The Role of Vernacular Practices in the Mitigation of Impact of Climate: Insights from the Vernacular Settlement of Guledgudda in India.

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Abstract

Vernacular architecture depicts the relationship between natural and manmade environments, which have evolved from their roots in climate and culture. Vernacular buildings link people and the environment through indigenous knowledge and values. They integrate local building traditions, passive design strategies, and community involvement to address the human needs of respective climatic conditions. However, technological developments and globalisation have resulted in contemporary designs that strongly impact the environment in terms of increased carbon footprint. For these, there is much to be learnt from the vernacular settlements.

In this context, this study investigates the climatic solutions used in vernacular architecture that provide thermal comfort conditions and sustainability. It employs case study method and analyses the vernacular typologies in Guledgudda, a weaver's town of Bagalkot district in North Karnataka, India. The study examines documentation of residential types and generates data through onsite field studies, observations and interviews of the residents. The buildings are analysed to ascertain the effective passive cooling techniques for preventing heat gain, heat dissipation, and heat modulation. For this, it uses simulations in Design Builder software.

The findings reveal the relationship between passive design strategies that involve shared walls which promote sustainable living environments in Guledgudda. Many other strategies also contribute. They are: passive design strategies using design elements like courtyards, thermal mass of thicker walls, shared walls, positioning of fenestration, wall-to-windows adding up to the first floor, and excessive parapet heights. The research thus concludes that they collectively contribute to creating comfortable living environments, reducing heat gain and dissipation. These passive design strategies in in built forms can enhance thermal comfort conditions.

Keywords: Vernacular architecture, Passive design strategies, Thermal comfort, Simulation, Design Builder Software.

Introduction

Communities around the world are currently grappling with the profound challenges brought about by the escalating impact of climate change, particularly in tropical regions like India. The effects of rising temperatures and extreme weather events are keenly felt, shaping the environmental, social, and economic landscapes in tangible ways. In fact, there has been an increase of about 0.7°C average temperature in India since 1901, and projections suggest further rises of 1.2°C to 3.5°C by 2050 (Ravindra et al., 2024), varying based on local climate conditions and human activities. There is an increase in the occurrence and intensity of heat waves, posing health and societal concerns for the global population. The importance of traditional architecture becomes even more apparent as temperatures rise. In this context, employing traditional building techniques can affect energy consumption by using locally sourced and minimally processed materials.

According to Baohua Wen et al. (2023) vernacular architecture is a significant artificial habitat landscape evolving with and responding to specific natural and social contexts. It is different from "formal architecture," which is dominated by architects. In fact, Oliver (1997) points out that it is often referred to as a living fossil of human habitation due to its anonymity, primitivity, and reflections of folk. This distinguished architecture is known for its effective thermal comfort conditions, making it sustainable and energy efficient (Michael, Demosthenous, and Philokyprou, 2017).

Rapid urbanisation, population growth, and improved living standards have led to tremendous societal changes, especially in developing countries (Mazraeh and Pazhouhanfar, 2018). Technology development has led to increased energy consumption, ignoring traditional building construction techniques. The loss of local building culture has diminished the aesthetic and cultural richness of communities and has intensified environmental challenges. As one of the leading carbon emitters, the building construction sector faces scrutiny for its environmental impact (Labaran, Mathur and Farouq, 2021). Unfortunately however, traditional regional culture and historical memory are slowly disappearing. Nevertheless, there is excellent scope for the resilience of vernacular architecture and cultural landscapes in the current context of climate change (Ausiello et al., 2020).

In this context, traditional building methods that have evolved over centuries present valuable alternatives. Therefore, studying vernacular architecture is a significant for understanding the traditional knowledge systems applied in built environmental design to regulate indoor thermal comfort through passive strategies (Yang, 2023). Indeed, the indigenous knowledge of vernacular architecture principles offers valuable insights into the design of contemporary buildings. It will help reduce dependency on energy to achieve thermal comfort. Though vernacular buildings are considered suitable and sustainable, more must be done to incorporate them as standard practice in contemporary buildings due to indifference and ignorance (Wahid, 2012). Thus, there is a need to examine the passive design strategies employed in vernacular architecture. This research aims to explore the strategies adopted in creating thermal comfort in vernacular settings. It focuses on traditional types of dwellings in Guledgudda in North Karnataka, India. Its objectives are:

The objectives of the study are:

1. To analyse the efficiency of a wall in heat gain, dissipation, and modulation
2. To identify the strategies adopted in creating thermal comfort in vernacular setting
3. To reveal the ways in which vernacular settlements use materials, form, and fenestration for preventing heat gain, heat dissipation, and heat modulation for climate response and energy efficiency.
4. To articulate vernacular principles and strategies that can be adopted for contemporary situations.

