Energy Optimization Techniques for Low Cost Building Using Design Builder

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Introduction

Energy consumption and greenhouse gas emissions to the environment attributed to buildings are significant contributors to this environmental impact. Massive construction activity is taking place globally to accommodate the migration of world's population to urban areas, a proportion that is expected to reach 60 per cent by the year 2030. Such a boom in construction is considerable factor in order to control global warming. The consumption of operational energy by buildings has the single largest impact on the environment. The building sector accounts for about 40% of total energy consumption and 38% of the CO_2 emissions in the U.S. About 27 per cent of the emissions in Great Britain are attributed to the building.

In India, rapid increase in residential building stock, coupled with increase in electricity use for space conditioning, is resulting in rapid increase in electricity use in residential buildings. Another important aspect is thermal comfort, which is of utmost importance in all kinds of housing, but more so in case of affordable housing, so as to ensure health and well-being of the occupants. BEE envisaged a phased approach for the development of the residential building energy conservation code. Making houses energy efficient is certainly a way of avoiding a long term futile electricity consumption liability in residential buildings.

Green buildings often include measures to reduce energy consumption, both the embodied energy required to extract, process, transport, and install building materials and the operational energy. Operational energy is the energy consumed during the in-use phase of a building's life to provide necessary services such as heating, cooling and providing power for equipment. Thermal aspect of the building operational energy is one of the key points to be investigated since it has the main proportion of operational energy consumption of the buildings. The thermal aspect of energy consumption can be reduced by using high-efficiency windows and insulation in walls, ceilings and floors which increases the efficiency of the building.

Keeping these above in view, the purpose of doing this research is to undertake a case study of a RC building and evaluate its energy demand with the protocols for performing the modeling of the building components using BIM tools. Using this protocol or tools, analysis of materials of few components like windows, doors, False ceiling, green path around the building can be done and refinement can be suggested after the investigation. This includes the modification of each component which affects the overall operational energy consumption of the building. Hence keeping the significance of this study in vies following objectives have been formulated.

Objectives

- To identify the energy consumption of conventionally used building material for EWS housing.
- To suggest different Green buildings building material having low U value for for EWS housing.

Review of Literature

A systematic and through review of literatures related to problem under this study helps in analyzing the problems, its historical status and its present status. The available review of literature isfocused on the promotion of energy efficiency in buildings.

Rosaria etal.(2020) studied on Waste Management and Operational Energy for Sustainable Buildings**.** Construction and demolition waste account for a significant part of the solid waste taking up landfills on a global scale. A considerable portion of the waste generated by the construction industry has substantial residual value, and therefore waste management and sustainability principles and techniques should be applied. Buildings consume a lot of energy during the operations phase,but decisions made during design and construction impact building operations.

Sarkar and Bardhan, 2020 conducted a study case on Socio-physical liveability through socio-spatiality in low-income resettlement archetypes of slum rehabilitation housing in Mumbai, India
This study looks into the socio-physical liveability through socio-spatiality in low-income settlement archetypes. Paradoxically, recently mushrooming slum rehabilitation housing which have delivered secured tenure to its inhabitants, face threats of being deserted from lack of socio-physical liveability. Recurring of informality issues has advocated to investigate the reasons behind the 'rebound' phenomenon. This study explores the efficacy of socio-spatiality and its linkages with socio-physical live ability, taking Mumbai slum rehabs as case study. A comparative analysis of the current built-environment indicators and liveability status of major informal archetypes was performed, followed by analyses of the socio-physical problems associated with it. While analysing the 'rebound' phenomenon, this study delivered a heuristics of socio-physical liveability, built-environment and their respective indicators. This method would aid the architects, planners and policymakers in reshaping the forth-coming built-environment while safeguarding the socio-physical liveability of the low-income sector.

Tarabieh and Khorshed(2019) carried out a study on Optimizing Evaluation Methods for the Embodied Energy and Carbon Management of Existing Buildings in Egypt. They found that There is an increasing demand for the decarbonization of existing buildings. Thedevelopment of standardized calculation methods has simplified calculation processes andenabled wider engagement with the topic. As the industry advances, optimization and accountingfor regional differences will increase in importance. The aim of the method was to assist in the renovation of existingbuildings by guiding the decision-making process through the proposed evaluation framework. Alocal case study of an existing multi-story apartment building was used to create a baseline fortypical local multi-story residential buildings and demonstrated the effectiveness of the proposedevaluation method. This framework provides the owners of buildings with a decision-makingprocess by which carbon impacts associated with future renovations and operations of existingbuildings can be minimized.

Koezjakov, etal, (2018) conducted a study on the relationship between operational energy demand and embodied energy in Dutch residential buildings. Reducing heat demand of buildings, due to legal and technological advances in the EU, shifts the ratio of operational vs. embodied energy towards an increasing share of the latter. This leads to a shifting focus on building materials (embodied) energy use. In this study the relationship between heat demand and embodied energy use was investigated, using Dutch residential buildings as a case study. The analysis was performed using the 3SCEP HEB (Center for Climate Change and Sustainable Energy Policy High Efficiency Buildings) model and a constructed Embodied Energy Database Management System (EEDMS), containing embodied energy use of materials most common in Dutch residential construction. The resulting embodied energy use in Dutch dwelling archetypes varies from 52 to 106 MJ/(m^2·a), annualized over building lifetimes and 3.0 to 6.4 GJ/m^2 in total. These values are for the building construction and exclude recurrent embodied energy and technical installations. For operational energy use the range is 124 to 682 MJ/(m^2·a). A total energy use reduction of 36% can be reached in 2050 through 46% reduction in operational energy use and 35% increase in embodied energy use, compared to 2015. This research confirms that the relative importance of embodied energy use is increasing: the embodied energy use in standard homes is about 10–12% of the total energy use, while it is 36–46% in energy efficient homes. Particularly in light of the goal to reach a maximum global temperature increase of well below 2 °C by 2100, it is important to include embodied energy use in future policy objectives.

Methodology

Modelling steps for housing built up plan.

