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An Investigative Comparison of Energy Efficiency in the Hospitality Industry: Analyzing Two Envelope Systems

[1]Ar. Shraddha Kapadia
Bharati Vidhyapeeth College of Architecture, Navi Mumbai

Abstract:- Typically, buildings are predominantly influenced by their exteriors, wherein the heat gain/loss through the envelope surpasses the internal heat generation (Givoni 1998). The building envelope's significance lies in its potential to contribute up to 73% of the total heat gain/loss (DOE 2004). Therefore, energy-efficient building envelopes can mitigate reliance on fossil fuels and minimize environmental pollution. This paper investigates the thermal performance of a hotel's envelope in Matheran concerning energy efficiency. As Matheran's tourism revolves around its pristine environment, preserving its quality necessitates environmentally sustainable development and operations. Consequently, the adoption of green measures becomes crucial, particularly in existing hotel envelopes, as new constructions are prohibited in Matheran.

To achieve this, understanding heat gain parameters based on the material characteristics of different envelopes becomes paramount. The primary objective is to conduct a comparative analysis of two distinct building envelopes within a Matheran hotel: the traditional load-bearing Laterite stone construction and the contemporary RCC framed brick structure. The aim is to identify the most energy-efficient option based on their potential for energy savings. Both envelopes undergo thermal performance simulation modeling using ECOTECT and eQUEST software. The analysis of the simulations reveals that the traditional construction's building envelope exhibits superior thermal performance, thus rendering it more energy-efficient. Furthermore, the study proposes enhancing the energy efficiency of the contemporary envelope by modifying its roof, wall, and fenestration properties. The proposed modifications are then subjected to simulation to determine their impact on thermal performance and potential for improved energy efficiency.

I. INTRODUCTION

In recent times, energy has emerged as a significant global concern due to the escalating apprehensions about CO2 and greenhouse gas emissions, coupled with the depletion of fossil fuel reserves. The hospitality industry has emerged as one of the major contributors to this predicament, primarily because of the rapid growth of tourism. The increasing number of hotels poses a considerable threat to the environment, given their energy-intensive nature. These establishments comprise various functional areas, leading to heightened energy consumption and consequent environmental degradation.

Hence, this research delves into the analysis of the thermal performance of the envelope of a hotel situated in Matheran, with a primary focus on enhancing energy efficiency. By understanding and optimizing the building envelope's thermal behavior, the aim is to mitigate the environmental impact of the hospitality sector and pave the way for a more sustainable future.

➢ *Rationale for the Study:*

In recent decades, Matheran has experienced a significant surge in tourism due to its convenient proximity to Mumbai and Pune. Despite being declared an Eco-sensitive zone (ESZ) in 2003, the number of newly constructed hotels and the conversion of local houses into home stay accommodations has risen, despite a State Government ban on new constructions. This rapid influx of tourists has strained the area's infrastructure and exacerbated the uncontrolled growth of hotels. Consequently, Matheran's ecologically fragile environment is facing increasing pressure, leading to a surge in energy demands for electricity, fuel, wood, and oils to operate these facilities.

The core of tourism in Matheran lies in its environmental appeal, necessitating the preservation of its pristine quality and attractiveness. To achieve this, there is a compelling need to promote environmentally responsible development and operations. Implementing energy consumption management measures is crucial to attain a more energy-efficient hotel operation, reduce operational costs, and enhance the overall comfort and service quality. Given the restrictions on new constructions in Matheran, focusing on achieving greater energy efficiency in existing hotel facilities becomes imperative.

➢ *Aim / Purpose:*

The primary goal is to achieve optimal energy efficiency for the hotel in Matheran. This will be accomplished through a comparative analysis of two distinct building envelopes (traditional and contemporary) to determine the most energy-efficient option based on their potential for energy-saving. Additionally, the aim is to enhance the energy efficiency of the contemporary envelope by implementing various strategies either individually or in combination.

- *To Achieve this Aim, the Study has the following Objectives:*

✓ Investigate existing energy-saving strategies for hotels and assess their potential for energy conservation based on previous research.
✓ Conduct a comparative analysis between two different envelopes in the hotel, namely the traditional load-bearing Laterite stone construction and the contemporary RCC framed brick structure.
✓ Apply the findings of the analysis to a simulation model of the hotel to evaluate the envelopes' thermal performance.
✓ Determine the superior envelope in terms of energy-saving potential based on the results of the simulation analysis.
✓ Propose and implement green strategies to enhance the energy efficiency of the contemporary envelope.

Overall, the study seeks to identify the most energy-efficient envelope option for the hotel and explore ways to further improve the contemporary envelope's energy performance using sustainable design strategies.

➢ *Significance of Study:*

The significance of studying envelope thermal performance for energy efficiency lies in its ability to evaluate the average heat gain within the building's envelope. This parameter serves as a crucial measure of the building's energy efficiency, all while allowing design options to remain unimpeded. Given the current need to retrofit existing hotels in Matheran, this research becomes essential due to the region's designation as an Eco-sensitive zone in 2003, which prohibits new construction.

While climate factors may remain constant for a specific location, architectural factors can vary significantly. Thus, it becomes imperative to thoroughly investigate heat gain parameters for both traditional and contemporary envelopes, taking into account their material characteristics. This research holds particular importance in identifying tailored and environmentally conscious solutions for enhancing energy efficiency in existing hotel structures, contributing to sustainable practices and mitigating the environmental impact in Matheran.

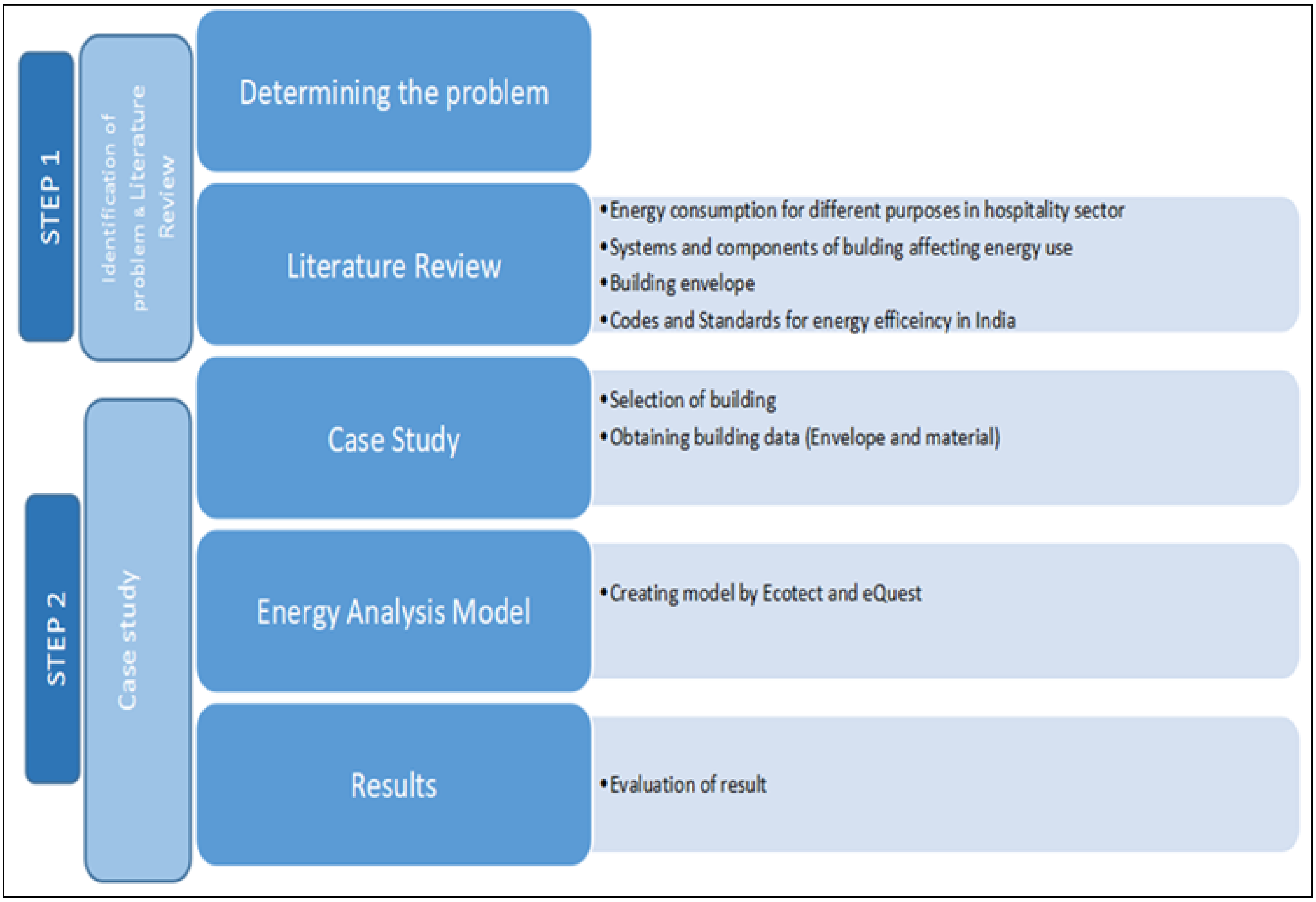

Fig 1 Structure of Study
Source: Author

➢ *Energy in Hotels:*

"The hospitality sector, particularly hotels, consumes significant amounts of energy and fossil fuels to ensure excellent guest services. However, there is potential to achieve substantial cost savings and energy reduction without compromising the quality of services provided.

II. ENERGY USAGE FOR DIFFERENT PURPOSES

- *A Hotel can be Perceived as a Unique Architectural Amalgamation of Three Separate Zones, Each Catering to Distinct Purposes:*

Table 1 Important Zones of a Hotel

Three distinct zones of hotel		
Guest Rooms	**Public areas**	**Service area**
(Bedrooms, bathrooms/showers, toilets) Individual spaces with extensive glazing, utilization and varying energy loads	(Reception, lobby, bars, restaurants, meeting rooms, swimming pools) Spaces with high rate of heat exchange with the outdoor environment (high thermal losses) and high internal loads (occuants, equipments and lighting)	(Kitchen, offices, store rooms, laundry, staff facilities, machine rooms and other technical areas) Energy intensive areas typically requiring advanced air handling (ventilation, cooling, heating)

Source: Author

- *Physical and Op Erational Parameters Play a Significant Role in Influencing the Energy Consumption of Hotels*