The study brings to light the thermal comfort properties in the vernacular houses of Guledgudda in terms of three passive cooling techniques: prevention of heat gain, heat dissipation, and heat modulation.

Review of Literature

Research on vernacular architecture has extended from humanities to hard sciences (Benkari et al., 2021). According to Alexander (1997), vernacular architecture is unique to each region, portraying the people's daily lives and activities. It is an essential heritage representing the harmony of the natural environment and architecture that reflects peoples' traditions, needs, and future expectations (Benslimane and Biara, 2019). In fact, the vernacular typologies of a region demonstrate the locally adapted approaches to readily available building materials, offering comfort in the local climate with the optimisation of the structural system (Bodach, Lang, and Hamhaber, 2014).

The origin of vernacular architecture can be traced back to prehistoric civilisations that developed the earliest dwelling types such as huts, caves, tents, shielings, and more. These were built primarily to provide shelter from the natural conditions and for safety against wild animals. These primitive architectural structures have been inspired by Nature and borrowed ideas from bird's nests and lairs of the beasts, beginning with twigs and tree branches covered with mud. In simple terms, vernacular architecture can be defined as the 'native science of building' (Oliver, 1997). Rapoport (1969) discusses vernacular architecture as a folk tradition or oral knowledge passed down from generations that physically manifest social, cultural, economic, and religious belief systems of a particular community.

Climatic conditions of a region play a vital role in the spatial organisation and design approach of any vernacular building. In fact, they determine the construction techniques and materials to be used (Motealleh, Zolfaghari & Parsaee, 2016). One of the primary features of vernacular architecture is its ability to control the micro-climatic conditions within a space, like thermal comfort, heat dissipation, temperature regulation and energy performance. For instance, research by Dilli, Naseer, and Zacharia (2011) on traditional architecture of Kerala demonstrates that the widespread use of modular construction, internal open courtyards aligned with ancient geometrical grids, appropriate proportions and scale, verandas, building orientation, organisation of internal spaces, and the utilisation of local materials and specialised construction techniques contribute to the creation of a comfortable indoor environments in houses without the need for external energy equipment.

Similar research carried out by Ngyuen, Tran, and Reiter (2011) proves that the climate-responsive design principles embedded in vernacular architecture of Vietnam demonstrate that the design features, spatial organisation, and building physics of vernacular houses are exceptionally well-suited to the local climate, resulting in the natural maintenance of indoor thermal comfort. As a responsive solution, vernacular architecture is a significant factor in achieving sustainability and sustainable development.

Therefore, adopting vernacular principles in the development of cities could be an excellent way to reduce energy consumption. Thappa, Sharma, and Kumar explore several dimensions of sustainability, such as "environmental sustainability, socio-cultural sustainability, and socio-economic sustainability," with a comparative study of Turkish and Indian typologies. Globalisation, the availability of new materials, and changes in socio-cultural and economic conditions have triggered transformations in Vernacular architecture. According to Verma, Kamal and Brar (2022), traditional buildings are more efficient than contemporary buildings. In fact, the transformation rate could be faster in rural areas compared to urban areas (Jagatramka, Kumar & Pipralia. 2021).

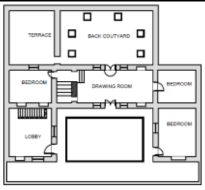
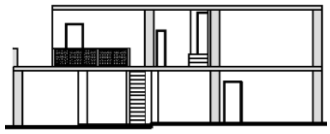
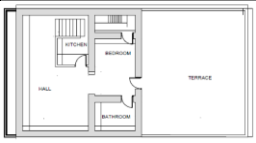
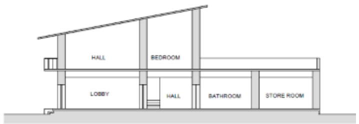
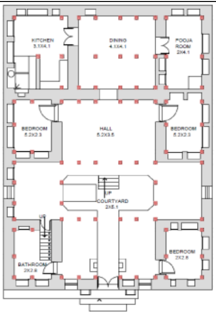
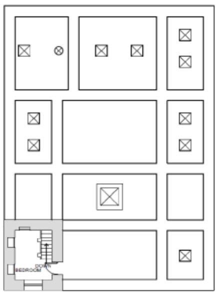
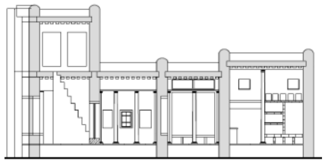
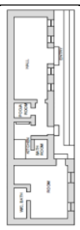
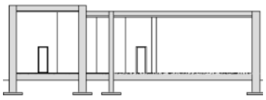
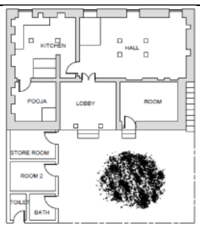
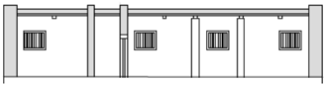
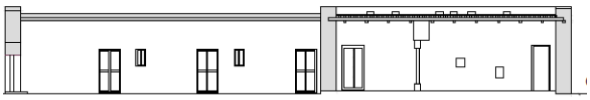
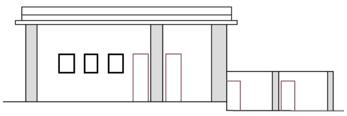
Research Methodology