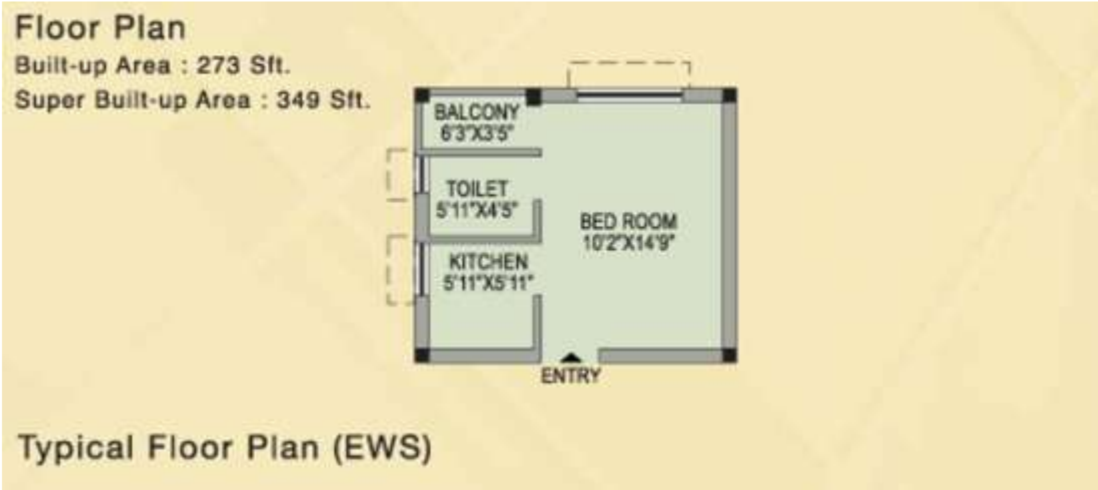
First of all we have to be clear about building geometry. This includes the outer shape of the building, fenestration pattern, shading devices, roof profile. all the part of the building will come in building geometry. Hence for the same building which have taken as simulation model in simulation software- design builder.

We have specified material for roof and wall, internal partions. All the opaque materials described here for their u values for their surface properties, specific heat, heat capacity, thickness ,layers of materials. Design buider software alredy have the thermal properties of these individual materials in built in to the software the moment we select the different layers ,it automatically calculate the U value for the selected combination of the material including all the layers.

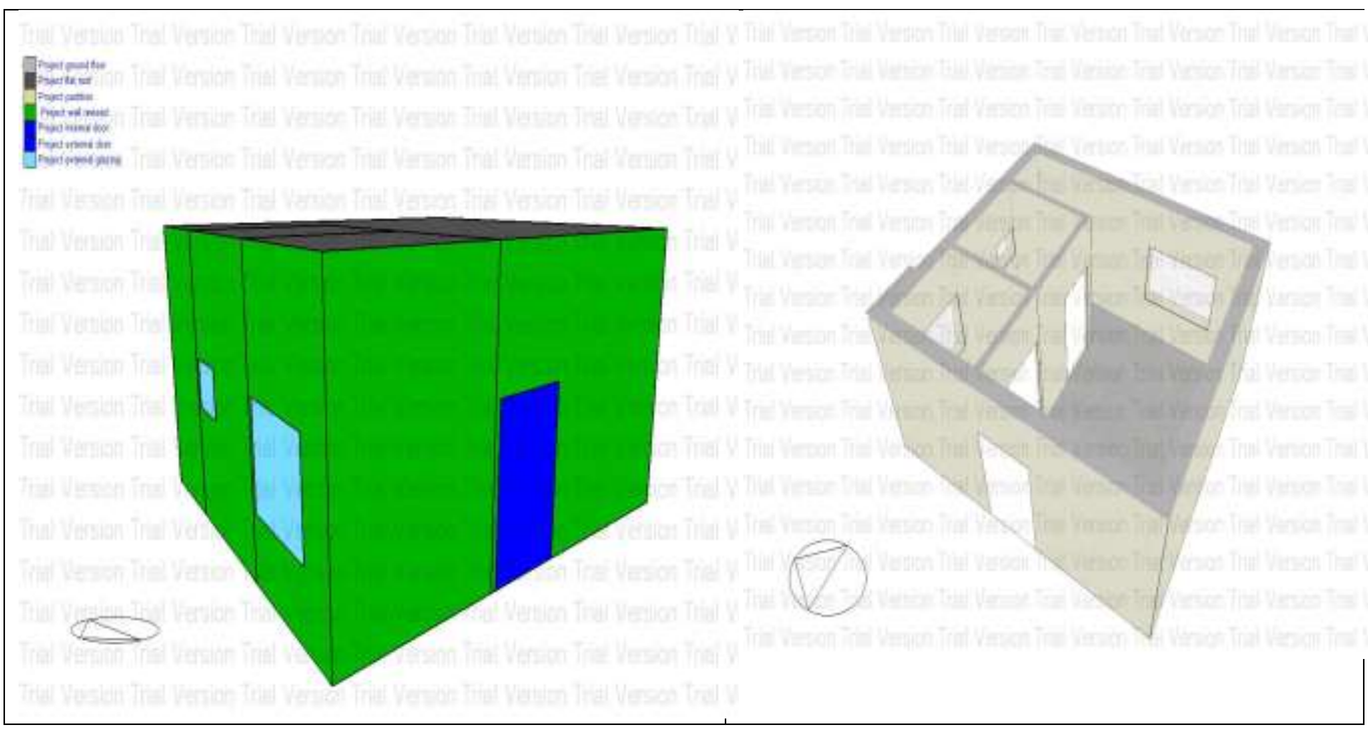
However if we want to use a material which is not defined in the material library, in that case the material specifications of thermo physical properties for the new material to be used. Then it has to be tested and those value has to be put in and a new material will have to be created which will then help us to calculate the U value of the combination of these material. These properties are essential because the moment we talk about energy simulation and the exchange of heat through the material. Then only new material and the properties of these materials has to be defined. After that proved this new material used as a better material for providing more insulation or will be batter for energy efficiency of the building overall.

The building geometry in the software has been made with adding windows as a part of the building geometry. Automatically the window wall ratio and orientation has been taken care. Glazing details of the windows which include U value, SHGC for the glass used should be defined and selected. Materials for the frames can also be defined as per the user.

