RNI: MAHENG/2016/68030 **VOLUME 10 (2025), ISSUE 1 : 1-15** **ISSN: 2456-5342 (print)**

MGMUNIVERSITY
JAWAHARLAL NEHRU
ENGINEERING COLLEGE

VISTA INTERNATIONAL JOURNAL
ON ENERGY, ENVIRONMENT & ENGINEERING

Analyzing Overheating in the Residences of Hot and Dry Climates in India

Nawaz Shaikh* and Sheetal Bagde
Department of Architecture, Jawaharlal Nehru Engineering College,
MGM University, Chhatrapati Sambhajinagar (M.S.), India

***Corresponding Author's E-mail:** iinnovatiquedesigner7@gmail.com,Mob..7447227777

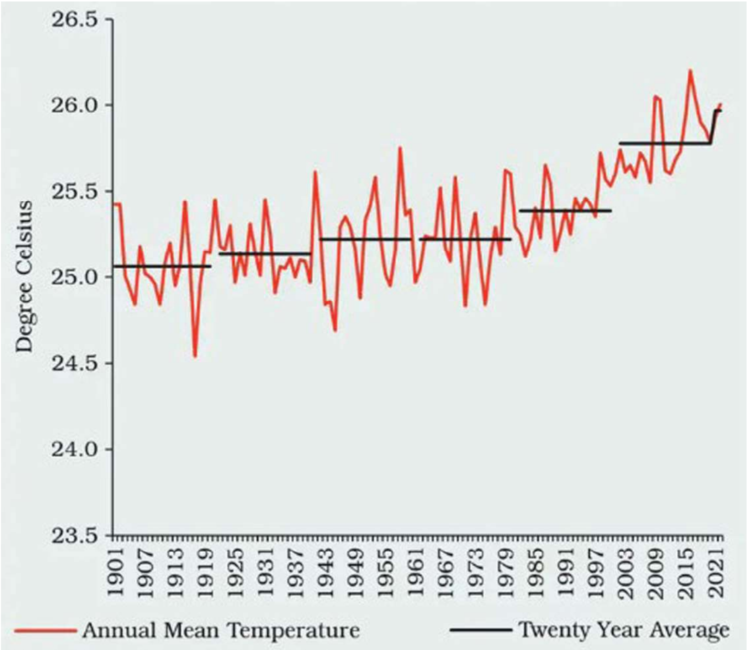
ABSTRACT

This study focuses on improving the thermal environment of residential buildings, particularly in hot, dry climates, focusing on India's hot and dry climates. This is important because the thermal comfort of buildings significantly affects theiroccupants' quality of life. In this study, several factors that influence the thermal performance of buildings were investigated. These factors include the thermal mass, insulation, material characteristics, window design, and shading. By examining these elements, this study aims to enhance occupant comfort.Following the requirements of the Energy Conservation Building Code (ECBC), the study focuses on the thermal performance of envelope materials and design interventions suitable for India's hot and dry climate.A literature review shows how building materials affect the control of indoor temperatures, and a climate analysis identifiesspecific regional factors that lead to overheating. The main focus of the research is a case study analysis that compares modern and old building designs under extreme weather conditions, utilizing simulation tools (TRNSYS). According to the results, traditional architectural techniques like thick walls, courtyards, and less fenestration—achieve considerably lower interior temperatures than modern buildings, highlighting their potential as sustainable housing options in the future. For residential structures in hot and dry Indian conditions, this study offers design strategies and prescriptive envelope recommendations for enhancing thermal comfort and energy efficiency.

Keywords : *Occupant, simulation, hygrothermal, envelope, Design Builder*

1. Introduction:

As global temperatures continue to rise, indoor overheating has become an important issue for residential buildings in hot and dry climates, particularly in regions in India, such as Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh. The building Envelope includes all the building components that separate indoors from outdoors[1]. The building envelope consisted of walls, roofs, windows, and fenestrations. Increasing outdoor temperatures are the main cause of overheating in residences [2]. In this study, the overall hot and dry climatic conditions, issues of thermal discomfort, and indoor overheating control strategies were studiedwhile studying a previous case study of simulation-based comparison between traditional and modern materialsto control indoor temperature in residences of hot and dry climates in India.By examining the impact of these elements and referencing the Energy Conservation Building Code (ECBC) requirements, this analysis aims to provide an understanding of the optimization of building design in India's hot and dry climate for thermal comfort.



Sources: Data.gov.in; and India Meteorological Department (IMD).

Fig. 1. Annual Temperature in India from 1901 to 2021 [3]

The objectives of the study are as follows:

1) To investigate the reasons causing the effects of temperature rise in Indian homes located in hot and dry regions.
2) Analyze through research and case studies how to control overheating in residences of hot and dry climates in India.
3) To provide recommendations for improving envelope design techniques to thermal comfort in upcoming house constructions in hot and dry climates.

There are following Scope and Limitations:

i) This study mainly focuses onbuilding components- walls, roofs, and windows.
ii) The study analysis was limited to the hot and dry climate of India.

The paper investigates using the methodology to collect and analyze previous research on overheating in buildings and thermal comfort in hot and dry climates.

2. Literature review :

The literature review was conducted based on the building envelope and thermal comfort as follows:

2.1 Building Envelope :

- The building envelope acts as a protective barrier between living spaces and the outside world [4].
- A large amount of heat is gained through convection via the envelope, which is made up of walls, roofs, and openings [5].

- This envelope consists of vertical openings, solid structures (walls), and roofs, as shown in Fig.2 [6].

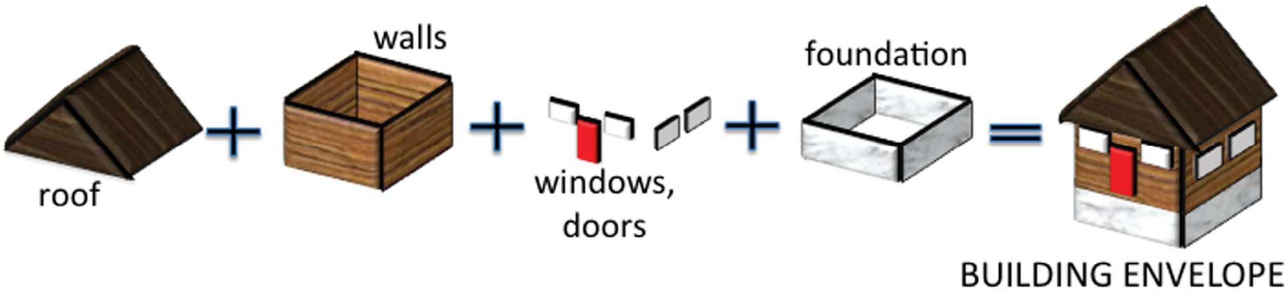


Fig. 2. The building exterior component [7]

- The main defense and sheltering mechanism has historically been the building envelope.
- The roof is responsible for 70.62% of total heat gains, while the four side walls contribute 27.11%, and windows make up 2.27% [8].