This research adopted case study method employing qualitative, quantitative, techniques for data gathering. Qualitative data collection and desk-based research assisted the initial idea and background research to understand vernacular architecture and its role in mitigating the impacts of climate through online resources and research papers. Interpretive, theoretical, and statutory frameworks were then used for the analysis that informed the research questions. Existing literature was critically reviewed based on the above subject to derive a comprehensive list of parameters for the study and analysis.

Table 1: Details of the Vernacular Types considered for study
Source: Author

Types	A	B	C	D	E	F	G
Plan Form	Type with a Courtyard. Square plan with a completely open courtyard.	Inward-looking rectangular plan form.	Typology with a rectangular semi-open Courtyard.	Rectangular plan without courtyard.	Square plan (L-shaped plan) with an adjoining open space.	Rectangular plan (L-shape) with an adjacent space.	Square plan (L-shaped plan) with an adjoining open space.
Orientation	North-South	East-West	North-South	North-South	North-South	East-West	East-West
Entry to Building	North; through Courtyard	West	South	East	North	East	West
Number of Floors	2 (G+1)	2 (G+1)	2 (G+1)	1 (G)	1 (G)	1 (G)	1 (G)
Types of Spaces	Living room, kitchen, Pooja room, sit-out, 3 bedrooms (all the bedrooms are located on the FF), bathrooms, weaving and storage area in the GF.	Living room, kitchen, 2 bedrooms, 1 bathroom, shops and storage in the ground floor.	Living room, kitchen, Pooja room, dining, 4 bedrooms and bathrooms.	Living room, kitchen, 1 bedrooms and 1 bathroom	Living room, kitchen, 1 bedrooms and 1 bathroom	Living room, kitchen, 4 bedrooms and bathrooms.	Living room, kitchen, bathroom, store room.
Shared Walls	On 3 sides: East, South and West	On 3 sides: North, East and South	On 1 side: South	On 3 sides: North, South and West	On 2 sides: East and West	On 2 sides: North and South	On 2 sides: North and South
Roofing System	Madras Terrace Roof in GF and FF	Madras Terrace Roof	Madras Terrace Roof in GF and FF	Madras Terrace Roof	Madras Terrace Roof	Madras Terrace Roof	Madras Terrace Roof
Roof Vents	Yes	No	No	No	No	Yes	No
Fenestrations	Doors and windows from the courtyard	Door from the street, no windows	Windows on North, East and West walls	Windows on the East wall	Windows on the South wall, Courtyard on the North side with no windows	Windows on East and West walls	Windows on East and West walls
Window-to-Wall Ratio	6.52 for walls in the courtyard	----------	East wall: 0.86 North wall: 2.4 West wall: 0.86	East wall: 2.64	South wall: 7.58	East wall: 3.05 West wall: 2.36	East wall: 8.86 West wall: 3.03

Table 2: Plan and Sections of the Vernacular Typologies considered for study
Source: Author

Typology	Plan forms
A	  
B	  
C	  
D	 
E	 
F	 
G	 

A weavers' settlement, "Guledgudda," in the Bagalkot district of North Karnataka, India, was identified as a case study, to gain an in-depth understanding based on the list of parameters. An integrated exploration that included thorough field studies, in-depth interviews and surveys with residents and detailed documentation of residential types was undertaken with the architecture students from the fifth semester of their Bachelor of Architecture degree at KLE Technological University. Sixteen vernacular houses were measured and drawn to develop plans, sections, elevations, views, and details. These houses were categorised into groups based on plan types, spatial planning, local materials, traditional construction techniques, and roofing systems.

The analysis of a vernacular type is conducted through digital simulation using a graphical user interface (GUI) tool for building energy modelling in the DesignBuilder software. DesignBuilder is an energy simulation software widely used to design and optimise buildings for energy efficiency, thermal comfort, and environmental performance. One of the strengths of the DesignBuilder software is that it supports an iterative design process. After running a simulation and reviewing the results, changes can be made to the building design (such as adjusting materials, optimising form, changing windows, or improving ventilation) and the simulation to see the effects. This helps in refining the design for better performance. DesignBuilder uses real-world weather files (EPW files) (e.g., hourly temperature, humidity, solar radiation, wind speed) for the building's location. The weather file in EPW (EnergyPlus Weather) format of Bagalkot is used for climate data, which is approximately 20km from Guledgudda. The EPW file used has historical data from 2009-2023, which contains all the values for the microclimate averaged out from 2009-2023. The simulation is performed for one year as a pilot study to analyse the passive design strategies in the vernacular typologies of Guledgudda.