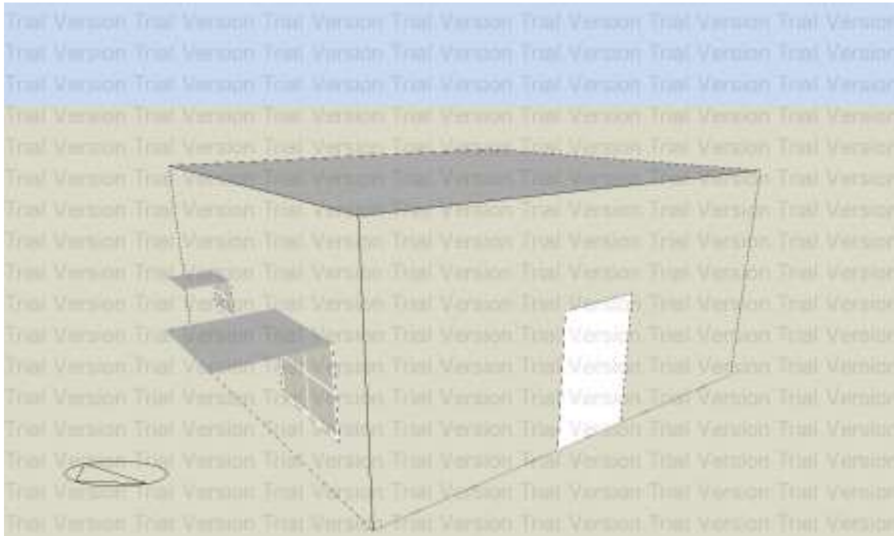
Occupancy schedule for a building which is going to be constructed which is proposed is to be defined as per the user's requirements. At first a design of residential building has been prepared client 4 person to 6 persons maximum. Defined occupancy schedule i.e the time the uilding is occupied. Then designed a 24 hr occupied residential building. This directly affected the internal heat gain. After that defined the space uses pattern of the building (for example: kitchen, toilet,living room etc). Most impotantly, before starting a whole building simulation, we have to specify the location of the building and its climate. A standard code i.e. ASHRAE Standard 90.1 has been used for creating a base case and have taken a building plan for EWS class as per govt. guidelines. This plan is provided below. As per the specification of the plan a building have been developed and modeled in the software.



The plan of the building have been taken as provided by state governments have been collected and modeled in Design builder software. Boundary conditions are set manually based on the conditions and utility of the houses planned. The orientation of the building will have to defined the location, country and climate properties will also be fed in the software.



(MODEL VIEW)



(RENDERED VIEW)

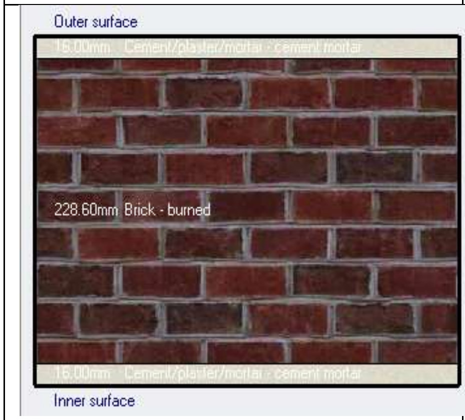
Material Properties of building envelope

The rate of heat transfer through building envelope is affected by properties of building materials. Heat flow across a building envelope depends on thermal conductivity and thickness of the material. Heat flow decreases with increase in thickness of the material. The thermal transmittance (U-value) determines the rate of heat transfer through a building element, Lower the U-value, the better the insulation is.

Physical and thermal properties of building envelope

Building envelope	**Construction**	**U value (W/m2-K)**
Wall	**Exterior Wall** 16 mm Plastering+228.60 mm Brick Burned+16 mm Plastering	2.069
	Interior wall 16 mm Plastering+228.60 mm Brick Burned+16 mm Plastering	**2.069**
Roof	150 mm cement concrete-dense-reinforced	4.567
Floor	100 mm concrete-medium weight +70 mm floor screed+6 mm clay tiles	1.959
Window	Single glazing, clear, shading provided	1.924

Image of the building envelop of base case

<table>
<tr><th>wall</th><th>roof</th><th>floor</th></tr>
<tr><td>
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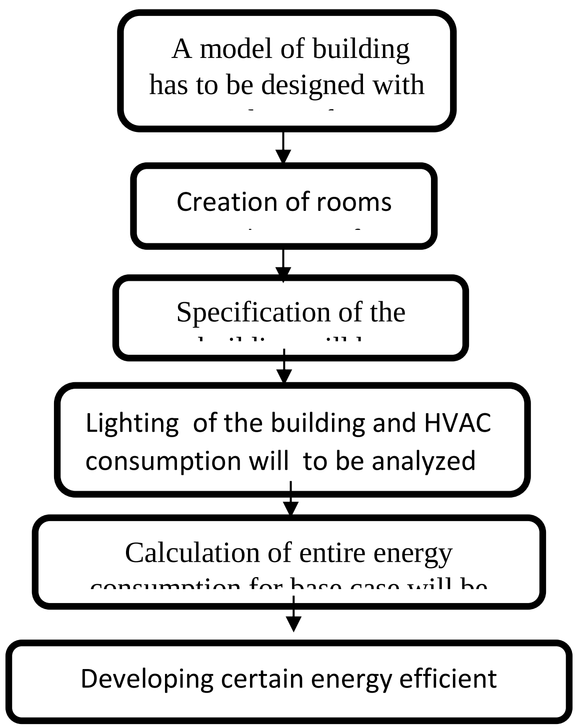
Selections of cities for thermal comfort analysis

Selection of Locales

Two locations with different climatic conditions have been considered for the project to analyse the effectiveness of the materials and their positions. These locations are:

- BHUBANESWAR(Hot and Humid)
- KOTA(Hot and dry)

Steps for building energy simulation



The same building was simulated for all the 4 cities we have taken in to consideration.
3.5 extracted simulation output for analysis. There were the three types of simulation that can be run in this software. They are 1.heating, 2.cooling,3.simulation for whole year. The result we got after simulating the base case model building has been recorded. These results are extracted for analysis and stored for comparison with the proposed case results. There are many type of results like comfort graph, heat gain graph, heat loss graph, internal gain graph etc. are provided after simulation.

Results

Simulations were run on design builder software using for a year and data has been collected and Monthly comfort data is shown as output.
Local climate results of cities

i. Bhubaneswar

The thermal comfort of a building depends on various outdoor weather conditions and therefore a climate study of the location is required. The weather data file for Bhubaneswar was downloaded from the Energy Plus website and imported to Climate Consultant 6.0 software to study the temperature data and the psychometric chart. The large range of thermal conditions, i.e. cooling in summer and heating in winter requires utilization of both radiation and wind effects and protection from them.