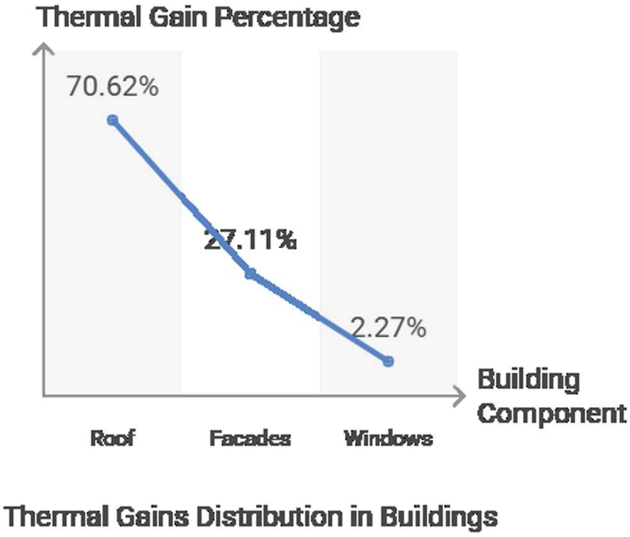


Fig. 3. Building envelope heat gain distribution in building [8]

- A thoughtful approach to managing the envelope walls, specifically designed for hot and dry climates (like choosing construction materials with high thermal inertia for walls and roofs, reducing window sizes, and adding solar protections), guarantees optimal comfort inside the building, even in challenging external conditions.

2.2 Thermal comfort in the building :

According to research and consensus, a comfortable indoor temperature range in hot regions of India is between 24°C and 28°C[8].Thermal comfort plays a crucial role in enhancing the quality of indoor spaces. It involves the relationship between the occupants, the building itself, and the external environment. Achieving thermal comfort is vital for creating pleasant atmospheres and ensuring the well-being of users [9].It is typically described as a feeling of satisfaction with the thermal conditions. Researcher characterizes it as the lack of discomfort from heat or cold, or as a state of thermal well-being [10].

2.3 Building materials and thermal comfort :

Selecting the right building materials is crucial for ensuring a comfortable indoor environment throughout the year. In other words, choosing the right materials for the building envelope serves as a passive strategy [11]. It is important to note that the building envelope not only separates the interior from the outside world but also protects the structure from climatic elements. Three main types of materials can be used for this envelope: opaque, transparent, and translucent. Heat can enter buildings primarily through transparent and translucent materials, as well as open windows, and is further influenced by the other materials used in the construction. The internal thermal comfort can be affected both directly and indirectly by the properties of these materials in relation to external temperature and humidity [12].

Thermal properties of buildings are given in Table 1.

Table 1. Thermal Properties of Building Materials

Material	U-Value (W/m^2K)	North Wall Indoor Temp (°C)	South Wall Indoor Temp (°C)	East Wall Indoor Temp (°C)	West Wall Indoor Temp (°C)
Burnt Clay Brick	1.7	29	34	32	33
Stone Masonry	1.8	29	35	33	34
AAC Block	0.35	27	31	30	30
Mud Brick (350 mm)	0.50	28	33	31	32
CSEB (300 mm)	0.40	27	32	30	31
Hollow Concrete Block (200 mm)	1.5	29	34	32	33
Rammed Earth (450 mm)	0.45	27	31	30	31
Double Glazed Glass	1.2	26	30	28	29
Single Glazed Glass	5.8	31	36	34	35
Gl Sheet	3.5	29	33	32	33
RCC	1.8	29	35	33	34

3. Climate of India :

India features a wide range of unique climatic zones that differ from one region to another. Essentially, these zones are characterized by their typical weather patterns and statistical descriptions of various factors over time, which can span from months to thousands of years. Five climate zones are identified by India's National Building Code (NBC): composite, temperate, cold, warm and humid, and hot and dry (NBC, 2016) [7]. In this analysis, we will focus on the hot and dry climate zone in India.

3.1 Hot and dry :

The hot and dry climate is found in the central and western regions of India, including states like Rajasthan, Gujarat, and Maharashtra. Here, the average monthly temperature hovers around 30°C with a relative humidity of about 55%. These areas experience intense solar radiation and hot winds, leading to significant temperature fluctuations between day and night. Rainfall is scarce, and winters are brief. Buildings in these regions are typically made from materials such as bricks, stones, cement, and steel, with flat roofs often constructed from sandstone slabs and Steel girders. Figure 4 illustrates the geographical spread of this hot and dry climate across India. (NBC, 2016) [7].

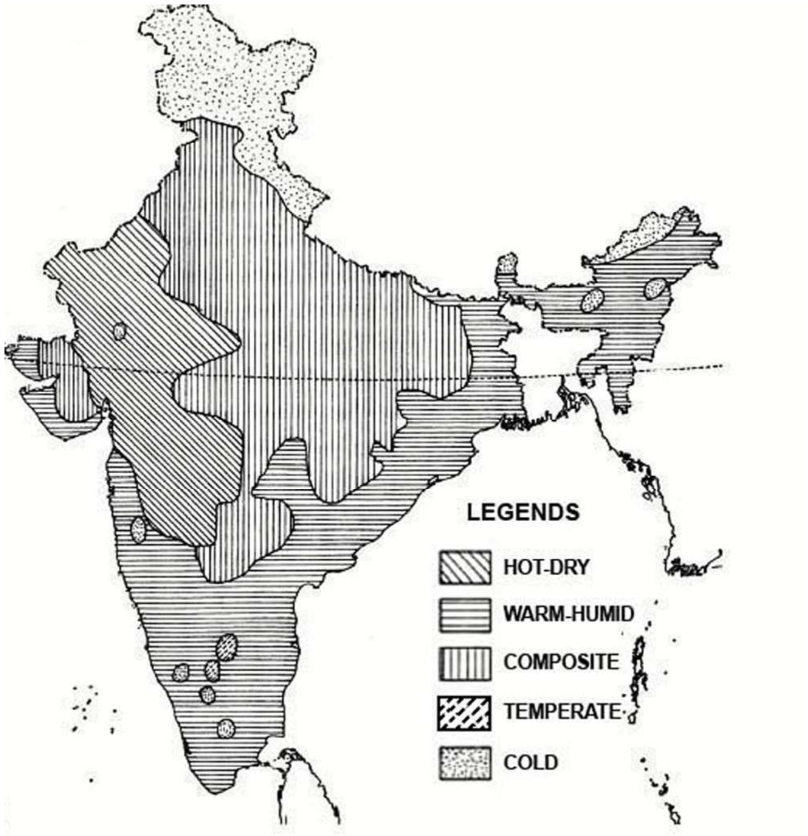


Fig. 4. Geographical distribution of climatic zones in India [11]

4. Prescriptive requirements of ECBC Building energy codes for hot and dry climate :

U factor for Roof Assembly of residential buildings is 0.33 W/m2K for hot and dry climate according to ECBC Compliant Building [13].