Area of Study: Guledgudda

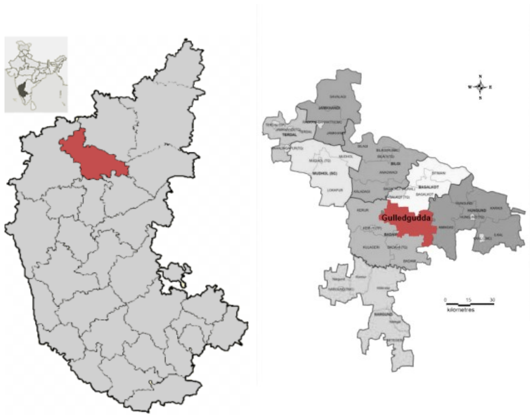


Fig. 1: District map of Bagalkot highlighting, Guledgudda; Maps of District | Bagalkote District | India
Source: https://bagalkot.nic.in/en/map-of-district/ (accessed 23 Sept 2024)

Guledagudda is a taluka in the Bagalkot district of Karnataka state in India, which is famous for its traditional Guledagudda Khana, a blouse piece. It is the only cluster in India making traditional blouse fabric with a GI tag. The Guledgudda Khana is often paired with Ilkal Sari in the Northern part of Karnataka and Maharashtra. Guledagudda is geographically located within proximity of 30 km distance by road to the historical sites of Aihole, the rock-cut caves of Badami, and the UNESCO world heritage site of the Group of Monuments at Pattadakal. The origination of Guledgudda dates back to 1580, during the regime of the second Ibrahim Adilshahi of Bijapur, by building a fort around the hill. The uphill dwellers migrated to the down around 105, known as a place of migration; Gule means migration, and Gudda means hill, hence the name Guledagudda. The town has the best sources of water reservoirs for cultivation, with 80% of the population involved in weaving arts and special techniques of cotton processing. People of different castes weave more than 3.5 lakh blouses yearly on 2000 power looms, 3000 handlooms, and 42 twisting factories in Guledagudda (Mane and Maligi, 2023).

Fig. 2: Types of houses along the street in Guledgudda
Source: Authors, 06 Oct 2023

The built fabric of Guledgudda is characterised by low rise and low density, with refined grains of vernacular houses and shared walls as a response to hot and dry microclimatic conditions. These vernacular houses are living canvases seamlessly blending functionality with local context and cultural nuances. The vernacular typologies are characterised mainly by a wooden structural system of posts and lintels with massive external stone masonry of 350-450 mm thick, often exposed, or sometimes brick masonry walls with mud plaster, which serve as a thermal mass to reduce heat gain. The minimum fenestrations to the exterior walls and courtyards facilitate ventilation to the interior of the houses, reducing solar heat gain. The roofs are flat terraces with roof vents made of wooden beams with mud, leaves, and lime mortar to impart strength and insulation to the structure.

The study of vernacular types of Guledgudda provides insight into climate-responsive and sustainable strategies that have evolved over the ages through collective wisdom. Investigating vernacular construction techniques and using materials in changing economic conditions can guide the construction of new buildings. Incorporating these passive design strategies rooted in vernacular practices can help buildings achieve improved thermal comfort and energy efficiency, reducing the construction industry's impact on the environment and contributing to the reliance on buildings and communities in the face of climate change.

The district of Bagalkote is located on the branch of River Ghataprabha. Its land mass is part of the Deccan Plateau; it is positioned at 16°12′N 75°45′E and covers an area of 6593 km² (Shruti, Gouda, and Rao, 2017). The average elevation in this area reaches approximately 610 m. The climate in Bagalkote is warm and dry throughout, with scarce rainfall—the district's semi-arid climate limits ample canopy vegetation. Majorly, three non-perennial rivers flow through the district, namely, Krishna, Gataprabha and Malaprabha.

Soil is composed of two compositions - mainly black and otherwise red. This region's hot and dry climate makes it susceptible to drought and crop failure, leading to residents opting for alternative livelihoods like weaving in Guledgudda. Guledgudda, a village on a hill, receives an average rainfall of 562mm, about 40 per cent of it during the southwest monsoon period from June to September.

