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THERMAL OBSERVATION IN VERNACULAR DWELLINGS OF GURJAKHANI, MYAGDI, NEPAL

Sampurna Maharjan[1]*, Mohan Moorti Pant[1], Ram Prasad Suwal[2], Orna Awale[3], Saurav Bhandari[4], Anita Lubanjar[4], Era Maharjan[5], Tenzing Sheraf Tamang[2]

[1] Khwopa Engineering College, Bhaktapur, Nepal
[2] Nepal Engineering College, Bhaktapur Nepal
[3] Architect, Lalitpur, Nepal
[4] Architect, Bhaktapur, Nepal
[5] Architect, Kathmandu, Nepal

Abstract

Indoor air temperature is a key parameter defined by ASHRAE Standard 55 for assessing thermal comfort. Numerous studies have examined thermal comfort conditions in vernacular architecture across different climatic regions. In particular, Dr. Hom Bahadur Rijal and Dr. Sushil Bajracharya, frontiers researchers in this subject have investigated the thermal comfort characteristics of vernacular buildings in high-altitude settlements and Kathmandu valley respectively. This study focuses on the thermal observations of vernacular dwellings in Gurjakhani, Myagdi, Nepal, situated at an elevation of 2638 meters above sea level. The region experiences cool summers, cold winters and occasional snowfall. The local buildings are primarily constructed with stone masonry bonded with mud mortar, while internal partitions are composed of timber planks. The flooring system consists of timber framing with mud overlay, and roofing materials typically comprise stone slates. The houses vary in height from one to three stories. Field measurements of indoor air temperature and surface temperatures within a designated room were conducted using available electronic sensors. Supplementary meteorological data were obtained from online sources to calculate the operative indoor air temperature. The CEB thermal comfort tool was used for thermal comfort analysis. Findings from the one-week field investigation conducted in October indicate that the indoor environment remains cold relative to the calculated operative temperature, yet demonstrated greater thermal satisfaction compared to the outdoor environment.

Keywords: Air temperature, Vernacular architecture, Operative temperature, Thermal comfort.

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1. Introduction

It is well understood that vernacular houses have developed in response to local materials, construction practices and microclimatic conditions. These traditional buildings create their own indoor microclimates and provide comfortable living environments using natural and climate-responsive strategies. They are the cleanest shelter structure that responds to the surrounding ecosystem and climate. During their evolution, communities relied on readily available natural resources and combined local knowledge with some imported technologies to construct their homes. These vernacular buildings are mostly naturally conditioned and their thermal performance is supported by both passive design features and user adaptation. Although, vernacular buildings perform well (Shaeri et al., 2018), they also have some shortcomings. Thermally adopted building has a limitation of heat exchange between indoor and outdoor through cracks and gaps in the wall and openings (Karn et al., 2022).

Globally, a substantial body of research has examined naturally ventilated spaces. For example, a study of classrooms in India was investigated (Singh et al., 2017). The study shows that 80% of the students experienced thermal comfort in naturally ventilated conditions. Rijal studied the thermal adaptation among residents and their

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*Corresponding author: Sampurna Maharjan
Khwopa Engineering College, Bhaktapur, Nepal
Email:sampurnamaharjan2001@gmail.com
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dwellings in the cold regions of Nepal, demonstrating the thermal satisfaction of the users. Similarly, (Fernandes et al., 2017) Studied vernacular earthen buildings in Egypt and Portugal, finding that the occupants reported satisfactory thermal conditions inside the buildings. This observation in Gurjakhani was conducted to assess the indoor living environment of local dwellings and evaluate their thermal performance in comparison with the thermal comfort standards outlined in ASHRAE- ("Thermal Environmental Conditions for Human Occupancy", 2017).

2. The site and the buildings

Gurja village is located in the northwestern part of Myagdi district in Gandaki Province. This rural settlement, situated at an attitude of 2638 m on the route to Gurja Himal, lies about 3800m northeast of the Dhorpatan Hunting reserve. The village is mainly inhabited by the Chhantyal community, with smaller populations of Vishwokarma and Pariyar communities. At present, there are about 200 houses. For this study, three houses were selected: those of Kali Chhantyal (A), Kamara B. K. (B) and Faram Bahadur B.K. (C). These houses were chosen based on characteristics such as number of floors, orientation and household occupancy.

Figure 1. Gurjakhani Settlement with the selected houses.