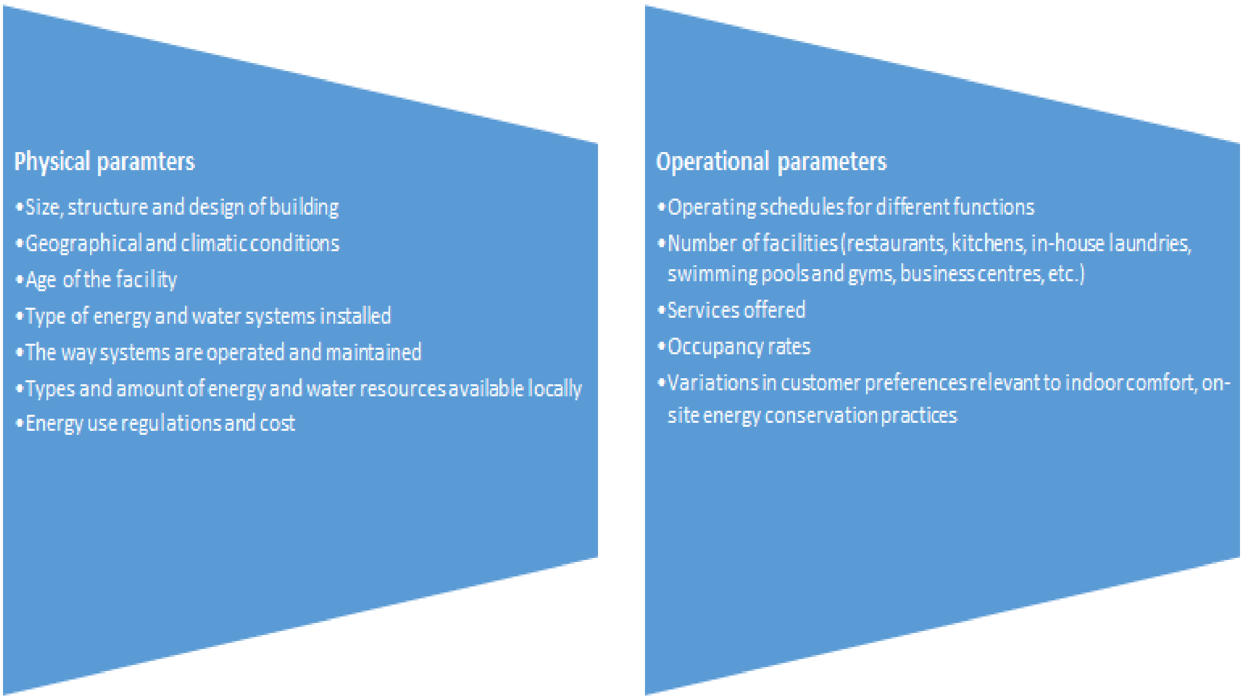

Fig 2 Physical and Operational Parameter that Influence Energy Consumption in Hotel
Source - Author

- *Passive Elements Influencing Energy usage:*

The orientation and planning of buildings are influenced by climatic factors, including outdoor temperature, humidity, and solar radiation. To optimize energy efficiency throughout a building's lifespan, it is essential to thoughtfully design and position structures while incorporating efficient heating, cooling, ventilation, and lighting strategies. (Adapted from "Green Building Illustrated" by D. K. Ching)

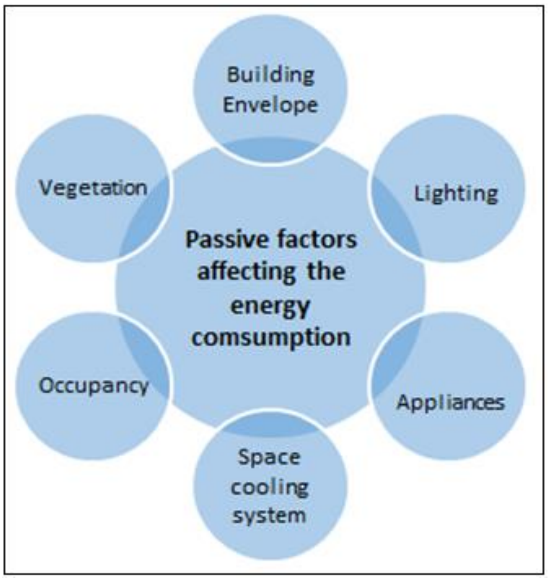

Fig 3 Passive Factors Affecting Energy Consumption
Source - Author

According to the United Nations Development Program, buildings have the potential to lower their energy consumption by approximately 20-50% through suitable design interventions in various areas. These include the building envelope, heating, ventilation, and air-conditioning (HVAC) systems (20-60%), lighting (20-50%), water heating (20-70%), refrigeration (20-70%), and other aspects like electronics, office equipment, and intelligent controls (10-20%).

➢ *Building Envelope*

The building envelope, often referred to as the outer shell of the structure, encompasses essential elements such as walls, windows, doors, and the roof. Adopting an outside-in design approach, starting from the building's perimeter towards its core through its envelope, offers numerous advantages. Gradually adding layers and ensuring the integrity and continuity of each component can significantly reduce various energy loads.

Key components of the building envelope that significantly influence the building's performance include:

Table 2 Components of Building Envelope

External walls	Roof	Fenestration	Shading devices	Building colour and texture
• Major part that is exposed to external environment • Heat storing capacity and heat conduction property of wall material impacts internal thermal comfort • Should be reflective and light coloured (can save energy for cooling by 12%)	• Receives the most of solar radiation as its shading is not possible • Shape of the roof • Large overhangs to protect walls and openings fron radiation and precepitation • Made of material with low thermal capacity and high reflectivity • Techniques to reduce heat gain - green roofs, reflective roof tops, cool roofs.	• Energy efficient windows and glazing to improve indoor air quality and providing proper insulation • Factors like U-value, solar heat gain coefficient (SHGC) and visible light transmittance(VLT) • Double glazed windows acts as good insulators and provides thermal resistance better than single glazed windows • Low-e glass	• Shading devices reduce solar heat gain in east, west and south facades thus reducing energy consumption for cooling • They also shield walls and windows from water intrusion and protect building materials from deterioration caused by sun's untraviolet rays	• Outer surface of external walls should be reflective and light coloured • Affects the amount of solar energy absorbed • Smooth, light-coloured finishes tend to reflect more than dark, rough finishes • Light colour has high emissivity and thus preferred where solar radiation is high.

Source - Author

The building envelope's attributes, including the building's shape and alignment, material properties, construction type and quality, as well as its interaction with outdoor conditions, play a vital role in determining the heat gain and loss through the envelope. Consequently, these factors directly influence the energy demands for space heating and cooling.

Table 3 Environmental Benefits of Energy Efficient Approaches

Approach Method	Benefits	Environmental Benefits	Comments
Improvement through the design of building envelope considering ECBC compliance method for building envelope and roof.	• Less energy consumption • Control the building energy use in design stage • Encourage climate responsive building planning and design • Predict the future energy demand for air conditioning • Suggest ways to improve energy efficiency in building through ECBC compliance	• Reduced GHG emissions • Provides options and encourages people to use energy efficient building integrated system	It's better to improve the energy efficiency in design stage rather than in occupancy stage

Source – Author

- *Characteristics of External wall in Building Envelope*

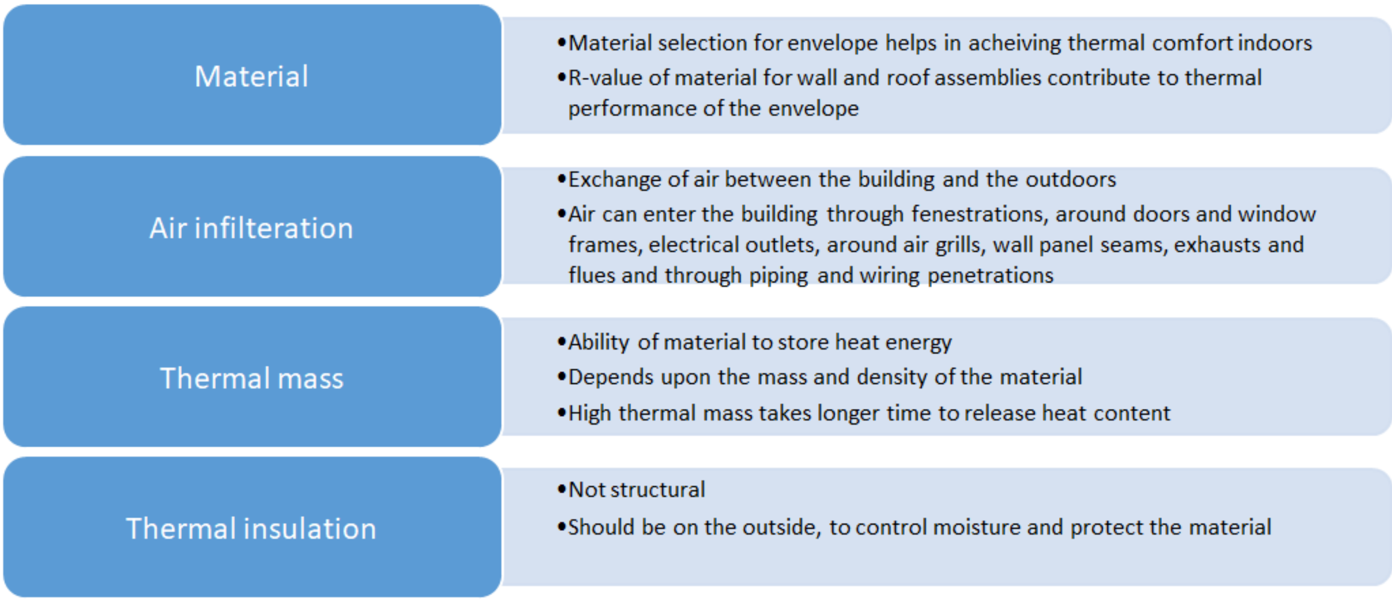

Fig 4 Characteristics of External wall in Building Envelope

- *Simulation Software for Energy-Efficient Building Design*

Simulation software for energy-efficient building design is a computer-based analytical approach that aids designers in assessing a building's energy performance and making necessary design modifications to enhance energy efficiency. The software employed for such analyses includes:

- *Ecotect:*

Ecotect is capable of calculating heating and cooling loads for models with various zones and diverse geometries. Designers can assign comprehensive material properties to all objects and define annual hourly operational schedules for factors like occupancy and internal gains.

- *eQUEST*:

eQUEST facilitates detailed comparative analysis of building designs and technologies using sophisticated simulation techniques to evaluate building energy use effectively.

- *Study Area Introduction - Matheran:*

Matheran, a picturesque hill station, is situated approximately 64 km Southeast of Mumbai (in Karjat Taluka, District Raigad), and about 125 km from Pune. The region falls within the Matheran Eco-sensitive area (ESA), covering a land area of 214.73 sq. km. Over 60% of Matheran's total area is designated as a 'reserved forest.' Positioned at latitude 18.9866° N and longitude 73.2679° E, Matheran is nestled within the Mumbai-Pune urban belt, making it an ideal getaway destination for both cities.

