow, India

***Abstract*- the climate of Varanasi as that of India, is controlled by south-west monsoon with a seasonal rhythm of weather, characterized by moderate to extreme conditions. During the months of January and February the weather remain fine. But whenever, the snow fall occurs in the north- western part of Himalayas, the air blowing down in the Ganga Valley becomes substantially cold, temperature falling sometimes even below 4 degree C at Varanasi. However the severity of weather is broken by the incoming of 'western disturbance' which cause some rainfall in these winter months. From the month of March the fast rise in temperature starts and attains more than 40 Deg. C in May. May and June are the hottest months in which scorching hot winds locally known as 'Loo' blow from west and south-west during day hours raising temperature occasionally even more than 44 Deg. C. By the end of June, Varanasi comes under the grip of the SW monsoon which retreats by the end of September and sky becomes clear once again. However, the cool breeze of winter does not blow before November. Days are much warmer and nights are cooler. From November the temperature falls below 20 Deg. C accounting for fine dust free cool weather. The annual normal rainfall at Varanasi is 1009 mm. The rainfall of the wettest year (1971) and driest year (2009) were 1583 mm and 500 mm, respectively. More than 85 per cent of the annual rain is received during four rainy months from June to September."**

***Keyword*- Bio-climatic design, Thermal comfort, Energy Efficiency, Sustainable development, Mahoney Table**

I. INTRODUCTION

India is expected to achieve an urban population of about 50% by 2030. Reducing emission from urban energy consumption would be necessary to prevent potential adverse impacts of global warming especially in the present scenario of climate change. The world's largest population without electricity lives in India and a very large number of people depend on inefficient sources of energy.

There is an urgent need to understand the complex relationship between factors driving urban household carbon emissions. We have studied the carbon from energy consumption of households in Varanasi city based on primary data in terms of socioeconomic classes, electricity, cooking and commuting activities.

Urban planning based on the identified factors influencing urban household carbon emissions would be necessary to formulate carbon mitigation policies. Inequality and lifestyle emissions at city level would strongly influence the development of Sustainable cities and societies.

II. CLIMATIC ZONE OF INDIA

As per IS 372-1978 "Guide for Heat Insulation of Non-Industrial buildings", India has been divided into four climatic zones i.e. (1) Hot and Arid Zone (2) Hot and Humid Zone (3) Warm and Humid Zone (4) Cold Zone. Some discrepancies were reported later on in this zoning and Central Building Research Institute (CBRI), Roorkee was entrusted with the task of carry out research for new climatic classification. The research was primarily based on two climatic factors which mainly affect thermal comfort i.e. air temperature and humidity. The aim was to find out extremes of these two factors that are likely to cause discomfort. As per the recent studies carried out, India has been divided into four climatic zones. i.e (1) Hot Dry(2)Warm Humid (3) Cold (4) Temperate and one sub-group i.e. Composite. A place has 1 been assigned to one or other climatic zones if defined climatic conditions prevail there for more than six months, otherwise it has been placed under composite zone.

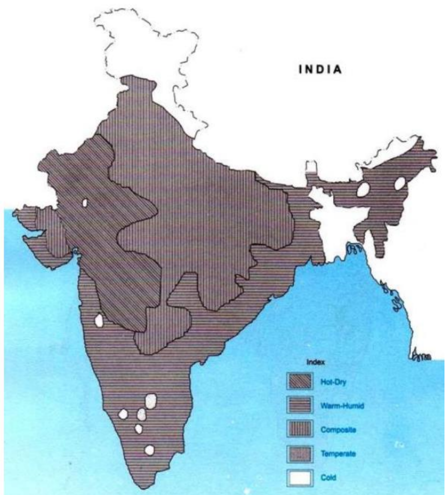
Table –1 shows recent climatic zones and its characteristics.

Climatic Zone	Mean Monthly Maximum Temperature (o C)	Mean Monthly Relative Humidity (%)
Hot Dry	Above 30	Below 55
Warm Humid	Above 30	Above 55
	Above 25	Above 75
Temperate	Between 25-30	Below 75
Cold	Below 25	All Values

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

Each climatic zone does not have same climate throughout the year. If the climate of a particular place matches with the characteristics of a particular climatic zone for more than six months, the place may be assigned to that particular zone. Few cities like Bangalore, Ahmedabad and Pune which present comfortable climate for greater part of the year conforms to temperate climatic zone, though it has been observed that there is no specific region under temperate climatic zone.