2.1. House of Kali Chhantyal (No. 'A'):

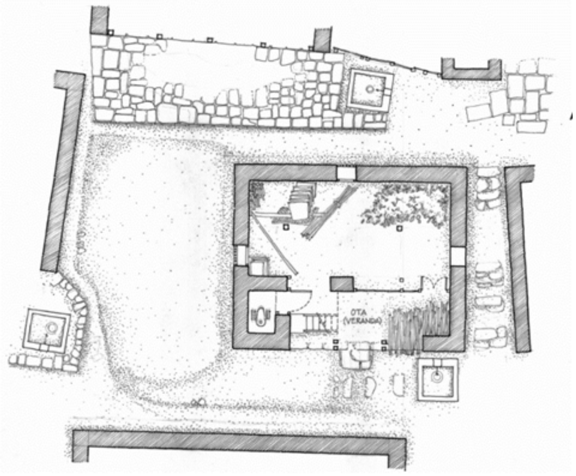
House (A) is a three-storey structure located near the center of the settlement as shown in Fig. 1. The building is constructed primarily with stone, mud and timber. The main entrance faces south and is accessed through a staircase in the front veranda. The ground floor consists of the front veranda (Ota) and a store room, both extending from east to west. The first floor features a south- facing veranda called 'Kausi', which provides access to two rooms on the north side. The northwest room serves as the main living space and contains the hearth, it functions as the living room, kitchen and bed room. The northeast room is a smaller bed room. A narrow staircase inside the main room leads to the attic which is used for storage. The common room and the bedroom are enclosed spaces with door, while the Ota and Kausi are semi open areas. A toilet has been added on the south west side of the ground floor, reflecting recent improvements commonly seen in the settlement. This semi open spaces are used for public activities and social gatherings. The main room, selected for temperature and humidity measurements are described in detail below.

- Wall: The room is constructed with 0.45 m thick stone masonry bonded with mud mortar. It has two windows on the north side. On the west side, there is a 20 mm thick timber partition measuring 3m in width and 1.2m in height. The east side has a stone wall with a window and the south side contains the entry door. The north and west exterior walls are directly exposed to the outdoor environment, while the south wall faces the kausi and the east wall adjoins a bedroom that was added later. The interior wall surfaces are finished with a mud plaster less than 10 mm thick. The floor to ceiling height is 1.95 m and the room contains small windows that provide light and ventilation.
- Floor and Ceiling: The floor is constructed using timber beams placed over timber joist; locally known as 'chirpat'. A compacted soil layer, at least 100 mm thick is placed on top of the chirpat. The floor to ceiling height is 1.9m. The ceiling is also made of timber and soil in a manner similar to the floor. A hearth is located near the center of the room. The ceiling includes an opening that provides access to the attic, measuring approximately 0.6 m by 1.15m.
- Door and Windows: The main entrance to the common room is on the south side and is reached from the first-floor veranda (kausi). The main entry door is 1m wide and 1.7m high. The north façade has two windows, one is 0.64 m wide and 0.84 m high and the other is 1m wide and 0.64 m high. On the east side, there is a window measuring 1.1m in height and 1.21m in width, which is currently used as an internal partition to the extended bedroom on that side. All doors and windows are made of single wooden planks, 20 mm thick. When closed, they block most natural light from entering the room.

2.2. House of Kamara B.K. (No. 'B'):

House (B) is located in the southwest quadrant of Gurja village. Fig. 4 shows its exterior. The main construction

Figure 2. House of Kali Chhantyal



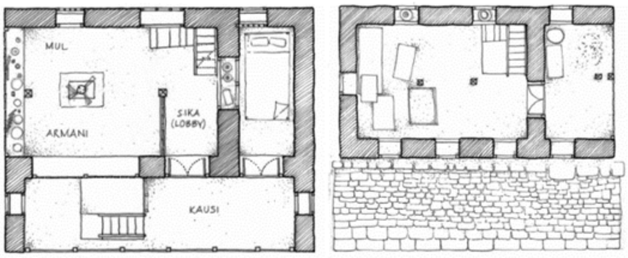


Figure 3. Floor plans of house of Kali Chhantyal

materials are stone, timber, mud and slate. It is a two-storied structure. The ground floor has a main room with hearth which functions as kitchen, living area and bedroom. A veranda is located on the south side, and the main entrance is also oriented to the south. Both verandas have now been enclosed with timber partitions and are currently used as extended bedrooms. Access to the first floor is through a narrow staircase, 600 mm wide, from the main room. The upper floor is used for storage. Fig. 5 shows the floor plan and functional layout of this house. Following are the details of the selected room used for the observation.