Fig 5 Location of Matheran
Source – Wikipedia

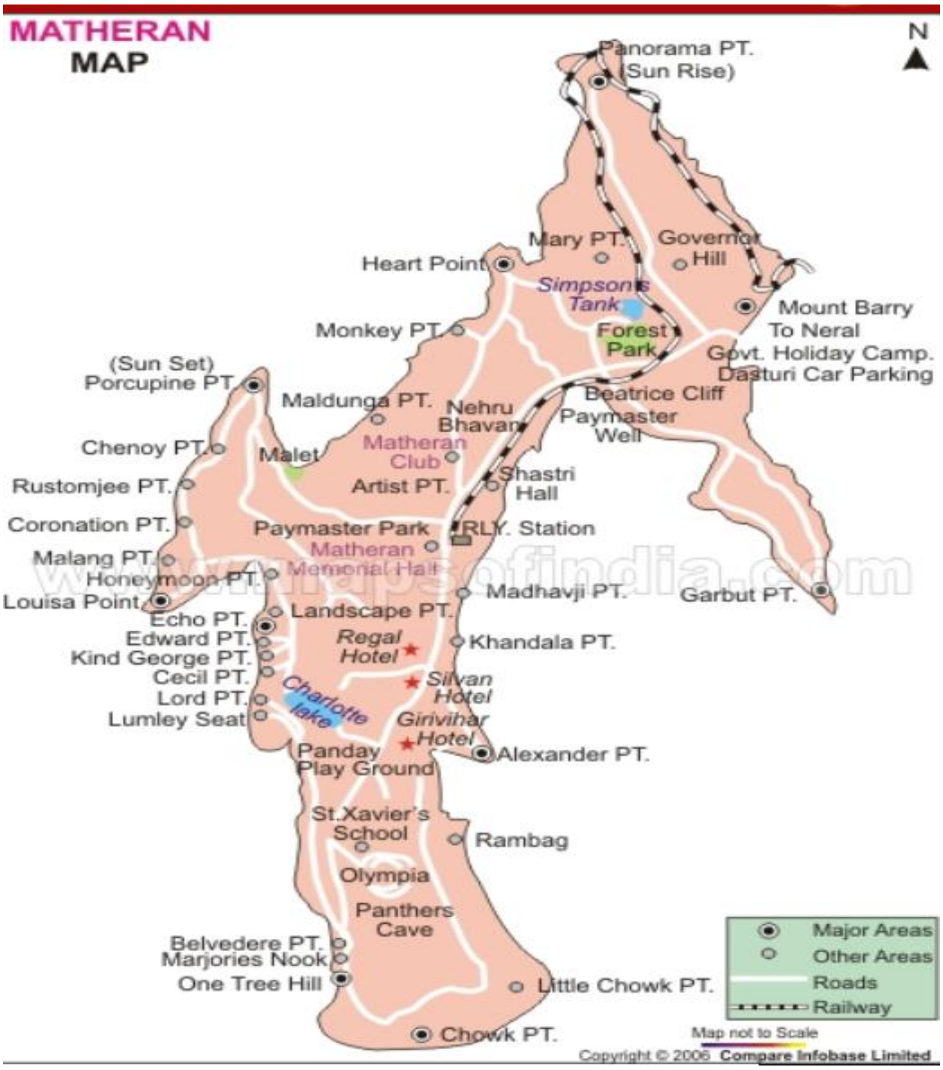

Fig 6 Matheran Map
Source – Maps of India

Owing to its elevated location, Matheran encounters milder winters in comparison to the neighboring major cities. The winter season spans from November to February, with daytime temperatures ranging between 28°C to 31°C, and nighttime temperatures dropping to around 12°C to 13°C. The region experiences abundant rainfall, totaling more than 3800 mm annually, primarily occurring from June to September. Summers are considerably warmer, with temperatures reaching up to 33°C to 34°C during the day and dipping to the mid-twenties during the night.

Table 4 Climatic Data of Matheran

Climate data for Matheran [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	28 (82)	30 (86)	31 (88)	32 (90)	33 (91)	32 (90)	30 (86)	30 (86)	29 (84)	33 (91)	31 (88)	29 (84)	30.7 (87.2)
Average low °C (°F)	13 (55)	14 (57)	16 (61)	19 (66)	22 (72)	22 (72)	21 (70)	21 (70)	20 (68)	19 (66)	17 (63)	13 (55)	18.1 (64.6)
Average precipitation mm (inches)	2.0 (0.079)	1.5 (0.059)	2.3 (0.091)	4.1 (0.161)	25.1 (0.988)	773.9 (30.469)	2,035.6 (80.142)	1,461 (57.52)	658.6 (25.929)	168.1 (6.618)	31.5 (1.24)	3.8 (0.15)	5,167.5 (203.446)

Source – Government of Maharashtra

- *Study Locale - Hotel Woodlands:*

The subject of this case study is Hotel Woodlands, which is located in the secluded interiors of Matheran, surrounded by trees on all sides. It presents an intriguing opportunity for study due to its two different envelope designs and strategic positioning. The hotel stands on a plot with a 4.5m wide road running along its north-western side. It is a full-service hotel with a restaurant, party hall, gaming area, and over 33 guestrooms with 2, 3, and 4-bedded occupancy, covering a gross floor area of 1715 m².

The main building of the hotel dates back to the late 19th century, while additional structures were added in the 1980s. The hotel underwent a light renovation about 15 years ago, but energy conservation measures were not a primary focus during that time. The hotel's proximity to the surrounding trees has both positive and negative effects, as they serve as windbreaks, impeding desirable breezes, and also block some daylight from penetrating. However, the presence of trees also provides beneficial shade to various areas of the hotel.

- *Planning and Orientation:*

The case study building's long axis stretches from the north-east to the south-west, resulting in larger facades on the north-west and south-east sides compared to the north-east and south-west elevations. The building's orientation is slightly deviated from the recommendation of TERI, which suggests that in tropical climates, the longer axis of the building should align in the north-south direction to minimize solar heat gain.

The orientation of the case study building was not primarily influenced by protecting against solar heat gain on the west and east sides. Instead, it was designed based on the site's layout and the goal of providing open spaces in front of the maximum number of rooms.

Fig 7 Plan Hotel Woodlands, Matheran
Source – Author

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III. BUILDING ENVELOPE OF THE HOTEL

The energy efficiency of the hotel's building envelope components, such as external walls, floors, roofs, ceilings, windows, and doors, plays a crucial role in determining the amount of energy needed for heating and cooling.

➢ *Opaque Components –*

- *External Walls:*

The hotel's external walls consist of two types of construction: the traditional one featuring 350mm thick Laterite stone walls, and the contemporary one made of RCC framed with 230mm burnt brick. Both types of walls have a cement plaster of 18mm and 12mm, respectively, over the brick and Laterite stone surfaces. Internally, the walls are finished with paints, while some exterior walls are painted with a light yellow color to enhance the facade.

According to Cheung et al. (2005), employing white or light-colored external wall finishes can lead to potential energy savings of approximately 12% on cooling energy.

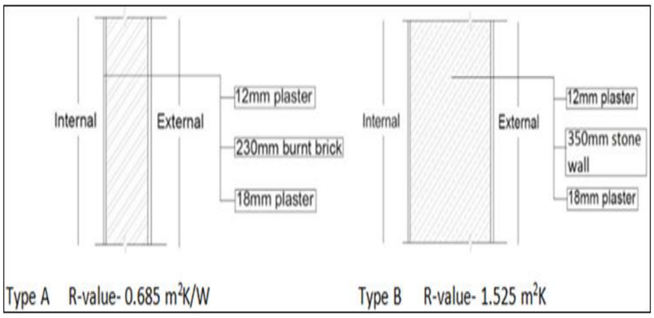

Fig 8 Types of Wall Construction
Source – Author

- *Roof:*

In the traditional Laterite stone building, the roof features a pitched design with a wooden frame and M.S. sheets as the roof covering. Additionally, it includes an attic space. On the other hand, the contemporary framed structure has a roof made of approximately 150mm thick RCC (reinforced concrete) with a waterproofing course of 50mm brick bat and 20mm PCC (plain cement concrete).

Fig 9 Types of Wall Construction
Source –www.woodlandsmatheran.com

The roof plays a vital role in energy conservation as it receives a significant amount of solar radiation, and shading this area is challenging. According to Vijay Kumar et al. (2007), Indian concrete roofs in single or two-story buildings, featuring 150mm thick reinforced cement concrete (RCC) and a waterproofing course with 75-100mm thick lime brick mortar, contribute to approximately 50%-70% of the total heat transmitted into the occupied zone. Consequently, they are responsible for a substantial portion of the electricity bill in air-conditioned buildings.

➢ *Fenestration System -*

- *Natural Lighting and Ventilation:*

The windows on the north-east and north-west sides are not efficient in providing adequate daylight and airflow due to their small sizes. Consequently, occupants often need to keep the lights on in these areas for most of the day.

Fig 10 Single windows in guest rooms
Source – Author

The Handbook on Energy Conscious Buildings by J.K. Nayak and J.A. Prajapati suggests that for proper cross ventilation, windows should be located diagonally opposite to each other. However, in this case study building, none of the guest rooms have provision for cross-ventilation through two pairs of windows located on side walls.

To address this issue, a solution would be to have two windows placed side by side on the same wall instead of just one, as recommended by the Handbook. Alternatively, another solution could involve having two windows, one at sill level and the other above the lintel level, which could facilitate fan-induced ventilation and stack ventilation.

Regarding size and location, the windows in the building are operable with wooden frames and consist of 6 mm thick frosted glass with fixed grills.

Fig 10 Windows of Guest Rooms
Source – Author

The study involved calculating the window to floor area ratio (WFR) for each guest room, obtained by dividing the window area by the floor area. Additionally, the window to wall area ratio (WWR) was determined by dividing the window area by the wall area in each guest room. The analysis revealed that the highest and lowest WWRs are 0.26 and 0.13, respectively.

Some guest rooms have WWR values below the recommended threshold, as suggested by Liping et al. (2007), who propose an optimum window to wall ratio of 0.24. Despite a few guest rooms having WWR values exceeding the recommended value (0.26), they still do not receive sufficient natural light due to obstruction by trees located on the south-east side of the building.

Table 5 Windows to Floor Area Ratio (WFR) and Window to Wall Area Ratio (WWR) of Guestrooms

Rooms	Window orientation	Floor area (in SQM.)	Window size (in SQM)	Wall area (in SQM.)	WFR (Window to floor ratio)	WWR (Window to wall ratio)
Room 1&3	N-W	30.5	2.88	18.7	0.094	0.15
Room 2	N-W	30.5	4.32	18.9	0.14	0.22
Room 4	N-W	16	2.4	13.5	0.15	0.177
Room 5	N-E	37.7	1.8	13.5	0.047	0133
Room 6	S-W	38	3.6	28.8	0.094	0.125
Room 7	S-E	32.5	0.6	12.3	0.018	0.048
Room 8	N-E	44	5.4	23.7	0.122	0.227
Room 9&10	S-E	25.6	3.6	13.5	0.14	0.266
Room11&12 Room18&19	N-E	18	1.8	13.5	0.1	0.133
Room 13	S-E	29.5	3.6	13.5	0.12	0.266
Room 14	N-W	16.6	3.6	15.6	0.21	0.23
Room 15,16&17	N-W	15.6	2.25	10.5	0.14	0.214
Room 20	N-E	20.9	3.6	14.7	0.17	0.24
Room21&23	N-W	18	1.8	13.5	0.1	0.133
Room22&24	S-E	18	1.8	13.5	0.1	0.133
Room25&26	N-E	18	1.8	13.5	0.1	0.133
Room27&29	N-W	19.5	1.8	10.8	0.09	0.166
Room28&30	S-E	24.8	1.8	10.5	0.072	0.171
Room 31,32&33	N-W	15.6	2.25	10.5	0.14	0.214

Source – Author

The remaining guest rooms have windows with a WWR below the recommended value of 0.24, ranging from 0.13 to 0.23. This is because none of the windows extend from the skirting to the lintel level, which is typically 2 meters in height.

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IV. SUMMARY

The following table provides a summary of the key characteristics of the case study hotel building along with the sources used for comparison of these characteristics.