Fig 1 Shows The Climatic Zones Of India.



III. AN OVERVIEW OF VARANASI CLIMATE

Varanasi or Banaras is one of the oldest cities in the world. It is situated on the bank of river Ganga spreading over 1535 sq.km area in the state of Uttar Pradesh. It is located between the confluences of river Ganga and Varuna and river Ganga and Assi rivulet. the urban agglomeration is stretched between 82° 56'E – 83° 03'E and 25° 14'N – 25° 23.5'N. The Varanasi city is geographically located at 25000' to 25016' N Latitude and 82050' to 83010' E Longitude. The topography of the city is averaging between 50 feet (15 m) and 70 feet (21 m) above the river. The Ganga River flows from South to North having the world-famous Ghats on its left bank. averaging between 50 feet (15 m) and 70 feet (21 m) above the river. It is located at 25.282°N latitude 82.9563°E longitude.

Varanasi experiences a humid subtropical climate with large variations between summer and winter temperatures. The dry summer starts in April and lasts until June, followed by the monsoon season from July to October. The temperature ranges between 22 and 46 °C (72 and 115 °F) in the summers. Winters in Varanasi see very large diurnal variations, with warm days and downright cold nights

The annual average rainfall in the basin varies between 39 cm to 200 cm, with an average of 110 cm. Eighty percent of the rainfall occurs during the monsoon months i.e. from June to October. Because of large temporal variations in precipitation over the year, there is wide fluctuation in the flow characteristics of the river. In Varanasi monsoons normally begin from late June. The annual rainfall varies from 680 mm to 1,500 mm with large proportion of its occurring during the months of June to September. The month of October receives about 5 % of rainfall, and only 8 % of the rain occurs in remaining seven months from November to May.

The best time to visit Varanasi is during the winter months (November to February). Although it gets fairly cold during the winter, this is the best time when you can explore the holy city without getting tired. The average low temperature is around 5 degree C. the minimum temperature in Varanasi today is likely to hover around 33 degree Celsius, while the maximum temperature might reach 41 degree Celsius. The mercury level is expected to hover around 37 degree Celsius throughout the day, with the wind speed around 4.45.

The dry summer starts in April and lasts until June, followed by the monsoon season from July to October. The temperature ranges between 22 and 46 degree Celsius (72 and 115 degree F) in the summers variations with warm days and downright cold night.

Table–2 Climate Data Of Varanasi

Year/ months	Temperature		Humidity (%) Average	Rainfall (mm)
	Mean Min (OC)	Mean Max (OC)		
January	1.0	31.4	66	16.7
February	1.7	36.1	58	22.8
March	6.7	41.5	41	9.2
April	11.1	45.2	30	5.7
May	17.3	47.2	38	16.8
June	20.5	47.2	53	106.8
July	20.0	45.0	78	260.9
August	20.4	40.1	82	280.8
September	17.8	39.7	82	228.9
October	11.7	39.4	71	29.0
November	5.0	36.0	61	7.2
December	2.2	32.8	64	4.2

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

IV. THERMAL COMFORT ANALYSIS

i. Mahoney Tables

Mahoney table is a series of tables devised by C Mahoney which is a very good tool for the purpose of climatic data analysis. The initial part of the table records the location, longitude, latitude and altitude of the place. Table 3 shows the geographical location of Varanasi, India.

Table 3

Location	Varanasi
Longitude	82.9524 E
Latitude	25.3561 N
Altitude	82 meter (above sea level

Monthly mean maximum temperature and monthly mean minimum temperature data from the metrological department of each month is recorded in the respective line in the table 4. Monthly mean range is calculated by subtracting the monthly mean minimum values from monthly mean maximum values. The monthly mean range for each month is entered in the respective lines. Highest mean and lowest mean temperatures during the twelve months are entered on the right side of the table. Annual mean temperature (AMT) is calculated by adding the highest mean temperature and lowest mean temperature values and dividing it by two. The same is entered in the respective box marked AMT. Annual mean range is calculated by subtracting the lowest mean minimum from highest mean maximum values and the same is entered in to the field marked AMR.