- Wall: The room measures 3.23 m in length and 2.54 m in width. The stone masonry walls on the north and west sides are 0.4 m thick. On the east side, a 20 mm thick timber partition separates this room from Ram Prasad's unit. On the south side, another timber partition separated the room from the veranda. The southern veranda is divided into an entry area and an extended bedroom. Of the four walls, only the north wall is directly exposed to the outdoors. Fig. 5 shows the spatial layout of both floors.

- Floor and Ceiling: The ground floor is made of compacted soil surface and the ceiling is constructed using timber structural members. A primary beam spans between the end walls and is supported at mid span by a timber column. Closely spaced joists are places above the main beam, followed by a 50 mm clay topping layer. The total floor to ceiling height is 2 m.

- Doors and Windows: The north wall contains a small window measuring 0.65m x 0.85m, fitted with two timber panel shutters. This is the only effective source of natural light for the room. A similar window exists on the west wall, but since it opens into an adjoining bedroom, it remains closed for most of the year. The main door is located on the south side and measures 0.85 m in width and 1.45 m in height. The door leaves are constructed from two timber planks, each 20mm thick.

Figure 4. House of Kamara B.K.

2.3. House of Faram B.K (No. 'C')

This house (C) is constructed using materials similar to those of the other houses. It is located in the same cluster as House 'B' sharing the same street. The entrance faces east and opens onto a veranda (Ota). From the veranda there is direct access to a small shop area. The main room containing the hearth is separated from shop by a timber partition. To the south is a storage or utility room, which was originally part of the veranda but later enclosed to form an interior space. The upper floor is accessed from both the main hall and the storage room via narrow staircase. The extended southern space is currently used as bedroom while the upper floor above the main room functions as a storage area. Fig. 6 shows the exterior of the house. The details of the selected room for observation are as follows:

- Wall: The observed room measures 2.94 m in length and 2.83 m in width. The stone masonry walls are 0.45m thick. Among the four walls, only the

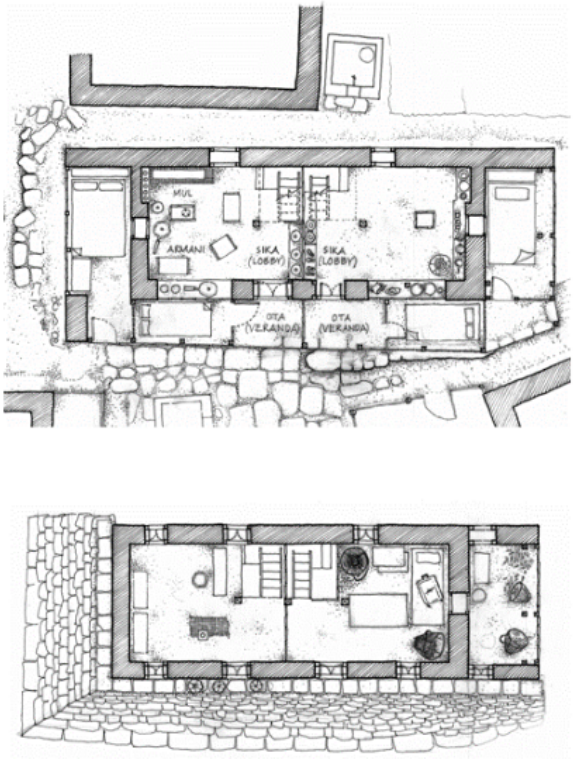


Figure 5. Floor Plans of Kamara B.K.

north and west walls are exposed to the outdoor environment. The south wall consists of two doors, a timber partition and 1.1 m long section of stone masonry wall. The west wall separates the room from the veranda while the east wall is a 20 mm thick timber partition composed of panel boards, separating the room from the adjoining shop. Fig. 7 illustrates the spatial configuration of the room.

- Floor and Ceiling: The floor and ceiling construction follow the same construction system used in House B of Kamara Bika. The only differences are the room dimensions and the floor to ceiling height which is 1.95 in this case.
- Door and Windows: The main room is entered through an east facing door measuring 1m in width and 1.35m in height. The south wall contains two additional doors each 0.9 m wide and 1.45 m high, fitted with timber panel shutters. The north wall includes a window measuring 0.87m in width and 1.2 m in height.

3. Methodology

The study was conducted in October 2024 AD corresponding to the transitional period between summer and winter. During the observation period, the weather was predominantly overcast, with an average of approximately two hours of daily sunshine. To assess the adaptive thermal comfort of the rooms under investigation, indoor and outdoor air temperatures and relative humidity were measured using HTC-2 device. Surface temperatures were recorded with an ST580C infrared thermometer. Additionally, a ten-year (2011–2020) climatic dataset was obtained from an online source (Weatherandclimate, 2025). Using this data, the mean radiant temperature (MRT) and operative temperature were calculated using the following formulae:

Figure 6. House of Faram B. K.