Table 6 Summary of the Case Study Hotel Building

Characteristics		Source
Location	Chinoy Road, Matheran. Maharashtra 410102	
Orientation	Oriented in 207° N direction and the front faces North-West	TERI-Best orientation- longer axis north south
Conditioned floor area	792 sq.m.	
No. of floors	G + 1	
Building shape	'U' shape with one wing smaller	TERI- EPI of Circular building form is lowest
Height	15ft. old building, 10ft. new building (floor to ceiling)	TERI- less is better as it lessens the surface area to floor area ratio i.e. Area ratio
No.of rooms	33 rooms	
Other spaces	Reception area, dining area, party hall, toilets, gaming area, pantry, kitchen, store rooms, staff facility	
Surroundings	No building shades, tree shades, paver blocks surrounding the building (Reflectance-0.2)	Best is green grass surrounding the building (Reflectance- 0.26)
Construction		
Construction type	Main building- Load bearing	As per ECBC,
Exterior wall	Laterite stone wall 1 ½ "thick	U factor-0.261 W/m²K
	18mm plaster on the exterior	R- value of insulation alone – 3.5 m²K/W
	12 mm plaster on the interior	
Roof	Low pitched roof with gable	
	Corrugated M.S. sheets	
	No shingles	
	EPS insulation R-4	
	Gypsum false ceiling	
Interior Floors	Vitrified tiles	
Windows	Gross window area: 12% of conditioned floor area (equivalent to 112 sq.m.), distributed equally for all the rooms	As per ECBC, vertical fenestration U-factor- 3.3 W/m²K Window wall ratio-0.31-0.4, so VLT-0.2
	Single pane window with 6mm frosted glass (U = 5.8 W/m²K, SHGC = 0.82 Wooden frames (U factor-2.8 W/m²K, frame conductance = 0.47, frame width = 60mm)	Maximum SHGC- 0.25
Doors	1mX2.1m (U value-2.8 W/m²K)	
Exterior shading	No shading and overhangs on windows	
Construction type	New building-Framed structure with brick wall	
Exterior wall	Brick wall 230 mm thick	
	Internal walls 150 mm thick	
	18mm plaster on the exterior	
	12 mm plaster on the interior	
Roof	R.C.C. flat roof – 150mm	
	Water proofing course -50mm	
Interior Floors	Vitrified tiles	
	½" gypsum board ceiling	

Source: Author

V. METHODOLOGY

➢ *The Chosen Methodology Comprised Three Primary Stages:*

- Creation of an Ecotect simulation model for the entire resort.
- Developing eQuest simulation models for two guest rooms with the same orientation but distinct material characteristics.
- Advancing one of the envelopes by implementing energy-efficient measures and conducting further analysis.

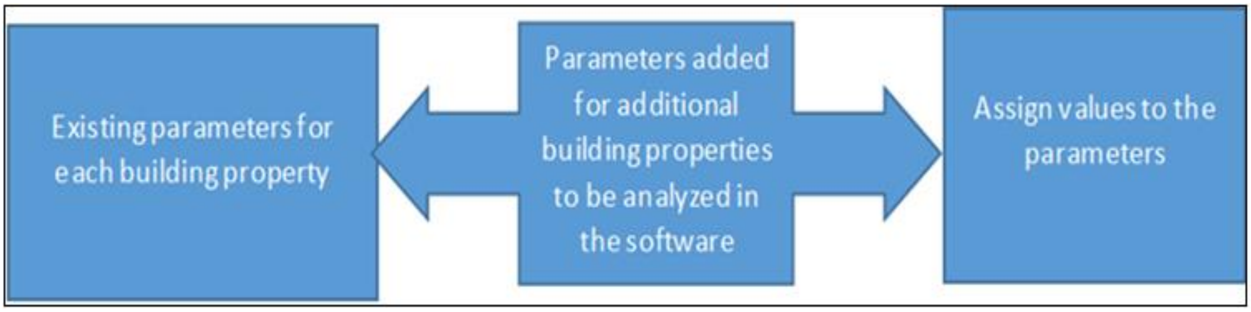

Fig 11 Development of Existing Hotel Model in Ecotect

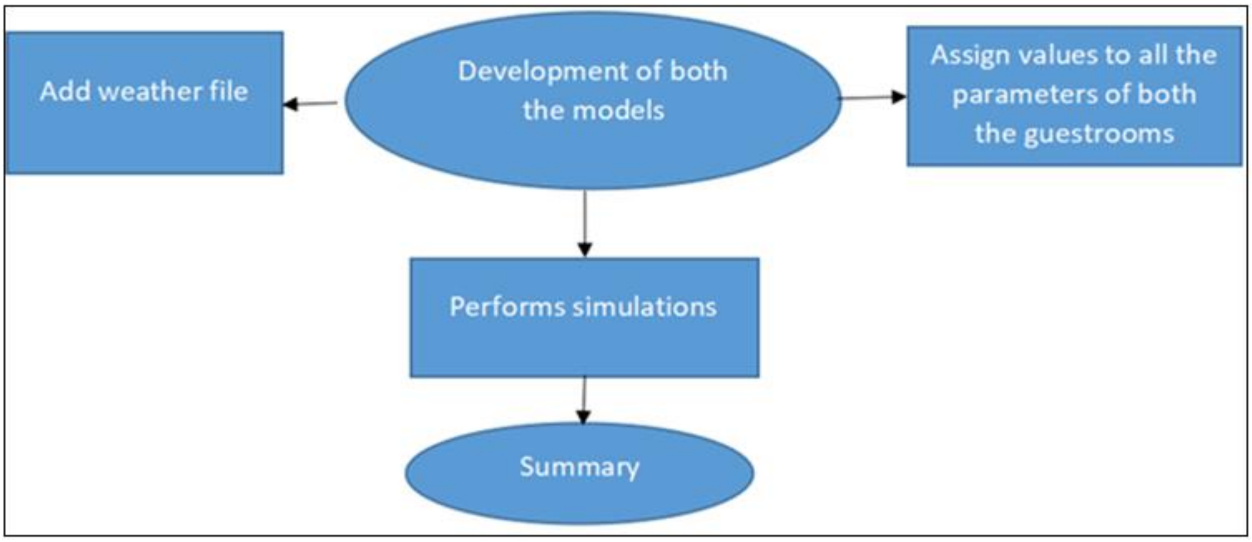

Fig 12 Development of Envelope of Traditional and Contemporary Construction of Two Guestrooms in Equest

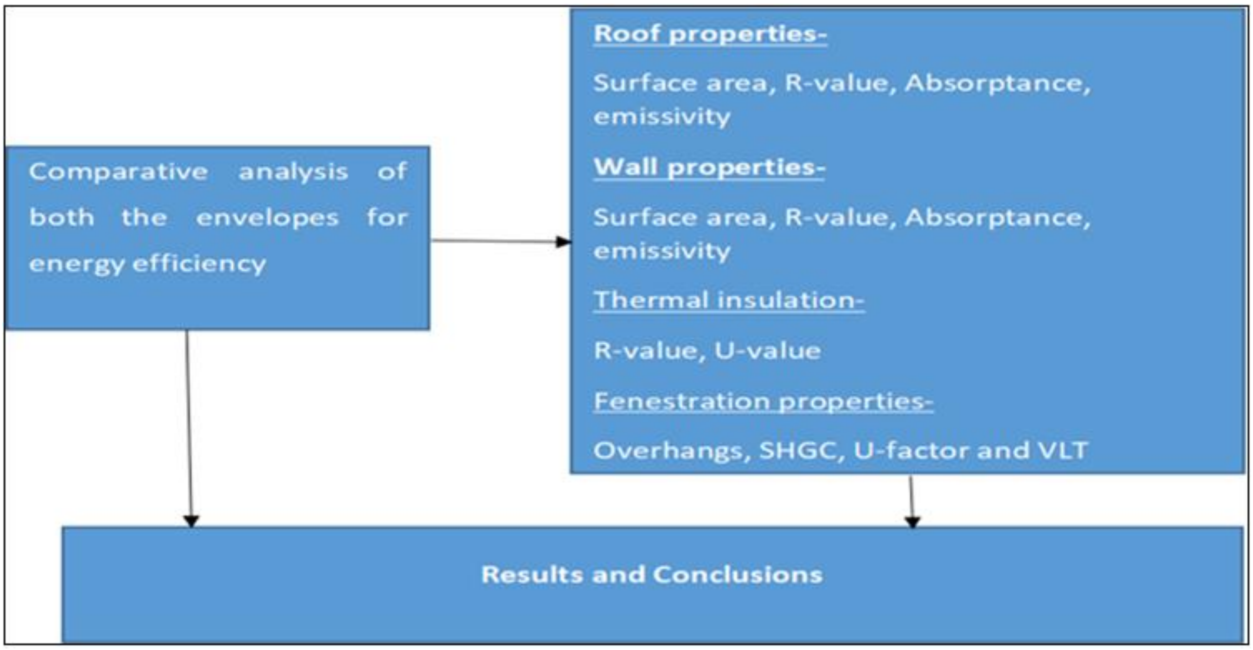

Fig 13 Determining the Energy Efficient Envelope from Both the Envelopes

➢ *Development of Simulation Model*

The simulation model was developed by assigning specific values to various building characteristics, including building geometry, location, and building envelope components. These values were determined based on the materials used on the site

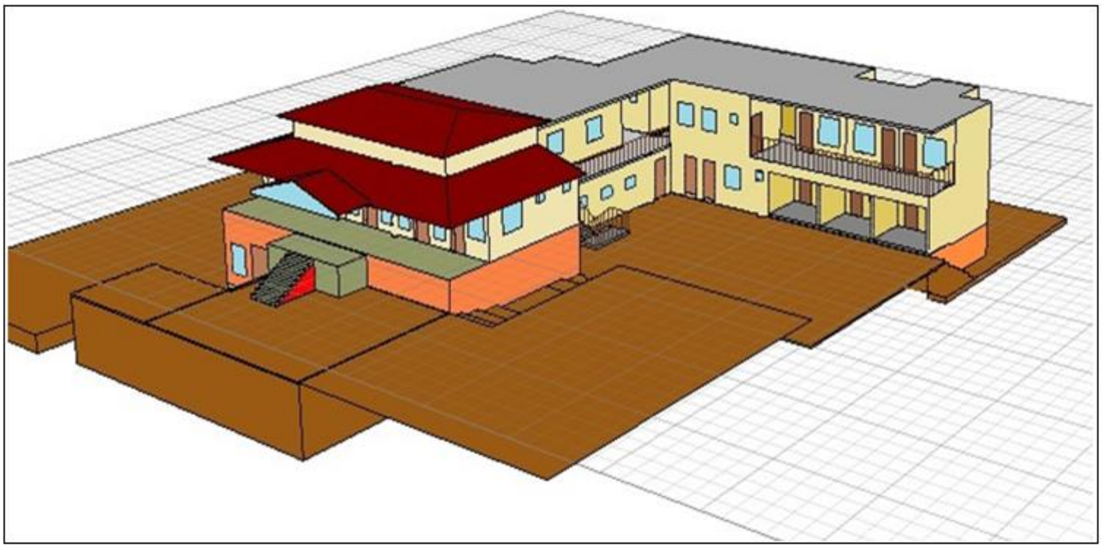

Fig 14 Hotel Model on Ecotect
Source: Author

The hotel was modeled in Ecotect software and subjected to simulations for various parameters, including hourly temperature profiles, passive gains, and monthly degree days.

The hourly temperature profile provides insights into the internal temperatures of each zone throughout the day, helping to identify critical periods when temperatures are at their highest.

Passive gains refer to the heat gains through different elements, aiding in pinpointing specific areas that require attention to control heat.

Monthly degree days are used to assess the cooling requirements, enabling a better understanding of the cooling needs for different periods.

- *Hourly Temperatures Profile for Hottest Day*

Hourly temperature graphs illustrate the internal temperatures of all visible thermal zones in the model in relation to the external temperature over a 24-hour timeframe, particularly on the hottest day.