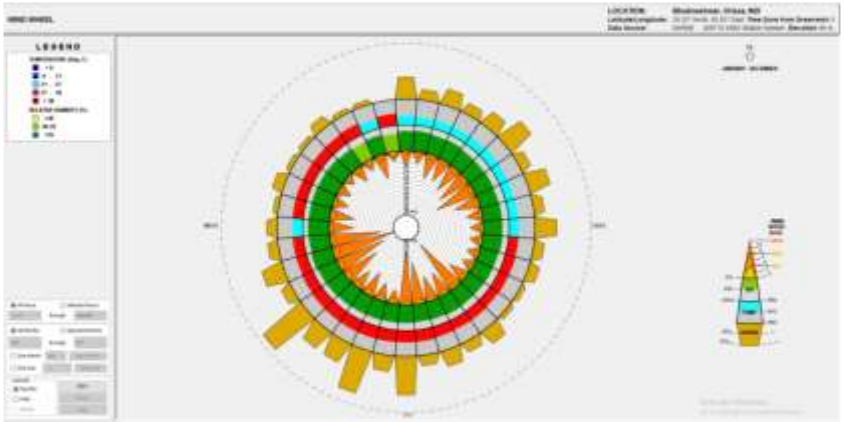
Temperature Data:

Bhubaneswar experiences a Hot and Humid climate with major changes in temperature between summer and winter. The city experiences four distinct seasons -Spring (January -February), Summer (March -August), Fall/Autumn (September -October), and Winter (November -January), along with the monsoon season setting in towards the latter half of the summer. The maximum daytime temperature in summers is in the range of 33–44 ºC, and night-time values are from 26 to 31 ºC. The values are between 20 to 35 ºC during the day and10 to 17 ºC at night in winter.

Fig.1Temperature Range (Climate Consultant)

Wind Wheel

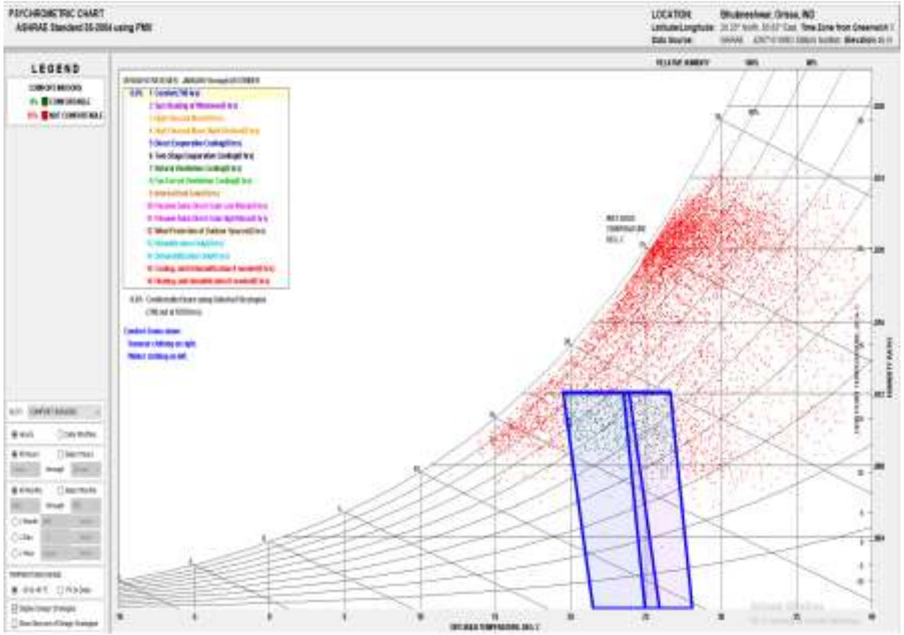
The wind wheel incorporates wind velocity and direction data along with temperature and relative humidity. For the study, monthly wind data throughout the year is studied.



Wind Wheel (Climate Consultant)

Psychometric Chart

A psychometric chart is a useful graph developed by Givoni(1976) for determining the thermal parameters of air. By measuring DBT (dry bulb temperature) and WBT (wet bulb temperature), it becomes easier to understand the indoor and outdoor air conditions. Strategies are devised accordingly to understand the applicable air conditioning processes such as cooling, heating, humidification, dehumidification, and combination.

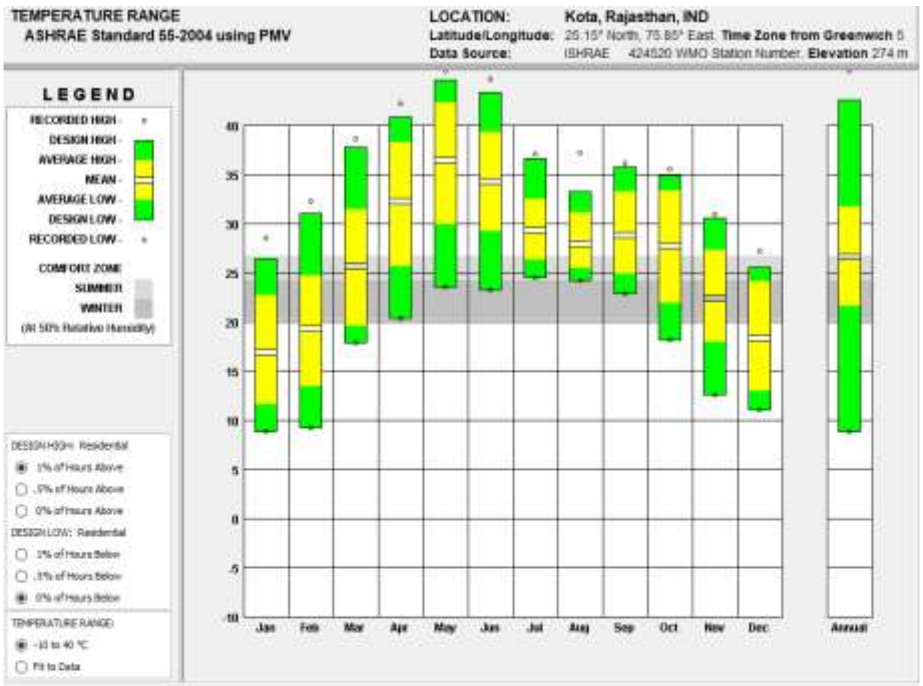


Psychometric Chart (Climate Consultant)