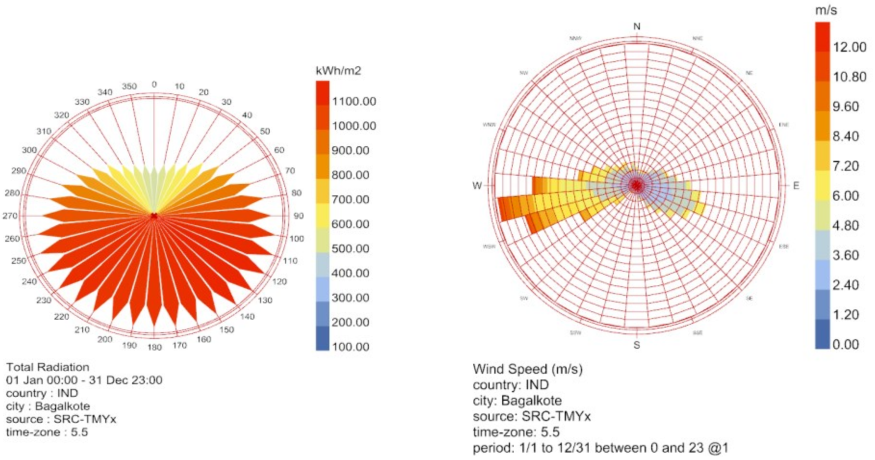


Fig. 3: Climate data of Bagalkot, Karnataka, India
Source: The EPW file is climate.onebuilding.org, and the software used is Rhino. (accessed 9.23.24)

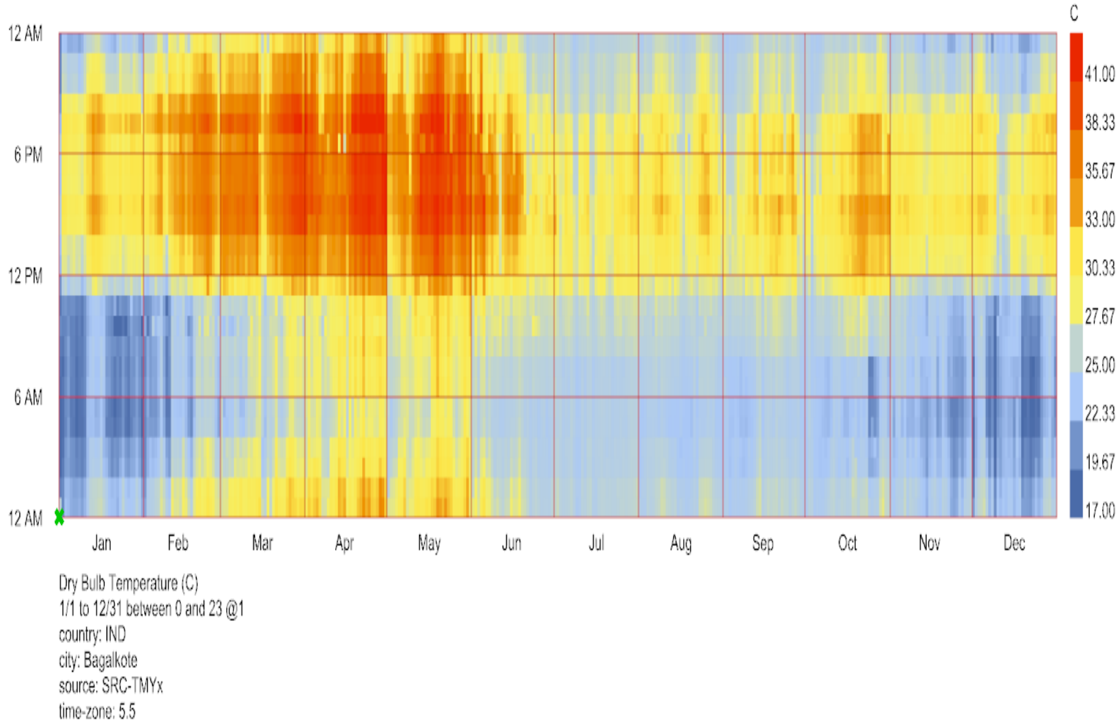


Fig. 4: Dry bulb temperature of Bagalkot, Karnataka, India
Source: The EPW file is climate.onebuilding.org, and the software used is Rhino. (accessed 9.23.24)

Findings and Discussion

The digital simulations of typologies analyse passive design strategies by studying the performance of walls in terms of U and R values, the difference in internal and external temperatures, radiant and operative temperatures during summer and winter with and without shared walls, Predicted Mean Value (PMV). The typical features of vernacular typologies in Guledgudda considered for digital simulation are Stone Masonry with mud or lime plaster, timber structural system of post and lintel, Madras terrace roofing and Cuddapah flooring.