Table 2. Vertical Fenestration Assembly U-factor and SHGC Requirements for ECBC Buildings [9]

Parameter	Hot and dry
Maximum U-factor (W/m².K)	3.00
Maximum SHGC Non-North	0.27
Maximum SHGC North for latitude ≥ 15°N	0.50
Maximum SHGC North for latitude < 15°N	0.27

5. Case studies :

The author studied various case studies of buildings in hot and dry climates as follows:

5.1 Case study 1 – Building in the hot and dry climate of Kenadsa, Algeria [6] :

In the south-west region of Algeria, the hot and arid climate has shaped the design of comfortable buildings. Residents have relied on traditional methods to regulate temperature. While the comfort needs have changed over time, modern designs often fall short. The summers are long and scorching, necessitating buildings that can withstand both heat and cold. Kenadsa, in particular, experiences extreme heat. This study examines the comfortable temperature levels in both modern and traditional homes using TRNSYS simulations.

Kenadsa is located in south-west Algeria, approximately 20 km west of Bechar and 950 km south-west of Algiers, at an elevation of 806 meters, with coordinates of latitude 31°38′N and longitude 2°15′W. During summer, the shaded temperature exceeds 40°C, with a day-night temperature variation of about 15°C and low humidity around 27%. Figure 6 shows the models analyzed: wast-ed-dar (WD), ain-ad-dar (AD), and modern house (MH). The WD features a large central area exposed to the sky, while the AD has a smaller 1m×1m space. The houses face each other with no street-facing windows; instead, all windows open into an inner courtyard, designed with long, narrow shapes to block sunlight. Thick walls create deep shadows at the openings, and narrow ventilation slots, positioned away from the courtyard, remain open during the summer.

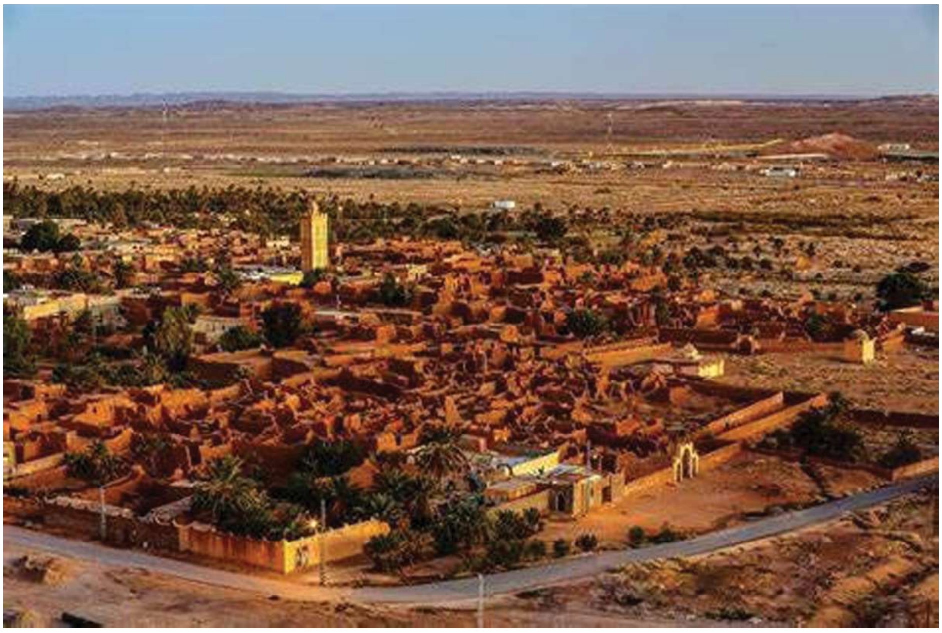
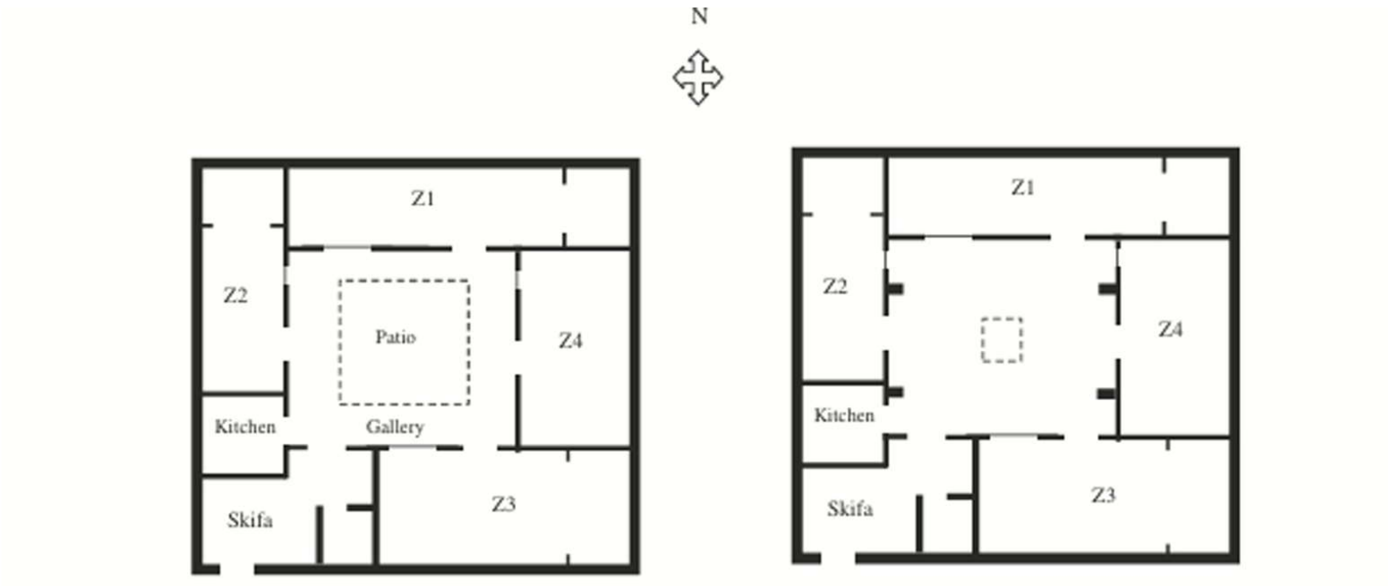