Table-4 Air temperature: °C

	J	F	M	A	M	J	J	A	S	O	N	D	High	AMT
Monthly mean max.	22.3	26.4	32.7	38.6	39.7	37.3	32.2	31.5	31.5	30.7	28	23.8	39.7	24.8
Monthly mean min.	9.9	13.1	17.7	23.1	26.6	28	26.5	26	25	21	15.8	11.3	9.9	29.8
Monthly mean range	12.4	13.3	15	15.5	13	9.3	5.7	5.5	6.5	9.7	12.2	12.5	low	AMR

Table-5 Relative humidity %

Months	J	F	M	A	M	J	J	A	S	O	N	D
Monthly mean max. (A.M)												
Monthly mean min. (P.M)												
Average	66	58	41	30	38	53	78	82	82	71	61	64
Humidity group	3	3	2	2	2	3	4	4	4	4	3	3

Table-6 Rain & Wind

months	J	F	M	A	M	J	J	A	S	O	N	D		total
Rainfall, mm	16	19	9	6	10	137	305	254	173	40	6	7		982
Wind, prevailing	WNW	WNW	WNW	NW	NNE	NNE	E	ENE	ENE	NE	W	WNW		
Wind secondary	WNW	WNW	WNW	NW	NNE	NNE	E	ENE	ENE	NE	W	WNW		

Procedure for tabulating table 5 is as follows.

i. From metrological record, enter the monthly mean maximum (early morning reading) and monthly mean minimum (afternoon reading) of relative humidity in the respective lines.

ii. ii. Calculate the average relative humidity and enter the values into third line.

iii. iii. Establish the humidity group of each month (1, 2, 3 and 4) according to the following categories as defined in

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

Fig.2

Humidity group:	1	If average RH: BELOW 30%
	2	30-50%
	3	50-70%
	4	Above 70%

Table- 7 Diagnosis

Months	J	F	M	A	M	J	J	A	S	O	N	D	AMT
Monthly mean max.	22.3	26.4	32.7	38.6	39.7	37.3	32.2	31.5	31.5	30.7	28	23.8	24.8
Dat comfort: upper	27	27	34	34	34	34	34	34	34	31	29	29	
Lower	22	22	26	26	26	26	26	26	26	25	23	23	
Monthly mean max.	9.9	13.1	17.7	23.1	26.6	28	26.5	26	25	21	15.8	11.3	
Night comfort upper	21	21	25	25	25	25	25	25	25	24	23	23	
Lower	17	17	17	17	17	17	17	17	17	17	17	17	
Thermal stress: day	C	O	O	H	H	H	O	O	O	O	O	O	
night	C	C	O	O	H	H	H	H	O	C	C	C	

Fig 3

		AMT over 20°C		AMT 15-20°C		AMT below 15°C	
Comfort limits		Day	Night	Day	Night	Day	Night
	1	26-34	17-25	23-32	14-23	21-30	12-21
	2	25-31	17-24	22-30	14-22	20-27	12-20
Humidity group:	3	23-29	17-23	21-28	14-21	19-26	12-19
	4	22-27	17-21	20-25	14-20	18-24	12-18

Table 7 is primarily used for the diagnosis of the climatic data. Procedure for tabulating table 7 is as follows.

i. Enter the monthly mean maximum temperature and monthly mean minimum temperature values from table 4.

ii. ii. Find the upper and lower comfort limit for the day and night of each month on the basis of Fig 3, as defined by the "annual mean temperature (AMT), and "humidity groups "and enter these values in the lines 2, 3, 5 and 6 respectively.

iii. Compare the day comfort limits with mean maximum and night comfort limits with mean minimum and establish the nature of thermal stress by entering the following symbols in last two lines. H- Hot if mean is above limit O- (Comfort) if mean is within limit C-(Cold) if mean is below Limit

Table-7 Indicators

Indicators	J	F	M	A	M	J	J	A	S	O	N	D	Total
Humid: H1				•	•								2
H2							•	•	•	•			4
H3							•	•					2
Arid: A1	•	•			•	•							4
A2					•								1
A3	•												1

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

Fig. 4

Applicable when:	Thermal Stress			Rainfall	Humidity Group	Monthly mean range
Meaning	Indicator	Day	Night			
Air movement essential	H1	H			4	
					2,3	Less than 10°C
Air movement Desirable	H2	OH			4	
Rain protection necessary	H3			Over 200mm		
Thermal capacity necessary	A1		H		1,2,3	More than 10°C
Out-door Sleeping desirable	A2	H	O		1,2	
		C			1,2	More than 10°C
Protection from cold	A3					

Mahoney table defines six indicators in Fig.4. First three are humid indicators i.e. H1, H2 & H3 and next three are arid indicators A1, A2 &A3. Procedure for tabulating table 8 is as follows.

i. Check the monthly mean range, humidity group, rainfall from table (4, 5 & 6) and thermal stresses values from the table 7 and place a tick mark in the line of appropriate indicator.

ii. In the last column, write the total number of ticks corresponding to a particular indicator.