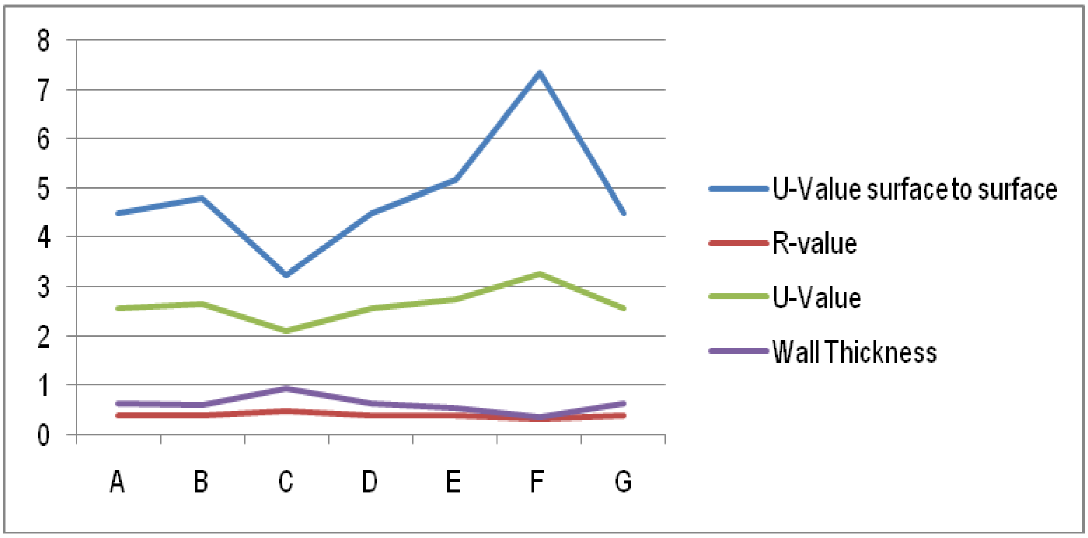


Fig. 5: Performance of wall thickness in terms of U-value and R-value
Source: Author

The results from Figure 5 indicate that typology C, having a wall thickness of 0.94m, provides maximum thermal resistance for heat gain and heat dissipation through thermal mass. The surface-to-surface U value of Typology C is the lowest compared with other typologies, indicating that an increase in thermal mass minimises heat gain and dissipation. Though the wall-to-window ratio (WWR) of Typology C is less than that of other typologies, the wall's thermal mass plays a significant role in preventing heat gain, heat dissipation, and modulation of heat. Typology A, having a courtyard, provides lesser resistance than Typology C because of lesser wall thickness.