Fig 5. Ksar of Kenadsa, Algeria [6]

Kenadsa is located in the south-west region of Algeria, approximately 20 km west of Bechar and 950 km south-west of Algiers, at an altitude of 806 meters, with coordinates of latitude 31°38′N and longitude 2°15′W. During summer, temperatures in the shade exceed 40°C, with a day-night temperature variation of about 15°C and a low humidity level of around 27%. Figure 6 shows the models that were examined: wast-ed-dar (WD), ain-ad-dar (AD), and modern house (MH). The WD model features a large central area exposed to the sky, while the AD model has a smaller area measuring 1m×1m. The houses are positioned facing each other, with no windows facing the street. Instead, all windows open into an inner courtyard, designed with long, narrow shapes that block sunlight. A thick wall creates a deep shadow at the entrance, and narrow ventilation openings, positioned away from the courtyard, remain open during the summer.



Wast-ed-dar (WD) with large open space

Ain-ed-dar (AD) with narrow open space

Modern house type (MH)

Fig.6. Model houses for simulation with particular zones [6]

5.1.1 Simulation :

This paper evaluates the strengths and weaknesses of a specific housing type using TRNSYS—a modular simulation tool for transient energy systems.

Table 3. Percentage of hours in year obtained by classification of the temperature

House Type	Zone	Tmax/Tmin (°C)	34°C < T (%)	32°C < T < 34°C (%)	30°C < T < 32°C (%)	18°C < T < 30°C (%)	15°C < T < 18°C (%)	T < 15°C (%)
WD (wasṭ-ed-dar)	Zone 1 (north)	35.71 / 7.63	1.08	5.81	7.12	42.35	13.34	30.30
	Zone 2 (west)	36.20 / 7.10	1.71	5.97	7.21	42.81	11.95	30.36
	Zone 3 (south)	36.72 / 7.72	3.35	6.14	6.49	44.06	14.18	25.91
	Zone 4 (east)	36.25 / 7.73	1.98	6.21	7.05	43.73	12.32	28.60
AD (ain-ad-dar)	Zone 1 (north)	33.54 / 3.07	0	2.94	10.39	44.50	11.73	31.76
	Zone 2 (west)	34.23 / 3.32	0.12	4.58	10.20	42.5	11.80	30.89
	Zone 3 (south)	35.36 / 3.49	1.00	8.16	7.70	42.96	12.00	27.08
	Zone 4 (east)	34.32 / 3.42	0.50	6.00	9.26	43.00	11.50	29.95
MH (modern housing)	Zone 1 (north)	38.69 / 6.7	16.59	5.78	5.17	36.64	9.58	26.23
	Zone 2 (west)	38.86 / 6.78	16.67	5.91	5.41	41.8	9.73	25.85
	Zone 3 (south)	39.63 / 8.19	17.44	5.44	5.94	39.01	11.56	20.52
	Zone 4 (east)	39.50 / 8.45	19.81	4.97	6.25	35.99	11.15	21.82

Table 4. Percentage of hours in the year obtained by classification of the temperatures

House Type	Zone	Tmax/Tmin (°C)	34°C < T (%)	32°C < T < 34°C (%)	30°C < T < 32°C (%)	18°C < T < 30°C (%)	15°C < T < 18°C (%)	T < 15°C (%)
WD	Zone 1 (north)	36.76 / 5.72	2.85	6.08	6.49	42.57	13.03	28.97
	Zone 2 (west)	37.45 / 5.30	3.78	5.92	6.62	42.20	11.15	30.33
	Zone 3 (south)	37.67 / 5.43	5.43	5.33	6.35	42.69	12.89	27.30
	Zone 4 (east)	37.50 / 5.72	4.25	5.81	6.67	42.71	12.08	28.48
AD	Zone 1 (north)	34.23 / 2.63	0.09	3.27	8.91	44.18	11.65	31.89
	Zone 2 (west)	34.76 / 2.74	0.43	4.21	8.59	43.78	11.72	31.27
	Zone 3 (south)	36.09 / 2.80	1.82	6.18	7.10	43.93	11.95	29.01
	Zone 4 (east)	34.98 / 2.84	0.66	5.31	8.24	43.84	11.52	30.42
MH	Zone 1 (north)	37.17 / 9.02	15.50	7.37	2.64	39.76	10.87	23.91
	Zone 2 (west)	37.14 / 9.23	15.98	6.94	3.07	39.88	10.71	23.42
	Zone 3 (south)	37.69 / 9.56	17.37	6.11	6.11	44.58	16.58	9.34
	Zone 4 (east)	38.72 / 11.70	22.84	2.89	9.17	38.61	12.56	13.91

Table 5. Percentage of hours in year obtained by classification of the temperatures (for more compact urban fabric)

House Type	Zone	Tmax/Tmin (°C)	34°C < T (%)	32°C < T < 34°C (%)	30°C < T < 32°C (%)	18°C < T < 30°C (%)	15°C < T < 18°C (%)	T < 15°C (%)
WD	Zone 1 (north)	34.97 / 9.64	0.33	4.34	7.39	43.65	16.07	28.13
	Zone 2 (west)	35.43 / 8.43	0.73	4.62	7.39	43.66	13.36	30.21
	Zone 3 (south)	35.95 / 8.11	2.13	5.97	6.18	43.71	14.24	27.76
	Zone 4 (east)	35.47 / 8.51	0.75	5.18	7.15	44.10	13.35	29.45
AD	Zone 1 (north)	33.30 / 3.41	0.00	0.33	5.60	50.28	12.34	31.44
	Zone 2 (west)	33.86 / 3.46	0.00	0.60	6.89	49.28	12.20	31.02
	Zone 3 (south)	34.80 / 3.43	0.22	4.13	9.26	46.03	11.88	29.07
	Zone 4 (east)	33.81 / 3.51	0.00	0.91	8.43	48.11	11.96	30.58
MH	Zone 1 (north)	38.49 / 7.44	18.20	5.29	5.04	35.85	10.34	25.28
	Zone 2 (west)	38.81 / 8.37	21.24	4.11	7.00	34.16	11.73	22.73
	Zone 3 (south)	39.14 / 8.61	20.90	3.65	6.63	34.47	11.50	22.85
	Zone 4 (east)	38.76 / 8.49	21.36	3.10	7.14	34.12	11.72	22.55

The study examines the effect of urban compactness on thermal behavior by simulating three housing scenarios, focusing on a case where a house is flanked by two similar ones,as shown in Table 7.