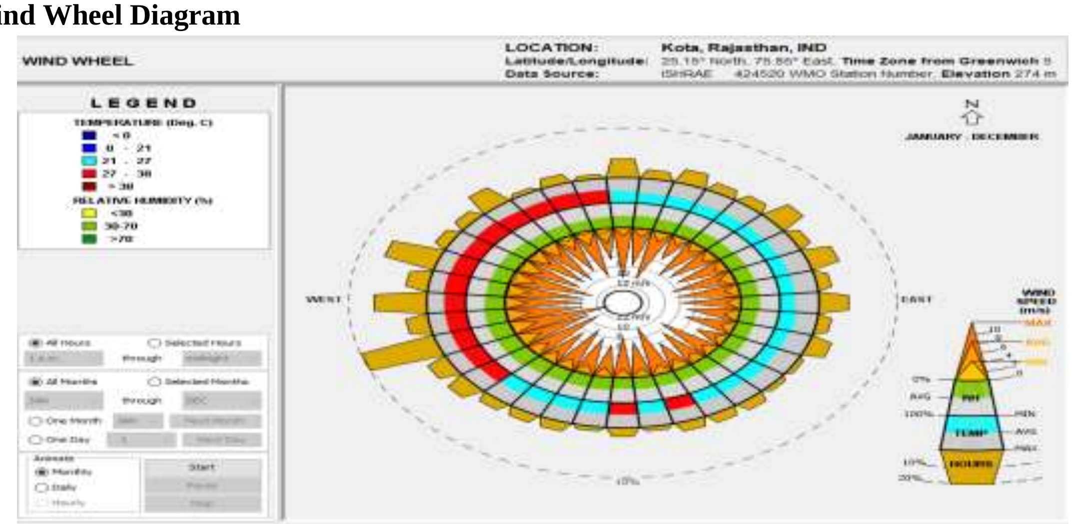
Kota

Temperature Data

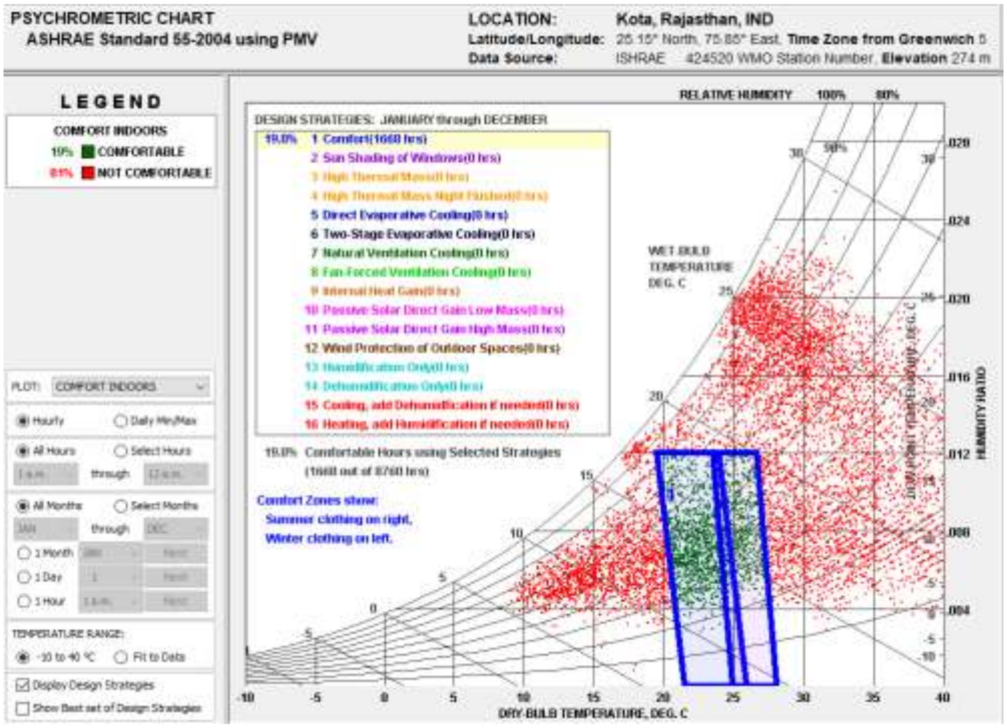
Kota experiences a Hot and Humid climate with major changes in temperature between summer and winter. The city experiences four distinct seasons -Spring (February -March), Summer (April -August), Fall/Autumn (September -October), and Winter (November -January), along with the monsoon season setting in towards the latter half of the summer. The maximum daytime temperature in summers is in the range of 33–42 ºC, and night-time values are from 26 to 31 ºC. The values are between 8 to 20 ºC during the day and 2 to 10 ºC at night in winter.



Wind Wheel Diagram



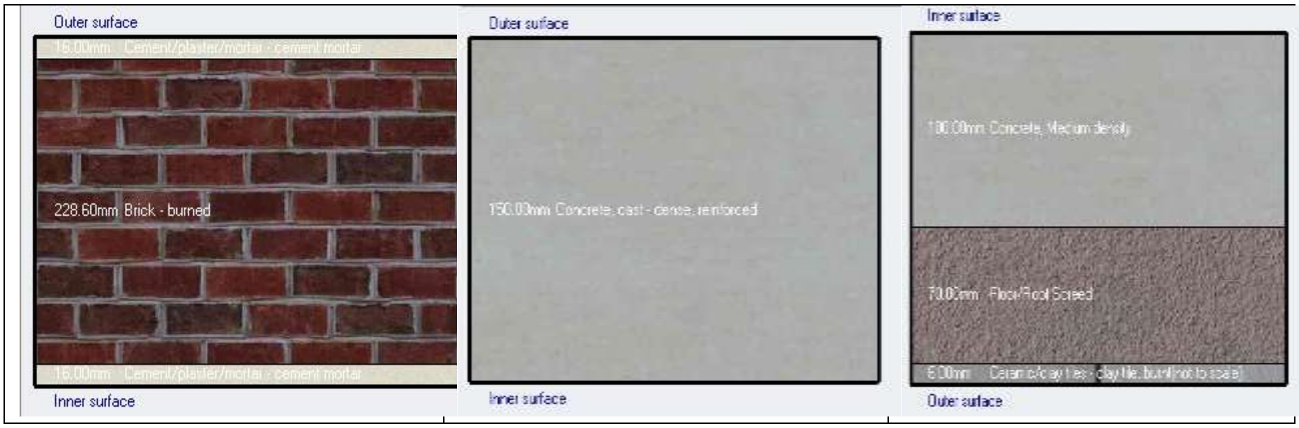
Psychometric Chart



Calculation for baseline model

Modelling is done for base case is done and simulation results are provided as below.
Wall ,roof and floor specification is provided as below.