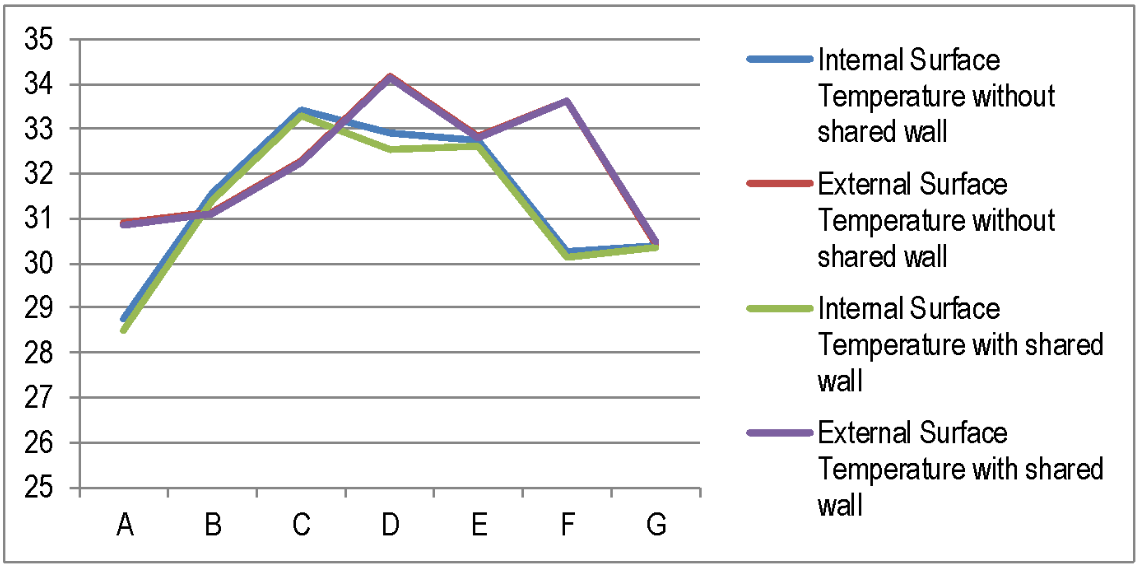


Fig. 6: Internal and external surface temperature during summer
Source: Author

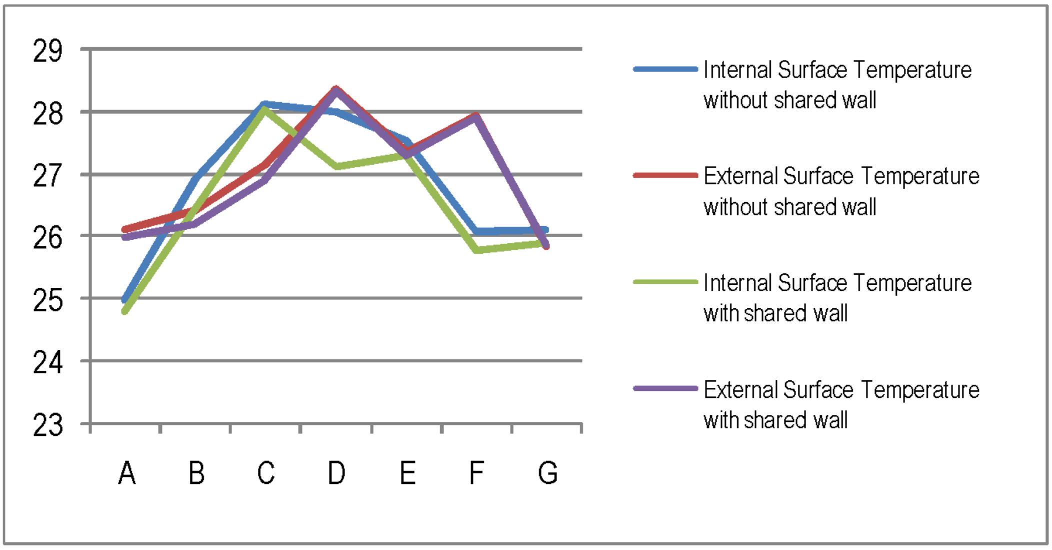


Fig. 7: Internal and external surface temperature during winter
Source: Author

Table 3 shows that the internal surface temperature is lesser than the eternal surface temperature, varying for typologies by less than 1-degree centigrade during summer and winter. In summer (Figure 6), the Internal Surface Temperature with shared walls is less than 0.1 degrees centigrade if the typologies are not sharing the walls because of thicker walls, roof vents, and orientation. The internal Surface difference with and without a shared wall is maximum for Typology D with 0.41degree centigrade due to sharing the walls on three sides. In winter (Figure 7), the internal surface temperature difference for all typologies except G is less than 0.5 degrees centigrade. For typology F, the internal surface temperature difference with and without a shared wall in winter is 1.7 degrees centigrade due to the orientation of the East-West axis with shared walls on the North and South sides, though WWR is more.

Table 3: Internal and external surface temperature analysis during summer and winter
Source: Author

Type	Internal Surface Temperature without shared wall during summer	External Surface Temperature without shared wall during summer	Internal Surface Temperature with shared wall during summer	External Surface Temperature with shared wall during summer	Internal Surface Temperature without shared wall during winter	External Surface Temperature without shared wall during winter	Internal Surface Temperature with shared wall during winter	External Surface Temperature with shared wall during winter
A	28.76	30.88	28.51	30.84	24.98	26.1	24.8	26.0
B	31.57	31.13	31.4	31.1	26.91	26.42	26.45	26.2
C	33.42	32.26	33.28	32.23	28.12	27.15	28.02	26.9
D	32.93	34.17	32.52	34.11	28.01	28.37	27.11	28.33
E	32.73	32.81	32.6	32.8	27.53	27.35	27.3	27.31
F	30.28	33.64	30.15	33.62	26.08	27.95	25.78	27.9
G	30.4	30.41	30.35	30.48	26.1	25.84	25.9	25.87

Figure 8 and Table 4 show that the annual average predicted mean value (PMV) for shared walls is less than the values for those without shared walls. The difference in the average PMV for shared and without shared walls varies up to 0.148, with a maximum difference for Typology D during summer and a maximum difference of 0.139 for Typology B in winter. Typology A, having a courtyard, shared walls on two sides, roof vents, and thicker walls, has the lowest Average PMV.