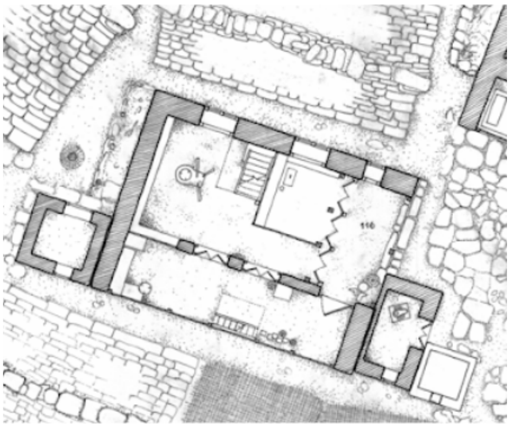


Figure 7. Floor plan of Faram B.K.

$$\mathrm{MRT} = \frac{\sum (T_i \times F_i)}{\sum F_i} \tag{1}$$

where MRT is the mean radiant temperature, T_i is the temperature of the surface in °C, and F_i is the factor of the surface. A value of $F_i = 0.3$ was assigned for walls, indicating that walls receive 30% of the radiation emitted by other surfaces, while a value of $F_i = 0.2$ was used for the ceiling and floor, considering that 20% of the radiation is received by the respective surfaces emitted by other surfaces in the room.

$$T_o = \frac{\mathrm{MRT} + \left(T_a \times \sqrt{10v}\right)}{1 + \sqrt{10v}} \tag{2}$$

where T_o is the operative temperature, T_a is the air temperature, and v is the air velocity. The collected data were subsequently analyzed to evaluate the adaptive thermal comfort of the occupants using the CBE adaptive thermal comfort tool for “Thermal Environmental Conditions for Human Occupancy” (2017). This tool is suitable for naturally ventilated, occupant-controlled spaces, with metabolic rates ranging from 1 to 1.3 met. This indicates that the occupants are in sitting position and engage in minimal physical activity. Thermal adaptation by occupants was assumed to occur solely through clothing, with insulation levels ranging from 0.5 to 1 clo., the value corresponding to wearing a normal jacket. The results were interpreted in relation to the thermal properties of the wall, floor and ceiling construction techniques (See Fig. 9).

Figure 8. HTC-2 and Infrared instruments

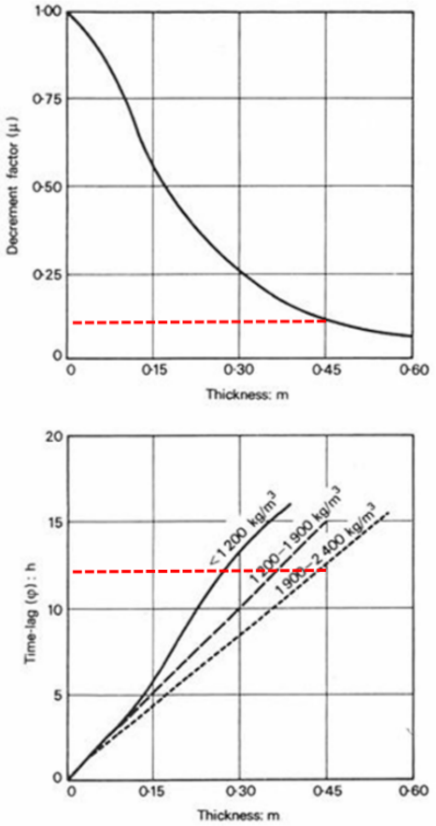


Figure 9. Decrement Factor and Time Lag Factor for Massive Walls (Koenigsberger)

4. Results and Discussion

During the study period, the residence of Kali Chhantyal was unoccupied, whereas the dwellings of Faram Bahadur and Kamara B.K. were actively occupied. Following, Table 1, is the summary of the field data along with the adaptive thermal comfort assessment generated using the CBE tool.