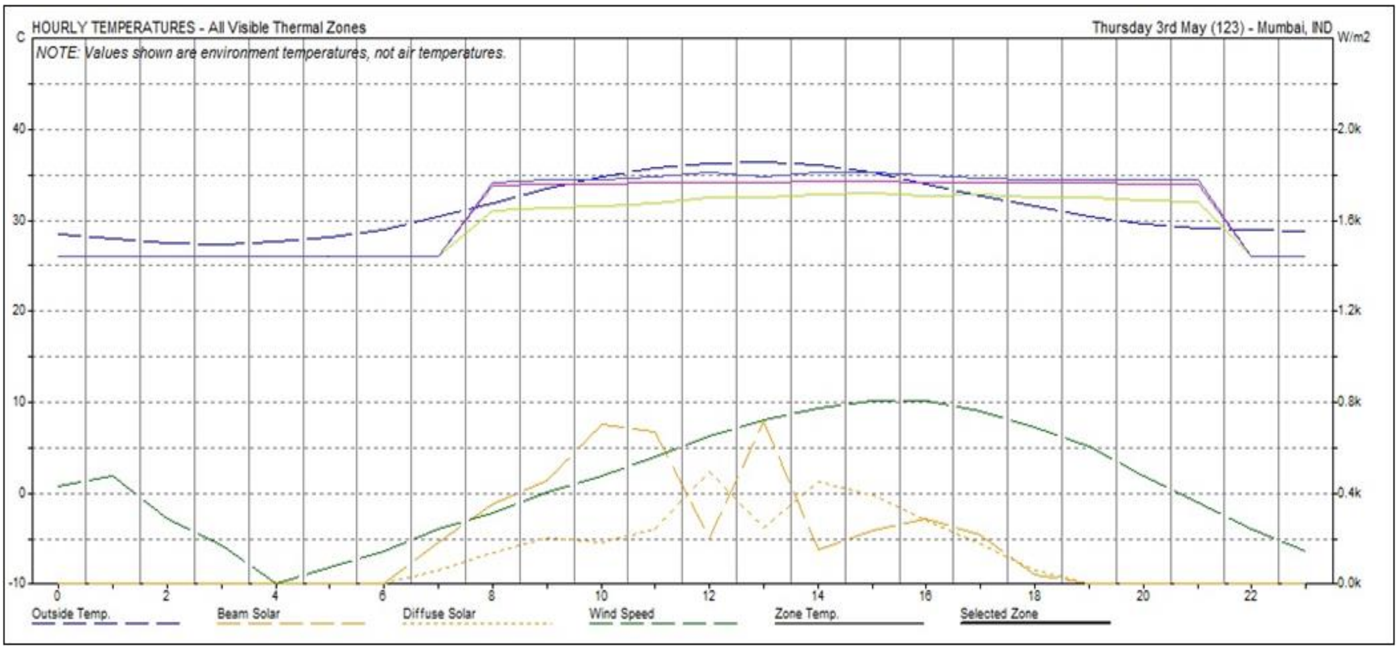

Fig 15 Hourly Temperature Profile for whole Hotel
Source: Ecotect thermal Analysis Software

The inside temperature of the front zone remains less compared to the back zone and the middle zone as shown in the bar charts below-

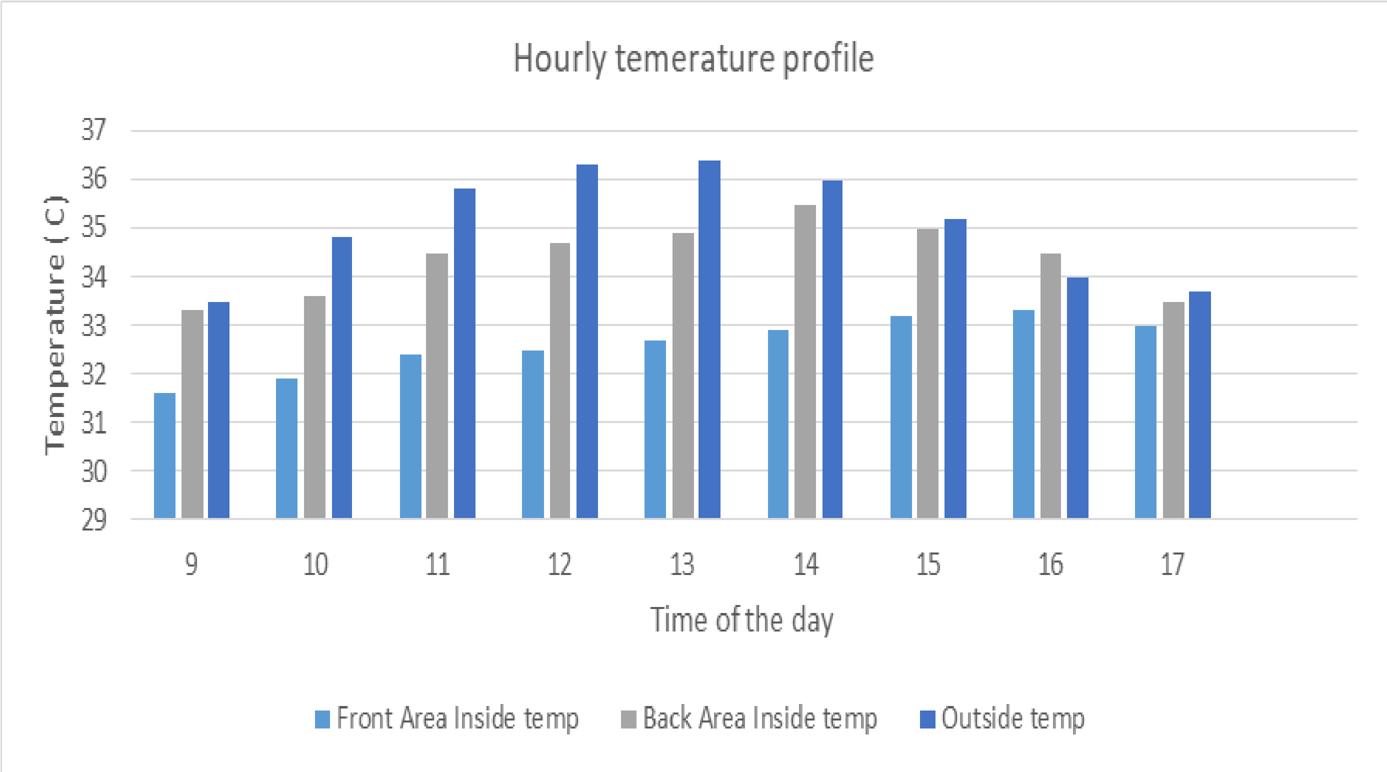

Fig 16 Comparative bar Chart for Hourly Temperature Profile
Source: Author

- *Passive Gains Breakdown*

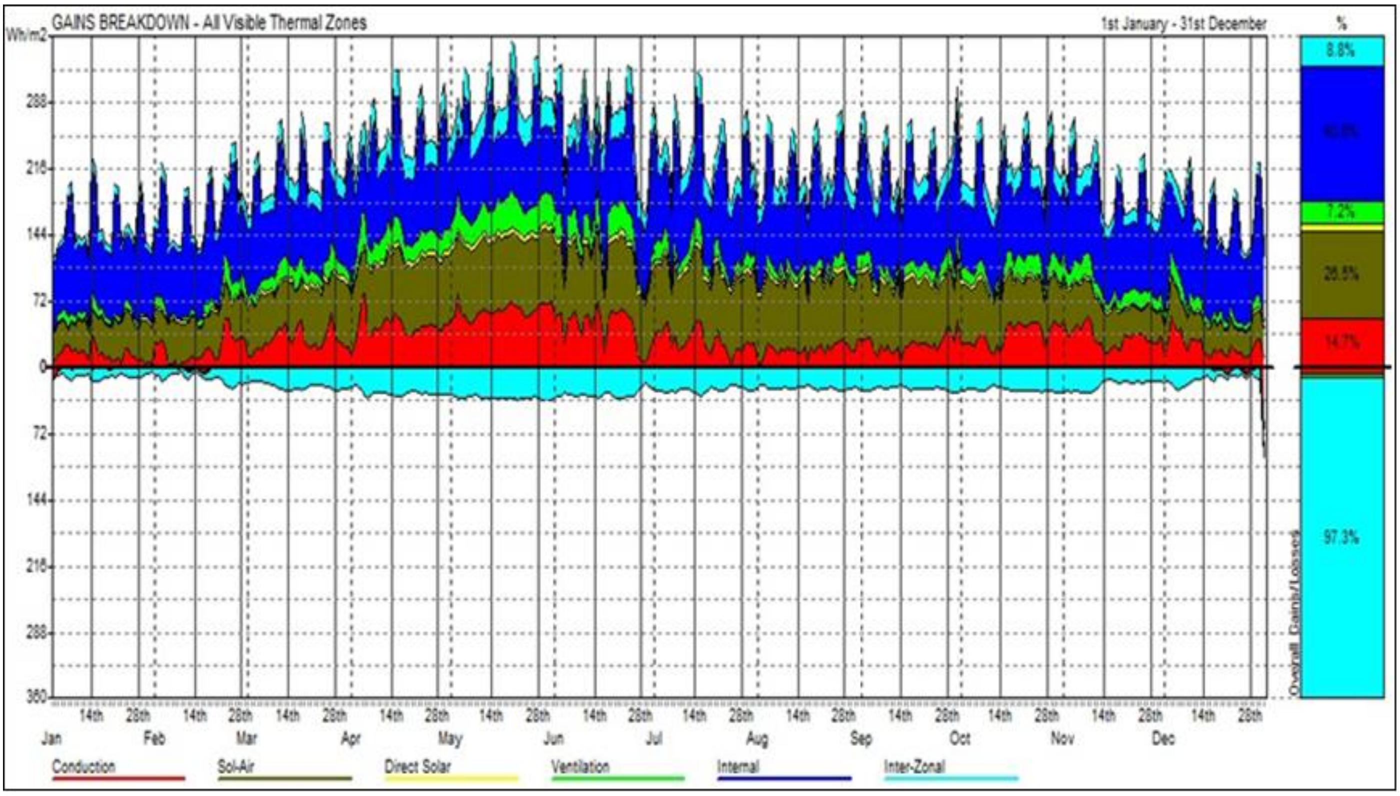

Fig 17 Graph for Passive Gains Breakdown for whole Hotel
Source: Ecotect Thermal Analysis Software

The Sol-air or indirect heat gain is maximum, if insulation is applied and colour of the wall and roof elements change to white, then the passive gains breakdown may reduce further.

- *Comparative Analysis of Both Envelopes for Energy Efficiency*

To conduct a comparative analysis of both envelopes for energy efficiency, two guest rooms were chosen, one constructed using traditional load bearing Laterite stone with a thickness of 350mm, and the other with a contemporary RCC frame and a 230mm brick wall, both having similar orientation, size, shape, and window area. The analysis focused on the building configuration, envelope, and system characteristics.

Using eQuest simulation, the energy-saving potential of these two guest rooms was evaluated. The table below provides a list of the building properties analyzed during the study.