Results show that for traditional constructions, the comfort hours within 18°C to 34°C decreased from 2.03% to 0.98%, while hours between 30°C and 34°C slightly increased from 17.62% to 20.24%, and overall comfort hours dropped from 38.36% to 34.65%. This indicates that urban compactness does not significantly improve thermal comfort for modern houses made with hollow perpend structures. Additional simulations using alternative materials (hollow perpend for traditional and adobe/stone for modern constructions) reveal that the choice of material only slightly affects the overall thermal performance in the comfort zone,as shown in Table 8.

Table 6. Percentage of hours in year obtained by classification of the temperatures For more compact urban fabric

House Type	Zone	Tmax/Tmin (°C)	34°C < T (%)	32°C < T < 34°C (%)	30°C < T < 32°C (%)	18°C < T < 30°C (%)	15°C < T < 18°C (%)	T < 15°C (%)
WD	Zone 1 (north)	36.33 / 7.41	2.89	5.93	6.65	43.74	14.88	26.98
	Zone 2 (west)	36.94 / 6.45	2.76	5.84	6.71	42.71	11.89	30.04
	Zone 3 (south)	37.13 / 5.96	4.52	5.51	6.43	41.99	12.45	29.08
	Zone 4 (east)	36.82 / 6.77	2.97	6.07	6.75	42.95	11.83	29.47
AD	Zone 1 (north)	33.38 / 2.98	0.00	0.88	7.64	47.59	12.06	31.81
	Zone 2 (west)	33.87 / 3.01	0.00	1.32	8.04	47.13	12.03	31.47
	Zone 3 (south)	34.74 / 2.91	0.25	4.29	7.51	42.41	12.38	33.15
	Zone 4 (east)	33.71 / 3.04	0.00	1.51	8.91	46.65	11.83	31.08

MH	Zone 1 (north)	41.41 / 15.00	37.51	7.50	7.21	40.54	7.24	0.00
	Zone 2 (west)	41.08 / 15.00	36.50	6.96	7.77	40.87	7.89	0.00
	Zone 3 (south)	40.75 / 14.91	34.41	5.71	8.77	42.40	8.62	0.09
	Zone 4 (east)	41.18 / 15.00	36.89	6.88	7.69	36.20	7.22	0.00

The simulation shows that modern houses are not well-suited to desert climates unless they rely on air-conditioning. In contrast, two traditional houses (using stone adobe and hollow perpend) perform better in the summer.

The WD house benefits from natural ventilation but is less comfortable than the AD type. Improvements can be made by optimizing features like the patio size, gallery width, and incorporating vegetation and water features. Additionally, using shading strategies helps maximize comfort. Future studies will look into how urban compactness impacts cooling and heating energy use.

5.2 Case study 2-Apartment building, Biskra, Southeastern Algeria :

This study examines the influence of building envelope materials on thermal comfort, focusing on the effects of various components of the opaque sections of apartment buildings—namely walls, roofs, and insulation within the hot and arid climate of Biskra.

5.2.1 Case of the City of Biskra: Climatic Characteristics :

The city of Biskra, situated in southeastern Algeria, is characterized by its Saharan climate, which features high solar radiation levels, a cold winter, and a hot, dry summer. Geographically, Biskra is located at a latitude of 34.48° N and a longitude of 5.44° E, with an elevation of 83 meters above sea level. The summer months can see maximum temperatures soaring to 45°C in July, while winter temperatures can drop to a minimum of 5°C in January. Precipitation is less frequent, averaging less than 30 days annually, and the average relative humidity is low, around 47%, peaking at 65% in December and dropping to a minimum of 28.29% during July and August [10].

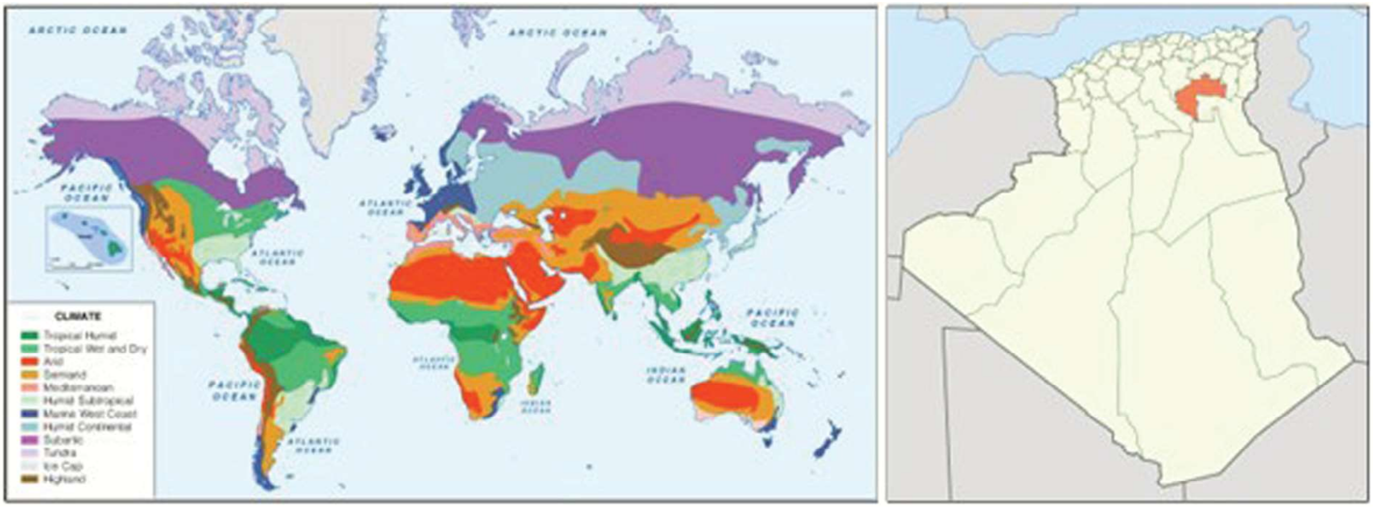
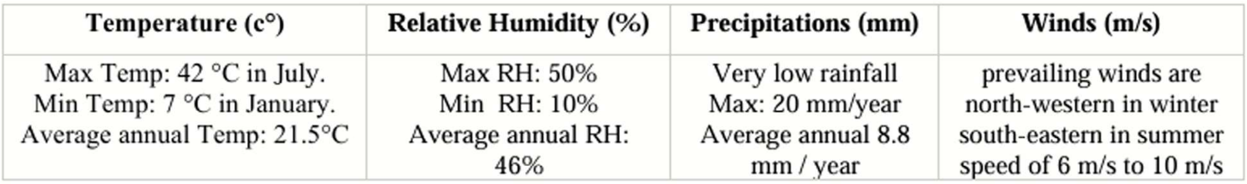