According to the data, House ‘C’ maintains thermally comfortable indoor conditions during the evening, while House A and B exhibit consistently lower temperatures throughout the day. Due to the unoccupied status of House A, no indoor activity occurred during the measurement period. The results show lower indoor air temperature (14.1 °C at 12 noon) compared to outdoor (17.3 °C at 12 noon), which has direct impact on indoor operative temperatures. Hence, creating a cold indoor environment for any potential occupants at all times of the day. House ‘B’ was occupied, however, the indoor environment remained cold throughout the day. The dwelling featured a hearth, which was utilized twice daily at 8:00 am and between 4-5pm.The hearth increased the indoor air temperature by approximately 4°C above the corresponding outdoor temperature. Despite this, the room’s operative temperature did not show a significant rise, likely due to heat losses through relatively large windows and doors, as well as by the open staircase connecting to the first-floor storage room, which facilitated the dissipation of heat generated during cooking. House ‘C’ exhibited slightly different thermal behavior compared to the other houses. This room also contained a hearth which was used for cooking in the morning and evening. The indoor environment remained cold during the morning but reached comfortable conditions in the evening. The morning cold conditions are comparable to those observed in House B, likely influenced by rainfall on that day, which caused the occupants to remain indoors for an extended period. The use of the hearth during this time contributed to indoor heat gain. As a result, adaptive thermal comfort was achieved only in the evening. The outdoor air temperature remained below the thermal comfort range (20°C - 27°C) as suggested by Olgay brothers. Additionally, the insulative properties of stone wall 450 mm thick masonry with U-value of 2.4 W/m^2 °C, timber panel of 20 mm thick with U-value of 0.33 W/m^2 °C and soil floor having U-value of 0.6 W/m^2 °C on timber battens, limited the heat flow in and out of the structure. The walls exhibited a time lag of approximately 12 hours, significantly delaying heat penetration from one surface to the other. Hence, indoor air temperatures remained consistently lower than outdoor air temperatures throughout most of the year, with notable influence during colder seasons and under wind exposure. During the summer season, the room likely provided a naturally cool indoor environment. However, during the

Table 1. Measured Indoor, Outdoor, and Operative Temperatures with CBE Comfort Evaluation

House	**Time**	$\mathbf{T}_{in}$ (°C)	$\mathbf{T}_{out}$ (°C)	$\mathbf{T}_{op}$ (°C)	**CBE**
House A	10	13.3	15.3	13.00	Too cool
	11	13.8	17.1	13.41	Too cool
	12	14.1	17.3	12.61	Too cool
	1	14.1	17.7	9.47	Too cool
	2	14.4	17.1	9.60	Too cool
	3	14.3	15.8	9.94	Too cool
	4	14.3	14.6	9.24	Too cool
	5	13.8	13.5	10.89	Too cool
House B	9	17.6	14.4	17.67	Too cool
	10	18.4	16.0	18.32	Too cool
	11	18.3	16.6	18.04	Too cool
	12	18.0	16.5	17.95	Too cool
	1	17.2	15.3	16.93	Too cool
	2	16.6	14.5	16.31	Too cool
	3	16.1	14.9	15.96	Too cool
	4	16.7	14.6	16.65	Too cool
House C	9	18.2	16.6	17.92	Too cool
	10	18.0	16.3	18.04	Too cool
	11	17.6	17.0	17.69	Too cool
	12	17.5	17.1	17.34	Too cool
	1	17.1	15.5	17.20	Too cool
	2	16.6	14.6	16.56	Too cool
	3	16.5	13.5	16.10	Too cool
	4	20.1	14.4	20.14	Comfortable
	5	19.5	12.5	19.33	Comfortable

intermediate and winter periods, supplemental heating was necessary to mitigate cold conditions. This explains the observed attainment of thermal comfort in the evening in House ‘C’.

5. Conclusion

In October, the primary living spaces of the vernacular houses exhibit low indoor temperatures, indicating that supplemental heat input is necessary from morning to evening to achieve a comfortable operative temperature. From a heat gain perspective, the compact spatial configuration, high wall to opening ratio, openings with blank timber planks, front verandas and insulative nature of construction materials indicates that the buildings are independent of outdoor temperature for indoor heating. From the perspective of heat loss, local wind measurements indicate predominantly gentle breezes with an average wind speed of 2.1kmh (0.58 m/s) in year 2020 AD and 8.6 kmh (2.38 m/s) in March (Weatherandclimate, 2025). This means that heat loss due to wind is minimal. Also, the heat influx through the building envelope is also negligible, with only potential losses occurring through gaps and cracks between walls and openings, or within the members of the openings. Comparing indoor and outdoor air temperatures of occupied houses ‘B’ and ‘C’, indoor air temperature is 2°C - 3°C higher than the outdoor, indicating that presence of occupants and use of hearth contributes to marginally elevated indoor temperatures. In contrast, in unoccupied House ‘A’, the indoor temperature is lower than the outdoor temperature. In conclusion, vernacular houses in Gurjakhani are designed to retain internal heat gains effectively. Construction materials and spatial configuration are optimized to minimize heat loss from the primary living spaces. There is potential to further optimize house design to enhance passive heat gain from outdoor conditions thereby increasing the indoor operative temperature.

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