Table 7 List of Building Properties Analyzed

Properties	**Values used for traditional guestroom (Laterite stone wall)**	**Values used for contemporary guestroom (brick wall)**
Building configuration	1:2 width to depth ratio, one-story	1:2 width to depth ratio, one-story
Roof and wall properties		
Absorptance	Roof-64 (Red galvanized sheet) Wall-0.4 (Laterite stone)	Roof-0.7 (R.C.C. slab) Wall-0.4 (Red clay bricks)
Emissivity	Roof-0.88 (Red galvanized sheet) Wall-0.7 (Laterite stone)	Roof-0.54 (R.C.C. slab) Wall-0.7 (Red clay bricks)
Insulation	**Roof-R-value-4.68 m^2.K/W** Air film outside-R-0.06 Al sheets-R-value-0.14 Wooden floor – R-0.6 Expanded polystyrene-R- 3.75 Air layer inside-R- 0.13 **Wall-R-value-1.52 m^2.K/W (Laterite stone)** Air film outside-R-0.06 18mm outside plaster-R-0.025 380mm laterite stone wall-R-1.28 12mm inside plaster-R-0.02 Air layer inside-R-0.14	**Roof-0.424 (R.C.C. slab)** Air film outside-R-0.06 20 mm PCC-R- 0.03 50mm Brick bat – R – 0.08 150mm RCC slab-R-0.104 12mm inside plaster-R-0.02 Inside ceiling air layer-R-0.13 **Wall-R-0.685 m^2.K/W (Red clay bricks)** Air film outside-R-0.06 18mm outside plaster-R-0.025 230mm brick wall-R-0.44 10mm inside plaster-R-0.02 Air layer inside-R-0.14
Construction Type	Load bearing construction with 380mm thick laterite stone wall and wooden frames with Al commercial sheets with 20mm expanded polystyrene under the board insulation	R.C.C. framed structure with 230mm brick wall and 150mm thick slab with brick bat and PCC
Fenestration		
Window distribution	Windows (12% of floor area), only on the front side (North-west)	Windows (12% of floor area), distributed in two orientations (North-east & South-east)
Exterior shading	Verandah projection acts as shading	No overhangs
Glazing U-factor	1.09 (6mm frosted glass)	1.09 (6mm frosted glass)
Glazing SHGC	0.72(6mm frosted glass)	0.72(6mm frosted glass)

Source: Author

To investigate the impact of varying characteristics of different building systems and components, distinct values were assigned to the corresponding parameters. The study focused on three key building systems and components: (a) building configuration, (b) roof and walls, and (c) fenestration.

Hourly temperature profiles, hourly heat gains/losses, monthly loads/discomfort, temperature distribution, and fabric gains were plotted to assess the influence of thermal mass associated with specific measures. This allowed for a comprehensive analysis of how different modifications affected the building's thermal performance and energy efficiency.

➢ *Roof and Wall Characteristics:*

The heat gain/loss through the building envelope is influenced by the R-value, absorptance, and emissivity of the exposed surfaces. Since the angle of incident solar radiation varies between the roof and walls, they contribute differently to heat gain/loss. Consequently, the impact of R-value, absorptance, and emissivity was carefully examined for both the roof and walls.

Table 8 Roof and Wall Properties Assumed for Simulation

Properties of roof/wall	Old Traditional building		New Contemporary building		As per ECBC	
	Wall	Roof	Wall	Roof	Wall	Roof
Solar reflectivity	0.6	0.36	0.6	0.3	>0.7	>0.7
Surface emissivity	0.7	0.88	0.7	0.54	>0.75	>0.75
Absorptance	0.4	0.64	0.4	0.7	0	0
Insulation (Resistance R-value)	1.525 m2.K/W	4.68 m2.K/W	0.685 m2.K/W	0.42 m2.K/W	2.1 m2.K/W	3.5 m2.K/W

Source: Author

➢ *Fenestration Characteristics:*

The heat gain/loss through the windows is influenced by various factors, including shading, window distribution on different orientations, U-factor, and SHGC (solar heat gain coefficient) of the windows. Lower U-factor values are typically associated with double pane, low-e, or triple pane glazing, while higher values are linked to single pane glazing, which is present in the existing building.

Similarly, lower SHGC values are associated with reflected or tinted glazing, while higher values are linked to clear glazing. However, in both the traditional and contemporary envelopes, the fenestration properties remain unchanged, providing a constant factor for the analysis.

Table 9: Fenestration Properties Assumed for Simulation

Fenestration Properties	Old Traditional building	New Contemporary building	As per ECBC, WWR≤40%
U-value	1.09 W/m2.K	1.09 W/m2.K	3. 3W/m2.K
SHGC	0.72	0.72	0.25

Source: Author

➢ *Comparative Chart of Both the Envelopes*

A comparative chart was created based on the analysis of the energy-saving potential of various measures, including walls, roof, and fenestration properties, for both guest rooms. This analysis aimed to determine which envelope is more efficient in terms of energy savings. The chart presents a side-by-side comparison of the two envelopes, allowing for a clear assessment of their respective energy performance and efficiency.

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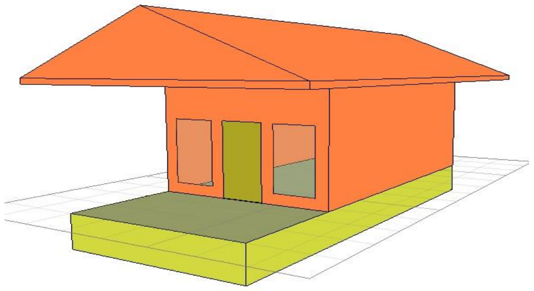
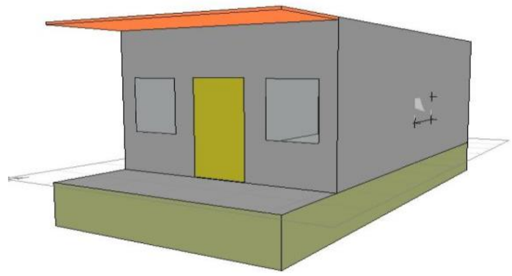
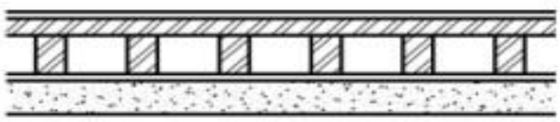
Table10 Comparative Analysis of Both the Envelopes

OLD BUILDING	NEW BUILDING
	

General Characteristics

Roof assembly (Old building)

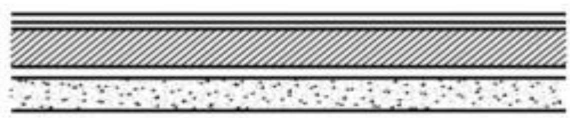


Metal corrugated sheet+1/2" plywood+wooden floor+expanded polystrene, **R=4.68 m²/K/W**

Material	Resistance R-value (m²/K/W)
Outside air film	0.06
Metal corrugated sheet	0.14
Wooden floor	0.6
Expanded polystrene	3.75
Inside air film	0.13

ECBC recommended R value for roof assembly= 3.5 m².K/W

Roof assembly (New building)



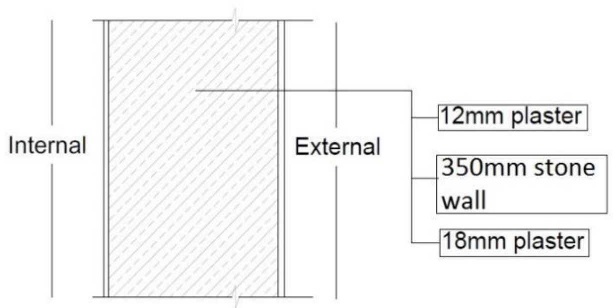
20mm PCC+50mm (avg. thickness) brickbat coba +150mm RCC slab + 12mm plaster, **R=0.424 m²/K/W**

Material	Resistance R-value (m²/K/W)
Outside air film	0.06
20mm PCC	0.03
50mm brick bat	0.08
150 mm RCC slab	0.104
12 mm plaster	0.02
Inside air film	0.13

ECBC recommended R value for roof assembly= 3.5 m².K/W

Wall assembly (Old building)

18mm plaster+350mm stone wall+12mm plaster, **R=1.525 m².K/W**

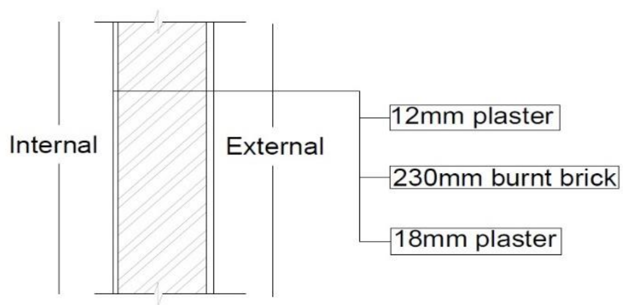


Material	Resistance R-value (m²/K/W)
Outside air film	0.06
18mm plaster	0.025
380mm stone wall	1.28
12mm plaster	0.02
Inside air film	0.14

ECBC recommended R value for wall assembly= 3.5 m².K/W

Wall assembly (New building)

18mm plaster+230mm brick wall+12mm plaster, **R=0.685 m².K/W**



Material	Resistance R-value (m²/K/W)
Outside air film	0.06
18mm plaster	0.025
230mm brick wall	0.44
12mm plaster	0.02
Inside air film	0.14

ECBC recommended R value for wall assembly= 3.5 m².K/W

The thickness of stone wall acts as thermal mass, which curbs down the heat more.	
Solar reflectivity	**Solar reflectivity**
Roof-The solar reflectivity of Terra cotta color aluminum sheet **= 0.36** Wall-The solar reflectivity of the wall= 0.6 ECBC recommended solar reflectivity for roof= >0.7	The solar reflectivity of cement plaster (PCC) **= 0.2-0.3** The solar reflectivity of the wall = 0.6 ECBC recommended solar reflectivity for roof= >0.7
Emissivity	**Emissivity**
The emissivity of Terra cotta color aluminum sheet **= 0.88** The emissivity of the wall = 0.7 ECBC recommended emissivity for roof= >0.75	The emissivity of cement plaster (PCC)**= 0.54** The emissivity of the wall = 0.7 ECBC recommended emissivity for roof= >0.75
Solar absorptance	**Solar absorptance**
The solar absorptance depends on the color of the surface Solar absorptance=1- Solar reflectivity For roof = 1-0.36 = **0.64** For wall = 0.4 ECBC recommended solar absorptance as 0	The solar absorptance depends on the color of the surface Solar absorptance=1- Solar reflectivity For roof = 1-0.30 = **0.70** For wall = 0.4 ECBC recommended solar absorptance as 0
Fenestration properties	
U- value	**U- value**
The U- value of the window assembly (Single pane, frosted glass with wooden frame) = 1.09 W/m^2.K ECBC recommended U-value = 3.3 W/m^2.K	The U- value of the window assembly (Single pane, frosted glass with wooden frame) = 1.09 W/m^2.K ECBC recommended U-value = 3.3 W/m^2.
SHGC	**SHGC**
The solar heat gain co-efficient = 0.72 ECBC recommended SHGC = 0.25	The solar heat gain co-efficient = 0.72 ECBC recommended SHGC = 0.25

Source: Author

VI. ANALYSIS OF THE RESULT

The analysis involved simulations on the existing traditional and contemporary guest rooms using both Ecotect and eQuest. The traditional guest room, constructed with 350mm Laterite stone, exhibited a higher thermal mass and an R-value of 1.52m2k/W compared to the contemporary guest room's 230mm thick brick wall without insulation. Additionally, the traditional guest room had an attic and 1" EPS roof insulation, contributing to significant energy savings.

On the other hand, the contemporary guest room, being an RCC structure with a 230mm thick brick wall and no insulation, showed less energy-saving potential despite having the same building configuration, orientation, shape, and size. The graph for the peak summer month (May) indicated that the cooling electricity use in the contemporary guest room was 1.21 times higher than in the traditional guest room when the outside temperature was at its highest.