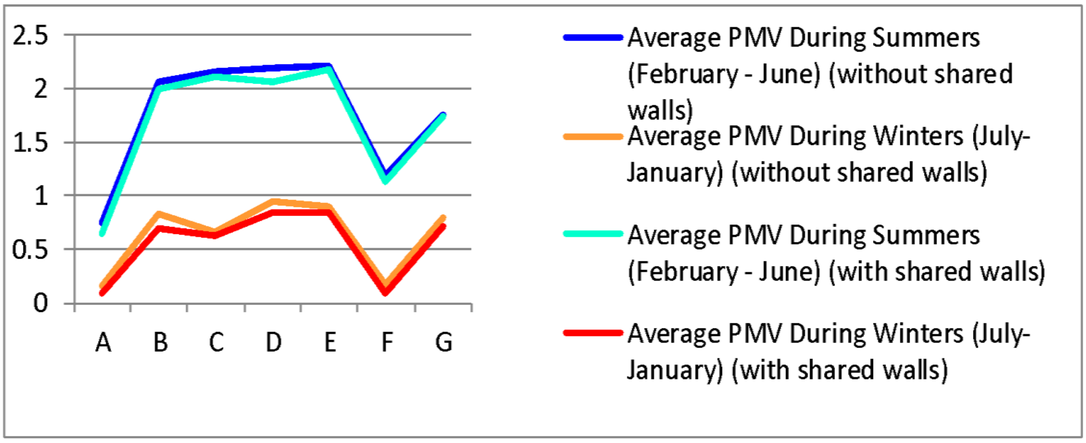


Fig. 8: Average PMV Analysis
Source: Author

Table 4: Average PMV values
Source: Author

Type	Average PMV During Summers (February - June) (without shared walls)	Average PMV During Winters (July-January) (without shared walls)	Average PMV During Summers (February - June) (with shared walls)	Average PMV During Winters (July-January) (with shared walls)
A	0.741	0.159	0.637	0.089
B	2.06	0.828	1.99	0.689
C	2.16	0.664	2.1	0.623
D	2.198	0.946	2.05	0.846
E	2.201	0.894	2.17	0.847
F	1.173	0.168	1.134	0.083
G	1.76	0.79	1.735	0.713

The results from Table 5 indicate that the radiant and operative temperature with shared walls is lower than those without shared walls; the difference is less than 1-degree centigrade during summer and winter. Typology A, having a courtyard and good wall-to-window ratio, has the lowest radiant and operative temperature because of the wall thickness, shared walls on three sides, roof vents, and orientation to the North.

Table 5: Radiant and Operative Temperature Analysis
Source: Author

Typology	Radiant temperature during Summers (February - June) without shared walls	Operative temperature during Summers (February - June) without shared walls	Radiant temperature during Winters (July - January) without shared walls	Operative temperature during Winters (July - January) without shared walls	Radiant temperature during Summers (February - June) with shared walls	Operative temperature during Summers (February - June) with shared walls	Radiant temperature during Winters (July - January) with shared walls	Operative temperature during Winters (July - January) with shared walls
A	26.4	26.54	23.69	23.8	26.04	26.18	23.42	23.52
B	31.6	31.57	26.97	26.96	31.37	31.34	26.43	26.43
C	33.08	32.17	27.93	27.17	32.86	31.97	27.76	27.03
D	32.52	32.18	27.84	27.5	32	31.68	27.45	27.13
E	32.71	32.44	27.6	27.4	32.56	32.31	27.28	27.11
F	29.03	29.15	25.34	25.35	28.86	29	24.94	25.02
G	30.35	30.34	26.13	26.13	30.27	30.26	25.85	25.86

Understanding the relationship between a typology's architectural design elements and thermal comfort is critical for optimal living conditions; the study also promotes sustainable building practices. The discussion synthesises findings to highlight essential factors influencing the thermal performances of the residential typologies, including layout, wall thickness, orientation, neighbouring structures, parapet walls, and roof design.

The wall thickness of residences impacts the thermal comfort of the building, thus impacting the living conditions in the house. In Guledgudda, walls are made of stone, further enhancing insulation properties. Thicker walls can reduce heat transfer, thus maintaining more stable indoor temperatures.

Conclusions

The study underscores the importance of traditional architectural practices in achieving thermal comfort in vernacular housing in Guledgudda. Passive design strategies using design elements like courtyards' thermal mass of thicker walls, shared walls, positioning of fenestration, wall-to-window ratio, adding up of the first floor, and parapet heights contribute to creating comfortable living environments, reducing heat gain and dissipation. The design of passive strategies in relationships with one another inbuilt forms can enhance thermal comfort conditions.

The research has limitations as the data in the current study is based on the field study and documentation by students reflecting specific typologies in Guledgudda, which still needs to be more accurate. In future research studies, detailed field investigations can be conducted on all the residential topologies on a more extensive scale to record architectural history that can provide references for contemporary architectural design. This study will further act as base work for future courses of action to consider vernacular principles in creating sustainable built environments. Future research should continue exploring these relationships to develop more effective passive design strategies that enhance energy efficiency while promoting sustainable living environments.

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