Procedure for tabulating table 9 is as follows.

i. Transfer the indicators total from table 8 to the first line of table 9.

ii. ii. Place a tick mark against the specification item in the same line corresponding to the indicator values

Indicator totals from table 2					
H1	H2	H3	A1	A2	A3
2	4	2	4	1	1

Layout

			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 lay-out of estates

Air Movement

3-12						•	6	Rooms single banked, permanent provision for air movement
			0-5					
1,2			6-12			•	7	Double banked rooms, temporary provision for air movement
	2-12							
0	0-1						8	No air movement requirement

Opening

			0,1		0		9	Large openings, 40-80%
			11,12		0,1	•	10	Very small openings, 10-20%

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 06, June-2023

Any other conditions							11	Medium openings, 20-40%
		3-12					12	

Walls

			0-2				13	Light walls, short time lag
			3-12				14	Heavy external and internal walls

Roofs

			0-5			•	15	Light, insulated roofs
			6-12				16	Heavy roofs, over 8 h time-lag

Out- door sleeping

				2-12		•	17	Space for out-door sleeping required

Rain protection

		3-12					18	Protection from heavy rain necessary

Table-10 Detailed Recommendations

Indicator totals from table 2					
H1	H2	H3	A1	A2	A3
2	4	2	4	1	1

Size of openings

			0,1		0		1	Large: 40-80%
					1-12	•	2	Medium: 25-40%
			2-5					
			6-10				3	Small: 15-25%
			11,12		0-3		4	Very small: 10-20%
					4-12		5	Medium: 25-40%

Position of openings

3-12						•	6	In north and south walls at body height on windward side
1-2			0-5				7	As above, openings also in internal walls
			6-12					
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 h time-lag

roofs

10-12			0-2				12	Light, reflective surface, cavity
			3-12			•	13	Light, well insulated
0-9			0-5					
			6-12				14	Heavy, over 8 h time-lag

External features

				1-12		•	15	Space for out-door sleeping
		1-12				•	16	Adequate rainwater drainage

The combined recommended specifications from table 9 & table-10 are tabulated in the table 11 which shows the design recommendation for energy efficient buildings in Varanasi.

Table 11 design recommendation for Varanasi

Parameters	Recommendations
Layout	Building orientation north and south (long axis east –west) to reduce solar radiation incident on the wall
Spacing	As 3, but protection from hot and cold wind
Air movement	• Rooms single banked, permanent provision for air movement • Double banked rooms, temporary provision for air movement
Size of Openings	Very small openings, 10-20%
Position of openings	In north and south walls at body height on windward side
Protection of openings	• Exclude direct sunlight • Provide protection from rain
Walls	Heavy, over 8 h time-lag
Roofs	Light, well insulated
Outdoor sleeping	Space for out-door sleeping required
External features	• Space for out-door sleeping • Adequate rainwater drainage

V. CONCLUSIONS

In Varanasi climate, buildings should be oriented in such a way that its longer axis should remain in east-west direction. In this orientation, the walls will receive less solar radiation in summer and more solar radiation in winter in comparison to other orientations. This orientation minimizes the heat load in summer and is a very effective passive cooling strategy. The walls should be thicker having time lag over 8 hours. Cavity walls or composite walls are also very helpful in controlling the heat transfer from outside to inside the building. When the air movement is necessary, the advantage of prevailing breeze should be taken by grouping the buildings in relation to the wind direction. Fenestrations should be made on the walls perpendicular to the wind direction. Direct sunlight must be excluded from the fenestration and window shades should be designed in such a way so that it cuts the summer sun but permits winter heat inside the building. Roofs should also be properly insulated so as to minimize heat transfer from the roof to the inside of the building. Provision of adequate rainwater drainage is also essential in this climate.

VI. BIBLIOGRAPHY

i. Koenigsberger O.H, Ingersoll T.G., Alan Mayhew and Szokolay S.V. “Climate Design: Manual of Tropical Housing and Building”, Orient Longman Limited, 1975

ii. Arvind Krishnan, Nick Baker, Yannas and Szokolay, S.V. “Climate responsive Architecture, A design handbook for energy efficient buildings”. Tata McGraw-Hill Education, 2001

iii. Wind & weather statistics Varanasi Airport - Windfinder