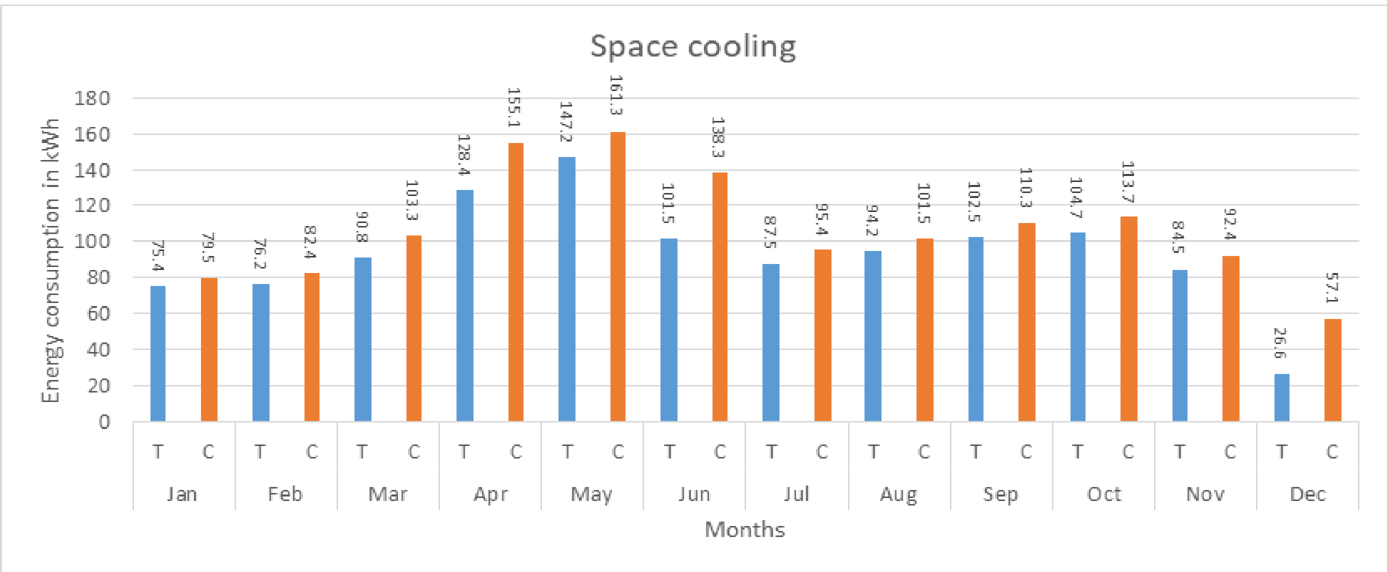


Fig 18 Monthly Energy Consumption by end-use for Space Cooling

Consequently, the traditional guest room necessitates a total of 1109kW of energy for space cooling over the course of a year, which is lower than the energy required for cooling the same area in the contemporary guest room, which amounts to 1288kW. Therefore, **the contemporary envelope demands approximately 15% more energy compared to the traditional one.**

➢ *Thermal Analysis in Ecotect*

The thermal analysis conducted in Ecotect enabled the evaluation of various parameters, including the hourly temperature profile, hourly gains and losses, and the breakdown of passive gains. These results were crucial for performing a comparative analysis of both envelopes.

Specifically, the hourly temperature profile for the average hottest day (Thursday, 3rd May) was studied to gain insights into the temperature variations throughout the day in both guest rooms.

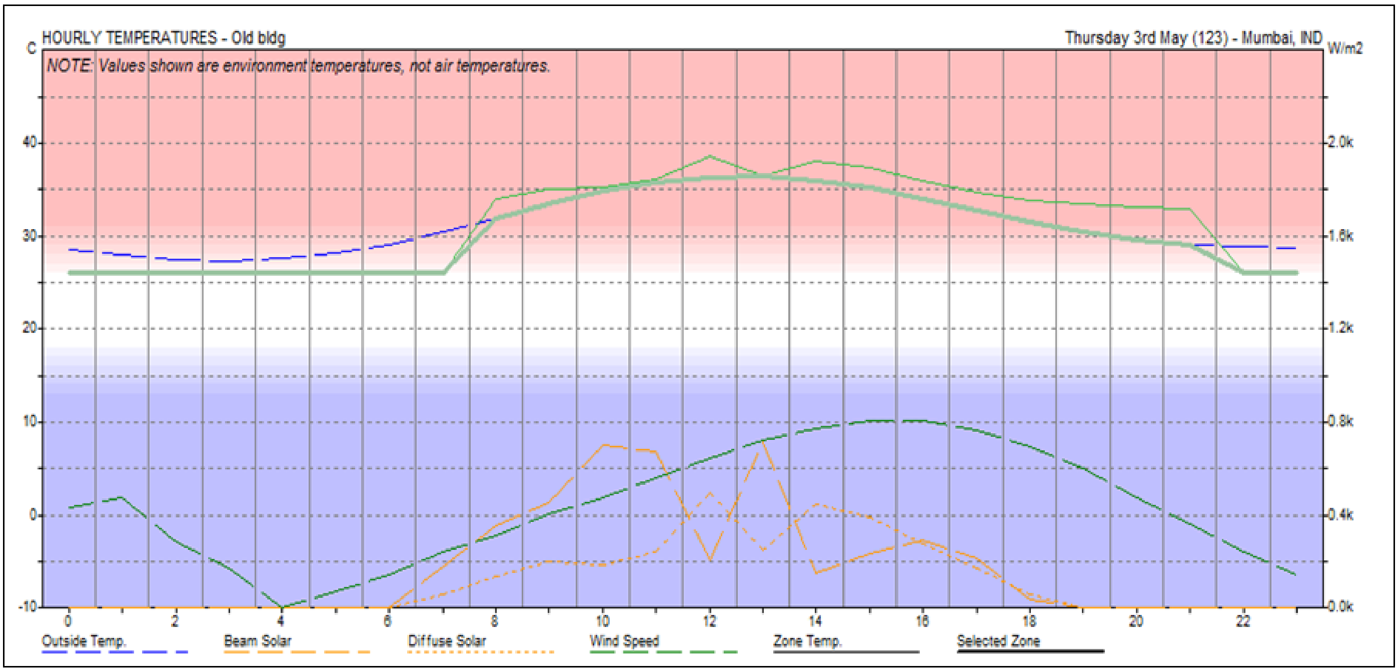


Fig 19 Hourly Temperature Profile of Traditional Envelope
Source: Ecotect Thermal Analysis Software

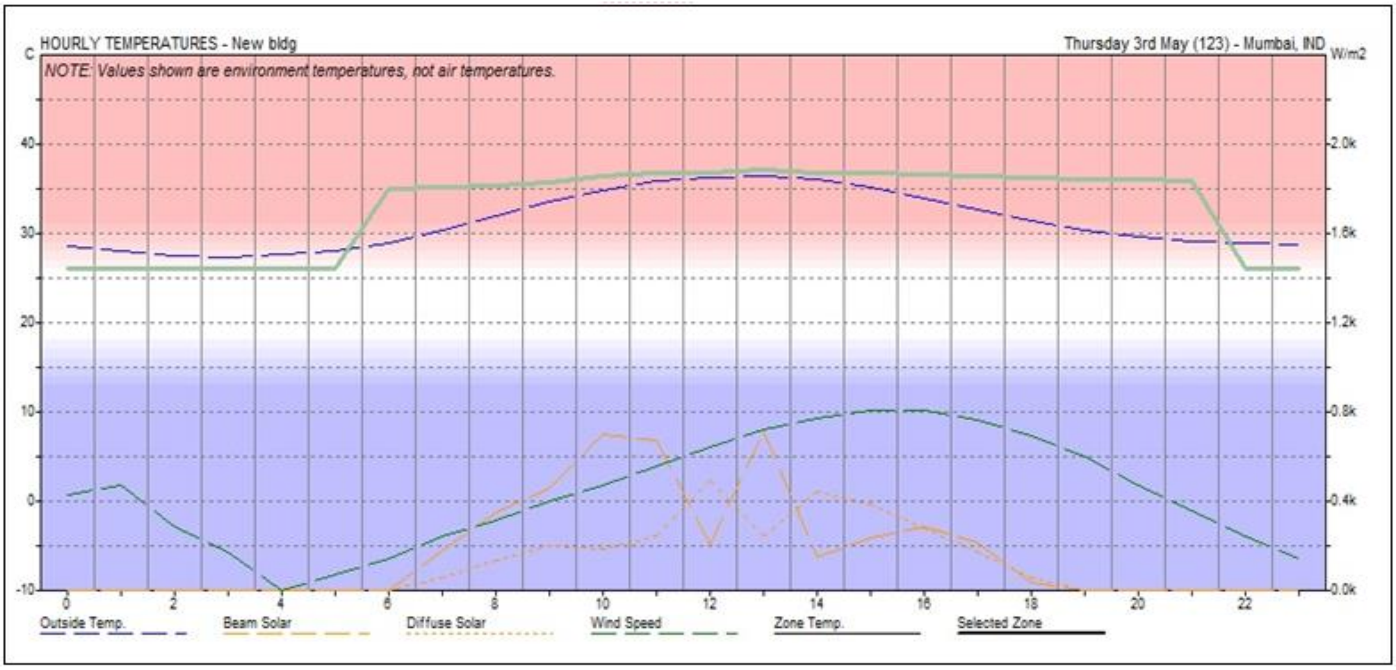


Fig 20 Hourly Temperature Profile of Contemporary Envelope
Source: Ecotect Thermal Analysis Software

The analysis of the hourly temperature profile for both the traditional and contemporary envelopes indicates that the traditional guest room tends to be cooler than its contemporary counterpart from 6 am to 9 pm. Specifically, the traditional guest room remains approximately 5% cooler than the contemporary guest rooms during this time period.

Table 11 Comparative of Hourly Temperature Profile of both the Guestrooms

Traditional guestroom				Contemporary guestroom			
Hourly temperature profile							
HOURLY TEMPERATURES - Thursday 3rd May (123)				HOURLY TEMPERATURES - Thursday 3rd May (123)			
HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)	HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
-----	-------	--------	---------	-----	-------	--------	---------
00	26.0	28.5	-2.5	00	26.0	28.5	-2.5
01	26.0	28.0	-2.0	01	26.0	28.0	-2.0
02	26.0	27.5	-1.5	02	26.0	27.5	-1.5
03	26.0	27.3	-1.3	03	26.0	27.3	-1.3
04	26.0	27.6	-1.6	04	26.0	27.6	-1.6
05	26.0	28.1	-2.1	05	26.0	28.1	-2.1
06	26.0	29.0	-3.0	06	35.0	29.0	6.0
07	26.0	30.4	-4.4	07	35.1	30.4	4.7
08	33.9	31.9	2.0	08	35.4	31.9	3.5
09	35.0	33.5	1.5	09	35.8	33.5	2.3
10	35.3	34.8	0.5	10	36.4	34.8	1.6
11	36.1	35.8	0.3	11	36.7	35.8	0.9
12	36.2	36.3	2.2	12	36.7	36.3	0.4
13	36.5	36.4	0.1	13	37.1	36.4	0.7
14	36.6	36.0	2.1	14	36.8	36.0	0.8
15	36.4	35.2	2.2	15	36.8	35.2	1.6
16	36.0	34.0	2.0	16	36.7	34.0	2.7
17	34.7	32.7	2.0	17	36.4	32.7	3.7
18	33.8	31.5	2.3	18	36.2	31.5	4.7
19	33.4	30.4	3.0	19	36.1	30.4	5.7
20	33.2	29.6	3.6	20	36.1	29.6	6.5
21	33.0	29.1	3.9	21	35.9	29.1	6.8
22	26.0	28.9	-2.9	22	26.0	28.9	-2.9
23	26.0	28.8	-2.8	23	26.0	28.8	-2.8

Source: Ecotect Thermal Analysis Software

The temperature difference between the traditional and contemporary envelopes can be attributed to the higher thermal mass of the traditional envelope's walls, which consist of a 350mm Laterite stone with an R-value of 1.525 m2k/W, compared to the contemporary envelope's 230mm brick walls with an R-value of 0.685 m2k/W. Additionally, the R-value of the traditional roof assembly, which includes an aluminum sheet roof, is higher at 4.68 m2k/W, whereas the contemporary roof with a PCC finish has an R-value of 0.424 m2k/W.