Fig. 7. The climatic zone and the geographic position of the city of Biskra [10]

Table 7. The Metrological characteristics of Biskra



Temperature (c°)	Relative Humidity (%)	Precipitations (mm)	Winds (m/s)
Max Temp: 42 °C in July. Min Temp: 7 °C in January. Average annual Temp: 21.5°C	Max RH: 50% Min RH: 10% Average annual RH: 46%	Very low rainfall Max: 20 mm/year Average annual 8.8 mm / year	prevailing winds are north-western in winter south-eastern in summer speed of 6 m/s to 10 m/s

The selected buildings are influenced by prevailing winds, which come from the northwest in winter and the southeast in summer, with speeds ranging from 6 to 10 m/s. The building envelopes analyzed are the most common types of walls, roofs, and insulation found in residential houses and apartments in Biskra. This study focuses solely on the opaque sections of the building envelope, as they play a significant role in heat transfer between the indoor and outdoor. Various temperature and humidity measurements were taken indoors and outdoors in three typical rooms across three residential buildings.

Table 8. Thermal properties of the chosen building envelope

Materials	Thermal conductivity (W/m.K)	Specific heat (J/Kg.K)	Density D (Kg/ m³)	Thickness T (cm)
Revetments Materials				
Cement mortar	0.80	1000	1900	0.2
Plaster mortar	0.57	1008	1150	0.2
Envelope (wall materials)				
Red Hollow brick	0.39	1000	1200	10-15
Full Cinder block	0.95	1080	975	20
Envelope (Roof materials)				
Hollow body	1.2	1008	2150	16
Compression slab	1.56	1008	2150	04
Floated slab	1.56	1008	2150	10
Envelope insulations				
Air	0.047	1000	1	5
polystyrene	0.038	1450	16-20	5

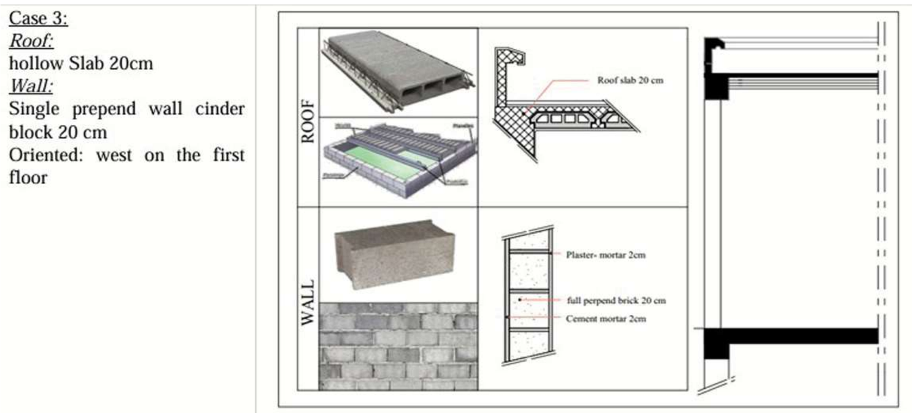
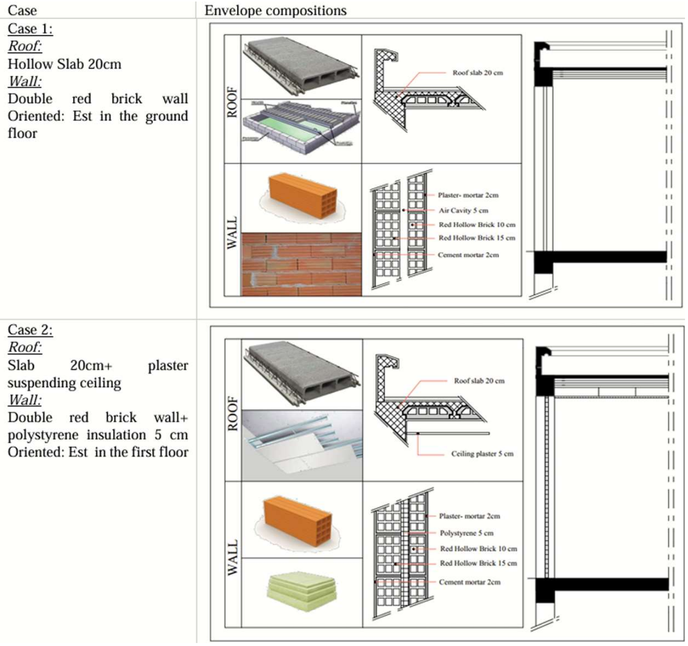


Fig. 8. Comparison of different case studies of building envelope compositions [10]

In this research, we employed a quantitative approach to assess indoor thermal conditions through both on-site measurements and numerical simulations. The measurement protocol involved collecting data on air temperature, relative humidity, and surface temperature both indoors and outdoors using the Testo 480 hygrothermal instrument. We recorded the ambient and surface temperatures, as well as relative humidity, on the surfaces of a wall, both inside and outside, as illustrated in Fig. 9.



Case	Envelope compositions
Case 1: *Roof:* Hollow Slab 20cm *Wall:* Double red brick wall Oriented: Est in the ground floor	
Case 2: *Roof:* Slab 20cm+ plaster suspending ceiling *Wall:* Double red brick wall+ polystyrene insulation 5 cm Oriented: Est in the first floor	

Fig.9. The Measuring positions of chosen parameters [10]

In the month of March (mild day), bi-hourly measurements were taken in the natural environment without the use of any active equipment, from 8:00 am to 10:00 pm. In order to evaluate the thermal comfort, a numerical simulation was conducted with "Design Builder 5.5" software. Design Builder is a tool for dynamic thermal simulation and energy consumption analysis of buildings. Based on real weather conditions (climatic weather data file), Design Builder was used to simulate the model of the buildings and envelope compositions under study.