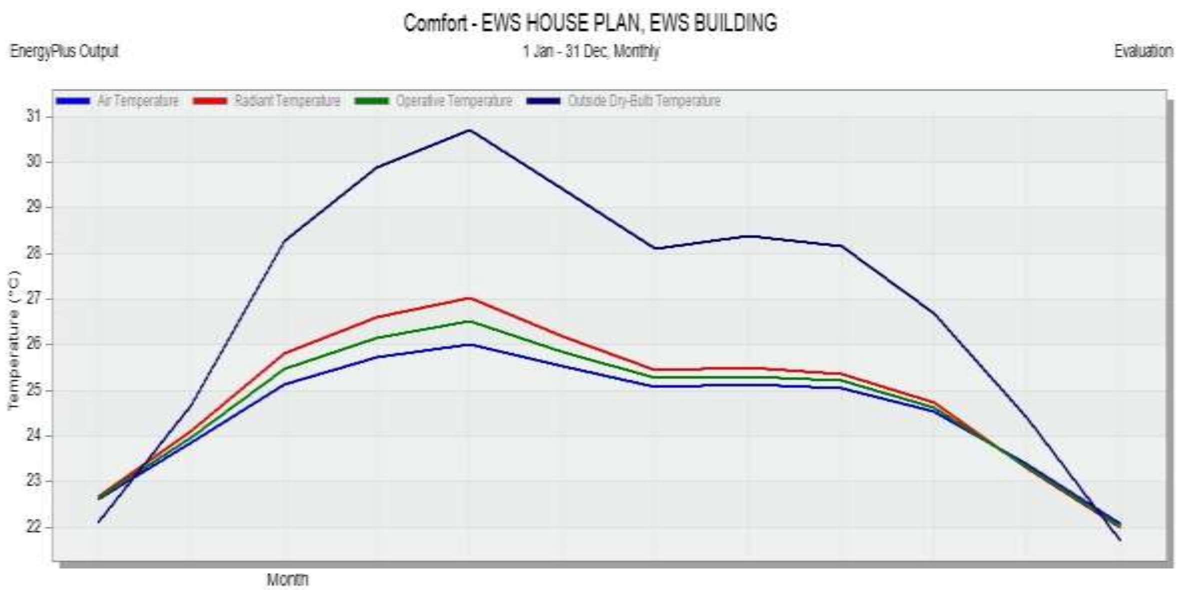
wall	roof	floor



Simulation Results for Bhubaneswar(Base case)

Comfort model

This model has been made to set a benchmark for the rest of the cases.



Air Temperature (°C)	22.63	23.87	25.13	25.72	26.01	25.52	25.08	25.13	25.04	24.54	23.38	22.07
Radiant Temperature (°C)	22.68	24.10	25.82	26.59	27.03	26.18	25.45	25.50	25.37	24.73	23.29	22.00
Operative Temperature (°C)	22.65	23.99	25.48	26.15	26.52	25.85	25.27	25.31	25.21	24.64	23.33	22.03
Outside Dry-Bulb Temperature (°C)	22.10	24.69	28.27	29.88	30.70	29.40	28.10	28.39	28.17	26.69	24.39	21.72
Relative Humidity (%)	63.02	65.25	68.88	74.22	73.53	81.62	84.98	85.45	86.57	83.12	82.41	69.97

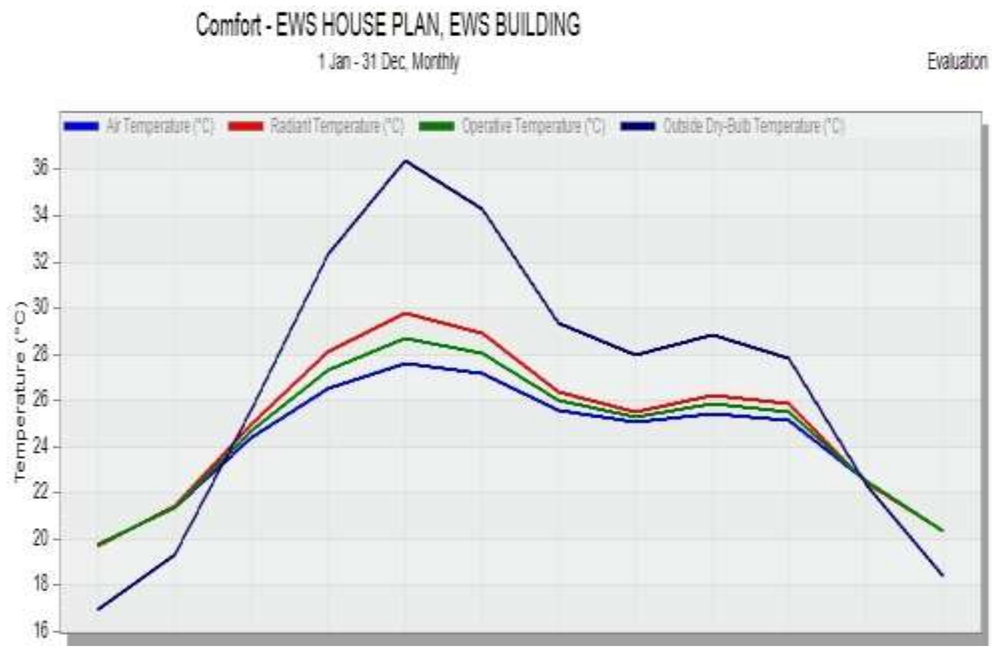
Energy consumption

Total enrgy consumption for whole year	3257.40 kWh

Simulation Result for Kota(Base case)