Moreover, the reflectance of the aluminum sheet roof in the traditional envelope is greater than that of the contemporary envelope's PCC finish roof. Additionally, the emissivity of the traditional roof is higher compared to the contemporary one. **All these factors collectively contribute to maintaining a lower temperature in the traditional envelope when compared to the contemporary envelope.**

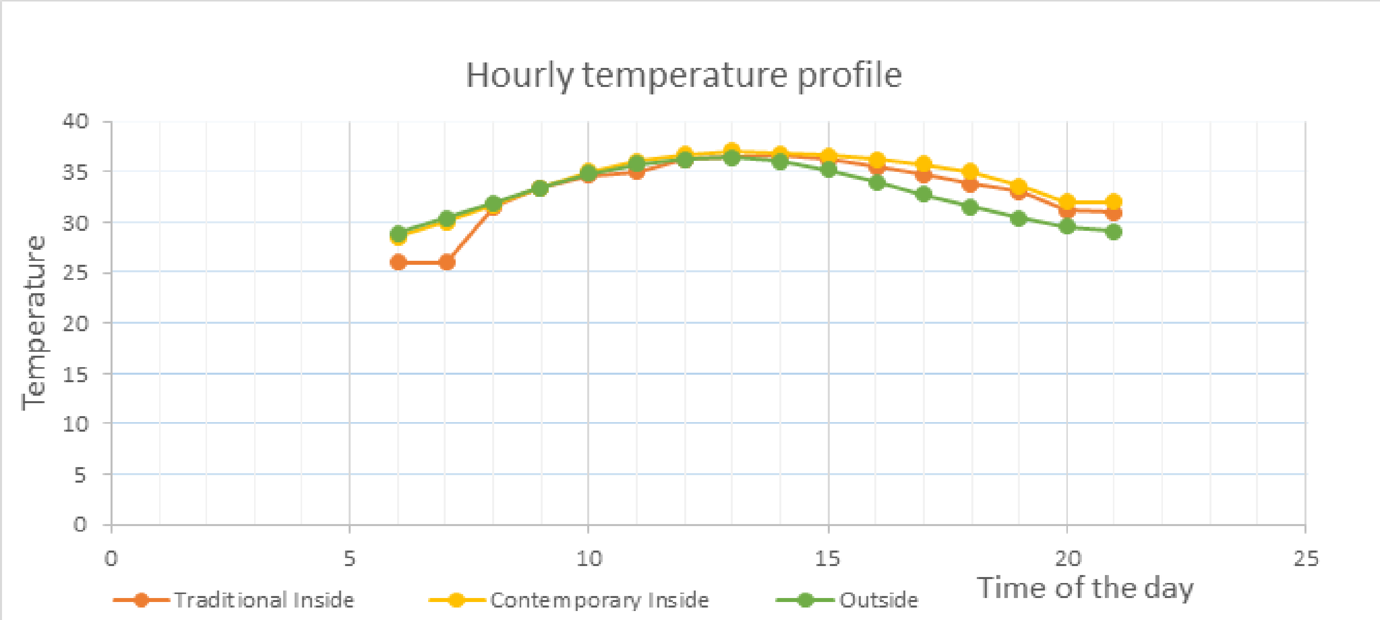


Fig 21 Comparative of Hourly Temperature Profile of Both the Envelopes
Source: Ecotect Thermal Analysis Software

The analysis of hourly heat gains/losses in both the traditional and contemporary envelopes reveals that the fabric gain in the traditional guest room is generally lower than its contemporary counterpart. This difference is more prominent from 7 am to 6 pm, during which the traditional guest room experiences gradual gains, primarily due to the high thermal mass of the walls and EPS insulation in the roof.

In contrast, the contemporary guest rooms exhibit a steeper slope of fabric gains after 7 am, primarily because of the lack of insulation on both the walls and the roof. This results in faster heat absorption and retention in the contemporary envelope compared to the traditional one.

Table 12 Comparative Passive Gains Breakdown for Both the Envelopes

Traditional Guestroom			Contemporary Guestroom		
Passive gains breakdown			Passive gains breakdown		
FROM: 1st January to 31st December			FROM: 1st January to 31st December		
CATEGORY	LOSSES	GAINS	CATEGORY	LOSSES	GAINS
-----------	-------	------	-----------	-------	------
FABRIC	4.4%	6.1%	FABRIC	2.2%	13.8%
SOL-AIR	0.0%	8.4%	SOL-AIR	0.0%	20.1%
SOLAR	0.0%	6.7%	SOLAR	0.0%	2.5%
VENTILATION	5.0%	7.5%	VENTILATION	0.8%	6.2%

Source: Ecotect Thermal Analysis Software

It is seen from the above table that the gains is more due to sol-air i.e. indirect solar gains in both the envelopes, but is much more in the contemporary envelope.

Based on the simulations' analysis, it is evident that the traditional guest room is more energy-efficient compared to the contemporary one. The traditional stone construction, with its higher thermal mass and roof insulation, resulted in a significant 17% energy savings compared to the contemporary construction.

However, further study and modifications in the contemporary guest room's envelope, such as altering the roof and wall properties, as well as adjusting fenestration characteristics like the R-value, emissivity, and absorptance parameters as per Table 8, can lead to a more energy-efficient contemporary envelope. By implementing these changes, the contemporary guest room's energy performance can be improved to approach or potentially surpass the efficiency of the traditional construction

In a one-story structure, a significant portion of the building's energy use is attributed to heat gain and loss from the roof and walls. Therefore, enhancing the insulation of both the roof and walls presents a considerable energy-saving potential.

To achieve improved energy efficiency in the contemporary guest room, the most effective approach is to insulate it. Insulation over the deck is preferable to under the deck since it prevents heat from entering the structure, resulting in better thermal performance and reduced energy consumption.

➢ *Green Roof Application*

The following points are considered for selecting green roof for retrofitting of the existing contemporary guestroom-

- *Building Energy Consumption*
- *Biodiversity and habitat*
- *Roof life*
- *Air quality*
- *Storm water runoff reduction*
- *Aesthetics and recreation*

➢ *The Thermal Properties of the Green Roof is Mention in the table below-*

Table 13 Thermal Parameters of Green Roof

Insulation	Thickness (m)	Thermal conductivity(k)	R-value (m2.k/W)
Gravel drainage layer (estimated as sand)	0.06	0. 27	0.24
Total assembly	0.1		2.15
Polyisocyanurate Insulation	0.05	0.02	2.13
RCC roof	0.175	1	0.42
Total	0.425	1.29	5.6

Enhancing insulation proves to be a highly effective energy-saving measure for surfaces characterized by high absorptance and low emissivity. **Consequently, a green roof appears to be the most suitable form of insulation.**

Regarding wall insulation, the simulation employed EIFS (External Insulation and Finish System) due to its over-the-deck insulation, which effectively prevents excess heat from penetrating the building's structure. The selection of EIFS was based on the following considerations:

- Over the deck insulation
- Green rated
- Moisture resistant.
- More energy efficient than under the board insulation

➢ *The Thermal Properties of EIFS is Mentioned in the table below:*

Table 14 Thermal Parameters of EIFS

Material	R value
230 mm brick wall	0.68
EIFS	4
Total	4.68

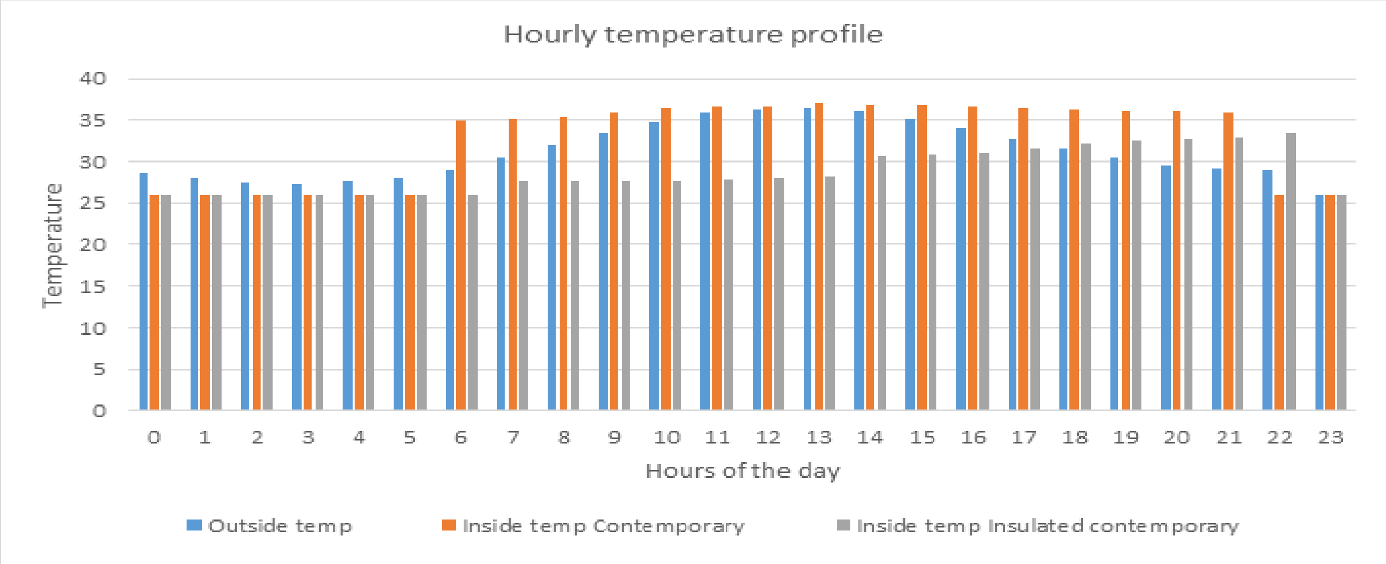


Fig 22 Comparative of Hourly Temperature Profile for Contemporary and Insulated Contemporary Envelopes

The graph illustrates a notable change in the hourly temperature profile of the insulated contemporary envelope compared to the non-insulated contemporary one. As a result of the insulation applied to the walls and roof, the hourly temperature profile of the insulated envelope is approximately 12% cooler than its non-insulated counterpart. Moreover, the average interior temperature decreases from 32.8°C to 28°C, even though the average daily outside temperature remains at 31.3°C, indicating an 8% reduction in interior temperature compared to the outside temperature.

VII. CONCLUSION

This thermal analysis parameter demonstrates that the insulated contemporary envelope outperforms the non-insulated contemporary one, making it a more favorable option for utilization in Matheran. The insulated envelope offers potential cost savings in cooling expenses, and the inclusion of a green roof helps maintain the ecological balance in the area.

In conclusion, this study delved into a comprehensive analysis of energy efficiency within the context of the hospitality industry, focusing on a comparative examination of two distinct envelope systems. Through an exploration of thermal insulation, air-tightness, solar heat gain, and overall energy performance, which sought to shed light on the intricate relationship between building and energy consumption.

In a world increasingly cognizant of the environmental impact of human activities, this study contributes to the growing body of knowledge supporting sustainable practices in the hospitality industry. By encouraging the adoption of energy-efficient envelope systems, this research paves the way for a more environmentally conscious and economically viable future for hospitality establishments in areas like Matheran which is an Eco sensitive zones, but due to abundance tourist influx.are bearing the burns of haphazard development.

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