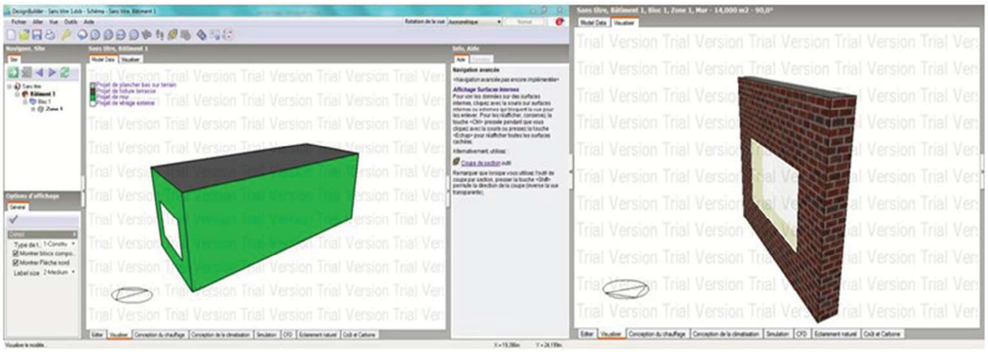


Fig.10. Design Builder interface [10]

- An annual simulation was conducted
- The simulation was conducted in natural conditions, the mechanical systems were inactive (ventilation, air conditioning).
- Ambient and operative temperature simulations were conducted -Three cases of the building were modeled and simulated (envelope and materials).

5.2.1 Results and discussion from case study :

Figure 11 illustrates the ambient air temperature readings taken inside the three cases. It is evident that, under the same outdoor temperature conditions, the indoor temperatures vary. This variation is attributed to the differences in the composition, thickness, and thermal properties of the building envelopes. In cases 1 and 2, where the walls are thicker and more durable, we observed that the indoor temperature (Ta) remains more consistent, with a difference of 4°C compared to case 3. The indoor temperature is higher than the outdoor temperature due to the heat accumulated throughout the day and the significant thermal mass of the wall materials, which retain the heat.

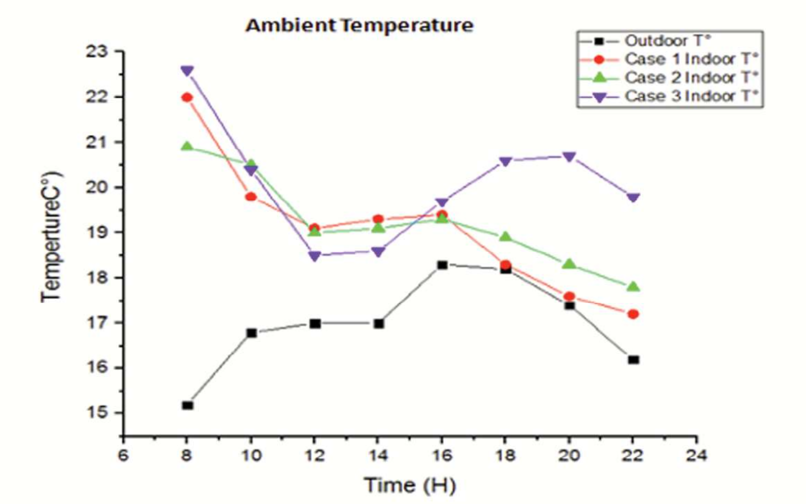


Fig.11. The ambient Temperature of indoor measured in the three cases [10]

5.2.2 Wall surface temperature (radiant temperature) :

The temperature of wall surfaces is the radiant temperature. Thegraph illustrates the measured temperatures of indoor and outdoor wall surfaces across three scenarios. As seen in Fig. 12, cases 1 and 2 indicate that the indoor surface temperatures remain relatively stable throughout the day, with an average lag of 3°C due to thermal inertia. The temperature of the external surface is directly influenced by sun exposure and radiation, while the internal surface temperature is affected by the materials used in the walls and their thermal properties, which determine how heat is conducted, accumulated, and resisted, ultimately impacting the indoor ambient temperatures. Consequently, the heat absorbed by the walls is retained within the various layers of the building envelope.

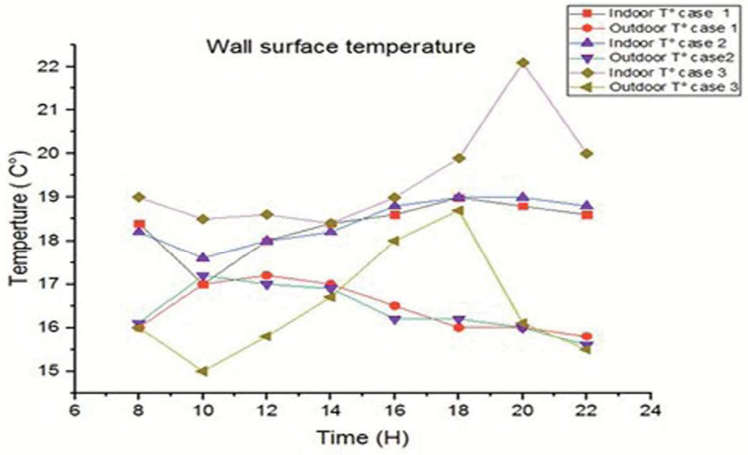


Fig.12. The wall surface (Ts) Temperature measured for three cases [10]

5.2.3 Roof surface temperature (radiant temperature) :

Fig. 13 illustrates the temperature of the roof surface (Ts) across three scenarios. The graph displays the indoor and outdoor temperatures of the roof surfaces for each case. Notably, there is a difference between case 1 and case 3, which features a standard cement slab and 20cm hollow bricks, compared to case 2, which includes a suspended plaster ceiling. The results indicate that incorporating the suspended plaster ceiling effectively reduces heat transfer from the outside to the interior environment.