Comfort model

This model has been made to set a benchmark for the rest of the cases



EnergyPlus Output — 1 Jan - 31 Dec, Monthly — Evaluation

Month												
Air Temperature (°C)	20.24	22.18	25.68	28.22	29.57	28.99	27.04	26.39	26.87	26.53	23.64	21.06
Radiant Temperature (°C)	20.36	22.58	27.09	30.96	32.98	31.95	28.81	27.72	28.66	28.21	24.04	21.24
Operative Temperature (°C)	20.30	22.38	26.38	29.59	31.28	30.47	27.92	27.06	27.77	27.37	23.84	21.15
Outside Dry-Bulb Temperature (°C)	16.93	19.33	25.68	32.31	36.40	34.32	29.33	27.99	28.84	27.80	22.41	18.35
Relative Humidity (%)	44.67	37.97	40.04	37.35	38.81	49.51	65.09	69.95	58.16	39.75	60.84	45.14

Energy consumption

Total energy consumption for whole year	6266.21 kWh

Proposed Model for BHUBANESWAR

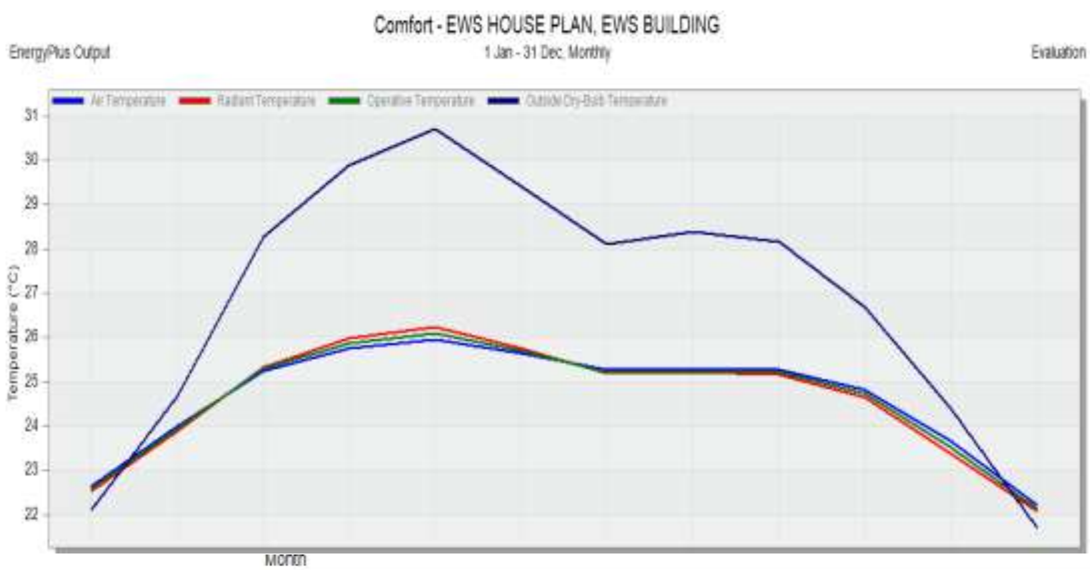
Proposed case 1:

We have changed the wall and roof material to see the improvement incomfort and energy consumption.we used expanded polystyrene of thickness 30 mmin between the reinforced concrete slab and plaster .in case of walls we have used AAC blocks in place of brunt clay bricks.

Then the model has been simulated for comfort results

Comfort graph of case 1:



Air Temperature (°C)	22.64	24.00	25.25	25.77	25.96	25.63	25.27	25.30	25.26	24.82	23.65	22.23
Radiant Temperature (°C)	22.52	23.88	25.33	25.97	26.23	25.75	25.19	25.22	25.16	24.65	23.39	22.06
Operative Temperature (°C)	22.58	23.94	25.29	25.87	26.10	25.69	25.23	25.26	25.21	24.74	23.52	22.15
Outside Dry-Bulb Temperature (°C)	22.10	24.69	28.27	29.88	30.70	29.40	28.10	28.39	28.17	26.69	24.39	21.72
Relative Humidity (%)	63.05	65.53	70.61	76.81	76.95	85.04	89.36	90.09	90.85	85.71	82.86	69.49

energy consumption

Total enrgy consumption for whole year for proposed case 1	2124.26 kWh
Total enrgy consumption for whole year for base case	3257.40 kWh

Proposed case 2:

In this case we have used eps panel on the both side of the brick wall before plaster is applied and we applyiedeps panel on the outer surface of the rainforced concrete roof.floor material remains the same.

Then the model has been simulated for comfort results and energy consumption.

Comfort graph for proposed case2:

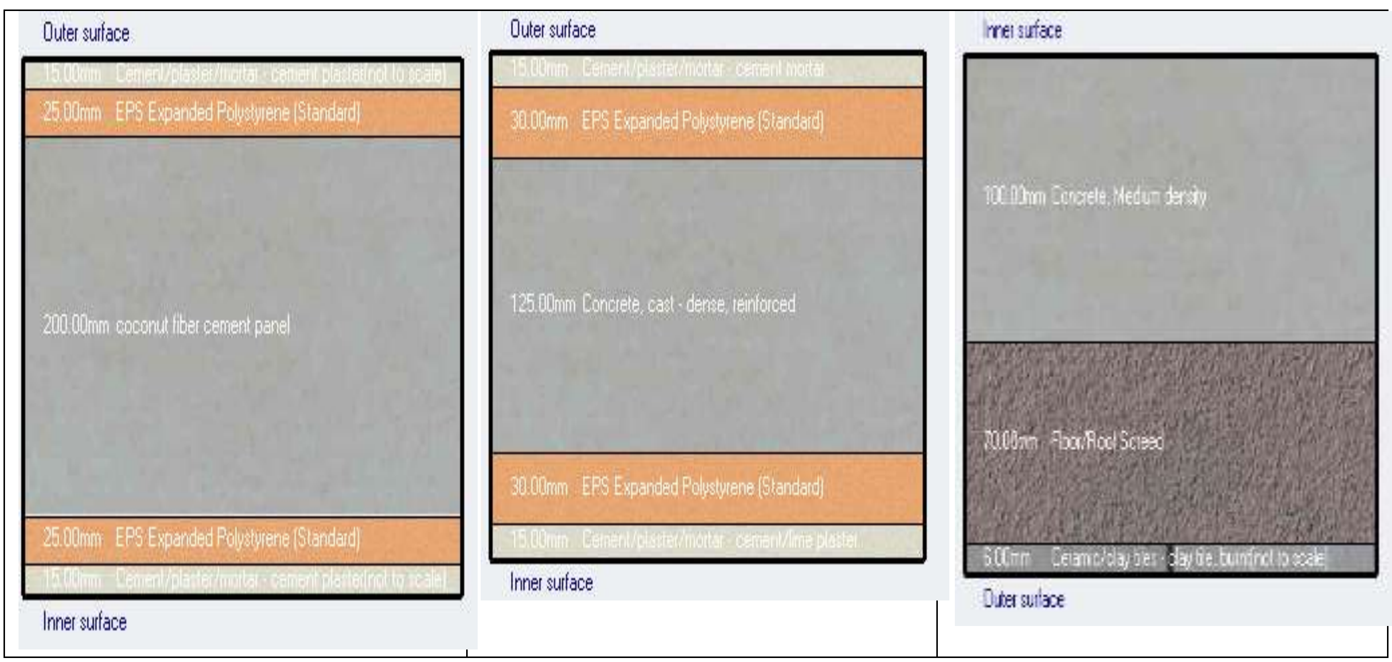
Month												
Air Temperature (°C)	22.52	24.01	25.31	25.85	26.05	25.70	25.30	25.34	25.27	24.73	23.57	22.08
Radiant Temperature (°C)	22.37	23.89	25.37	26.07	26.35	25.84	25.23	25.26	25.17	24.53	23.30	21.89
Operative Temperature (°C)	22.44	23.95	25.34	25.96	26.20	25.77	25.27	25.30	25.22	24.63	23.43	21.98
Outside Dry-Bulb Temperature (°C)	22.10	24.69	28.27	29.88	30.70	29.40	28.10	28.39	28.17	26.69	24.39	21.72
Relative Humidity (%)	63.45	65.41	70.10	75.99	76.25	84.82	89.47	90.22	90.98	86.85	83.34	70.13

energy consumption

Total enrgy consumption for whole year for proposed case 2	2033.59kWh
Total enrgy consumption for whole year for base case	3257.40 kWh

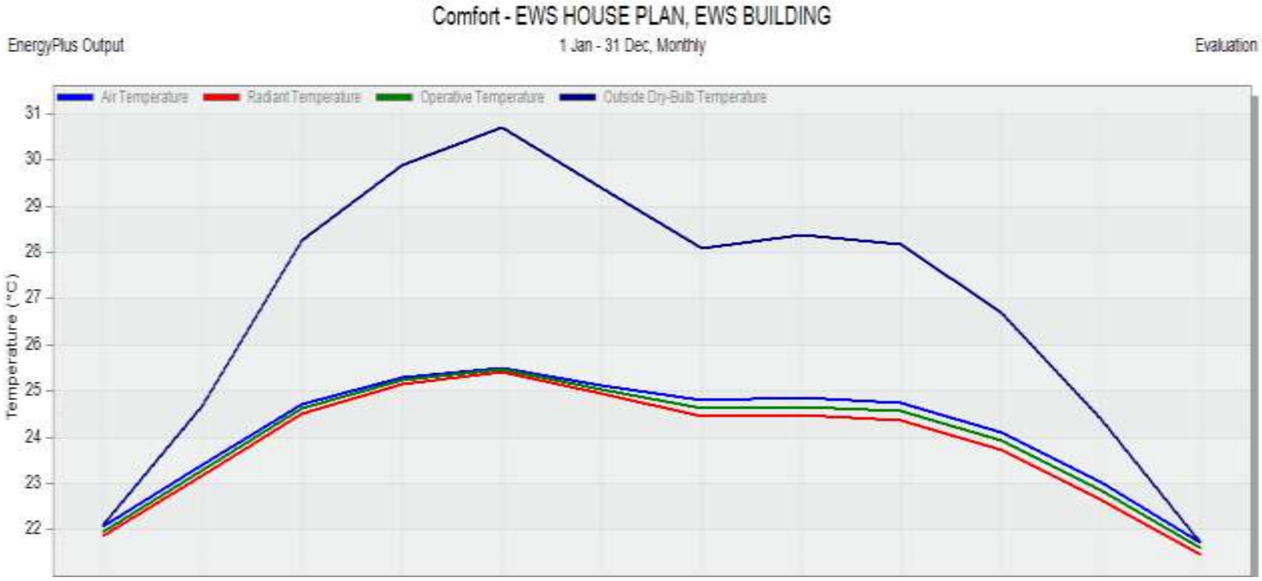
Proposed case 3:

In this case we have used a composite material called coconut fibre cement concrete in wall replacing brunt bricks.for roof we used eps layers on the both side of the rainforced concrete slab.floor remains the same.the same is illustrated below in figures.



Then the model has been simulated for comfort results and energy consumption.

Comfort graph for proposed case3:



Month

Air Temperature (°C)	22.06	23.40	24.72	25.30	25.50	25.13	24.80	24.85	24.74	24.11	23.02	21.71
Radiant Temperature (°C)	21.87	23.16	24.51	25.16	25.41	24.93	24.45	24.49	24.37	23.73	22.66	21.47
Operative Temperature (°C)	21.96	23.28	24.62	25.23	25.46	25.03	24.62	24.67	24.56	23.92	22.84	21.59
Outside Dry-Bulb Temperature (°C)	22.10	24.69	28.27	29.88	30.70	29.40	28.10	28.39	28.17	26.69	24.39	21.72
Relative Humidity (%)	65.38	68.43	75.58	82.85	82.21	89.61	94.81	95.31	95.46	90.58	85.73	71.76

energy consumption

Total enrgy consumption for whole year for proposed case 3	1519.03 kWh
Total enrgy consumption for whole year for base case	3257.40 kWh

Comparison of Energy Optimization

Bhubaneswar	**Reduction in energy consumption (%)**
Case 1	34.78
Case 2	37.57
Case 3	53.36
Kota	**Reduction in energy consumption (%)**
Case 1	60.66
Case 2	61.93

Case 3	70.62

Conclusion

From the above study it has been observed that use of conventional building materials leads to more consumption and does not support sustainable building design. After analysing the comfort graphs, it is quite evident that the Expanded Polystyrene showed the required optimum results when placed on the outer surface of the wall. Between all the three proposed cases the third cases for both the cities give significant reduction in energy consumption for EWS housing.

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