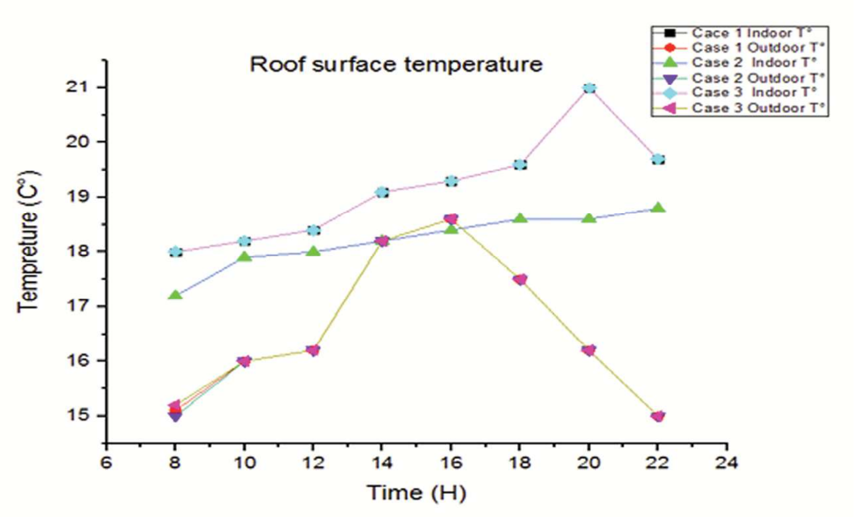


Fig.13. The roof surface Temperature(Ts) measured for three cases [10]

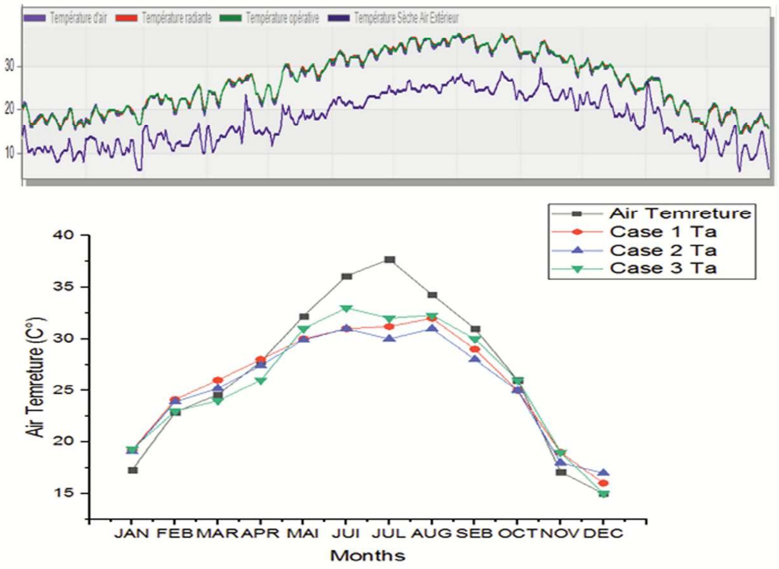


Fig. 14. Simulation results of Temperature measured for three cases[10]

6. Conclusions :

Hot and dry climate in India faces thermal discomfort in residences, and this problem is going to be worse in the future. This study has the following key conclusions.The simulation results indicate that without passive cooling strategies, modern residential buildings typically require air-conditioning to maintain thermal comfort, because of their design and materials; they do not suitably mitigate overheating.Traditional vernacular constructions using materials like stone adobe and hollow perpend perform better in summer seasons [14].

Walls with an air cavity or proper insulation showed more stable and lower indoor ambient temperatures compared to conventional walls. The indoor wall surface temperatures in cases with thicker walls showed an average lag of approximately 3°C compared to outdoor surfaces. This shows the importance of material layering, insulation, and passive cooling construction techniques meant to the climate to passively manage heat gains and improve occupant comfort.

References :

[1] Home owner Protection Office Branch of BC Housing. (n.d.). What is a Building Envelope. https://www.bchousing.org/publications/What-Is-Building-Envelope.pdf

[2] Agarwal, Aditi & Samuelson, Holly. (2021). Too Hot to Stay at Home: Residential Heat Vulnerability in Urban India. Journal of Physics: Conference Series. 2069. 012166. 10.1088/1742-6596/2069/1/012166.

[3] India Meteorological Department :https://mausam.imd.gov.in/imd

[4] L. Brackney, A. Parker, D. Macumber, and K. Benne, “Building Envelope Specification,” Springer, Cham, 2018, pp. 13–58. doi: 10.1007/978-3-319-77809-9_2. Available: https://link.springer.com/chapter/10.1007/978-3-319-77809-9_2

[5] G. Sudha, “Optimization of Building Envelope Towards Energy-Efficient Design,” Springer, Singapore, 2021, pp. 191–206. doi: 10.1007/978-981-15-9585-1_12.

[6] K. Mansouri and L. Sriti, “Investigating the effectiveness of the Building’s envelope materials in hot and arid climates to achieve indoor thermal comfort,” International journal of advanced natural sciences and engineering researches, vol. 7, no. 7, pp. 120–127, Aug. 2023, doi: 10.59287/ijanser.1346. https://asproceeding.com/index.php/ijanser/article/download/1346/1290

[7] National Institute of Building Sciences. (March 22, 2015). Building Envelope Design [Online]. Available: http://www.wbdg.org/design/env_introduction.php#fap

[8] S. Latreche, L. Sriti, K. Mansouri, and C. Berbouche, “Envelope design for thermal performance in residential buildings under hot arid climate conditions,” Technium Social Sciences Journal, vol. 38, pp. 755–767, Dec. 2022, doi: 10.47577/tssj.v38i1.7866

[9] Khoukhi, M., Fezzioui, N. Thermal comfort design of traditional houses in hot dry region of Algeria. Int J Energy Environ Eng 3, 5 (2012). https://doi.org/10.1186/2251-6832-3-5

[10] Givoni, B. (1978) L’homme l’architecture et le climat. Editions Le Moniteur, Paris, France.

[11] A. A. Kaushal, P. Anand, B. H. Aithal, and J. Sen, “Thermal comfort in Indian naturally ventilated buildings: A comprehensive review,” Energy and Buildings, Jan. 2024, doi: 10.1016/j.enbuild.2024.113923

[12] pei-yu, y. (2004). influence of external thermal insulation compound system on the indoor temperature and humidity. low temperature architecture technology. https://en.cnki.com.cn/article_en/cjfdtotal-draw200402041.htm

[13] Energy conservation building code 2017. https://beeindia.gov.in/sites/default/files/BEE_ECBC%202017.pdf

[14] Central Public Works Department, North Zone-IIICPWD, Jaipur, & Prashad, D. (2013). INTEGRATED GREEN DESIGN for urban & rural buildings in Hot-Dry climate zone. Central Public Works Department.