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Optimizing Thermal Comfort and Energy Efficiency in Block 4 KITSW Using Insulation Materials and Solar Radiation Analysis: A Case Study

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Abstract
This research investigates the potential for enhancing thermal comfort and energy efficiency in Block IV, the Administrative Building at KITSW, Warangal. In light of the increasing prominence of sustainable building practices, evaluating strategies for optimization is imperative. Leveraging Building Information Modelling (BIM) software and advanced sustainability analysis tools, a data-driven approach is employed. The methodology unfolds through a multi-phased process. Initially, a comprehensive 3D model of the building is crafted within Revit software, incorporating data from 2D CAD drawings and detailing materials, dimensions, and layout. Subsequently, employing a cloud-based tool, an exhaustive solar radiation analysis ensues, juxtaposing scenarios with existing and optimal insulation materials. This analysis discerns potential thermal vulnerabilities and scrutinizes solar exposure variations across the year. Further, within the BIM environment, a digital energy model is synthesized to scrutinize the building's energy consumption and daylighting conditions meticulously. This model integrates intricate details of the building's geometry, materials, and operational dynamics. Simulations are executed to pinpoint areas ripe for enhancing energy efficiency. Through systematic analysis of data gleaned from each phase, this research endeavors to uncover strategies for optimizing thermal comfort and energy efficiency in Block IV. The insights garnered are poised to inform tangible improvements in sustainability not only for this particular building but also for analogous educational facilities, thereby contributing to the broader discourse on sustainable building practices.

Keywords: Thermal Comfort, Energy Efficiency, BIM, Sustainability, Solar Radiation Analysis, Energy Analysis

1. Introduction

The environment is greatly impacted by the construction sector. The usage of resources, energy use, and the general balance of ecosystems are all impacted by buildings (1). This study investigates the relationship between building practices and their effects on the environment. Our research examines the connection between a building's environmental impact and sustainable design principles with a particular focus on Block-4, the administrative building at KITSW (35). Our goal is to demonstrate how carefully considering important factors like solar radiation absorption/insulation, energy efficiency, and GRIHA certification requirements may reduce the environmental impact of construction (1, 4).In today's energy-conscious world, optimizing a building's sensitivity to solar radiation is essential (35). This study simulates solar radiation absorption within Block-4's envelope using Revit's Insight 360 plugin (36). We can pinpoint places where insulation techniques need to be improved by comparing the average insulation values obtained by the study following the completion of this simulation (28). This will assist us in creating strategies to reduce heat gain, which will ultimately increase occupant comfort and energy efficiency (11, 16).

An additional crucial component of sustainable building is energy efficiency (35). We will examine state-of-the-art instruments and techniques to lower Block-4's energy use (28). We will investigate tactics such as enhanced insulation, better lighting controls, and the use of renewable energy sources (23). Our ultimate goal is to create a plan for a greener building that uses less energy and has a smaller carbon footprint (8). The goal of this study is to determine how to apply for GRIHA green certification for an existing building (35). A building's performance is assessed on a range of environmental factors, such as energy efficiency and solar radiation response, for GRIHA certification (31). We can determine what has to be done to improve Block-4's existing performance in order to fulfill or approach qualifying for this esteemed green building certification by comparing it to the GRIHA requirements (33). This strategy will highlight the possibility of sustainable building retrofits for already-existing structures. Thermal comfort and energy efficiency are hampered by the high levels of solar radiation absorption/insulation and energy consumption caused by the building materials used in Block-4, the KITSW administrative building (35). The building finds it challenging to meet the esteemed GRIHA certification requirements because of its inefficiency (32). The objective of this study is to determine the best insulating materials (OIM) and tactical material selection techniques to enhance Block-4's energy efficiency and thermal performance (28). The building can save running costs and its environmental effect while improving occupant comfort by accomplishing these objectives (29). The project is driven by the growing demand for sustainable buildings, especially in the field of education (35). Buildings at universities and colleges can make a big difference in accomplishing this goal of encouraging environmental responsibility (35). One of the best examples of an existing construction that could be made significantly more sustainable is Block-4, the administrative building at KITSW (35). The building materials used in Block-4 currently contribute to high levels of solar heat gain and energy consumption, which causes discomfort for residents and increases the building's environmental impact (29).

The goal of this project is to use the widely accepted green building standard, GRIHA certification, as a baseline for the sustainable transformation of Block-4 (31). Obtaining GRIHA accreditation would show KITSW's dedication to sustainability in the academic community while also improving the building's environmental efficiency (32). Through smart material selection and optimization of solar radiation absorption, this research seeks to find solutions that increase Block-4's energy efficiency and thermal comfort (28). In addition to helping KITSW, the effective application of these solutions will support a larger trend in the educational sector toward the use of sustainable building techniques (35). The following goals were pursued by this case study on KITSW's administrative building, Block-4 (35):

Improve Energy Efficient and Thermal Comfort: Examine how well the building is currently absorbing solar radiation and using energy. Determine where improvements can be made to make the living space more comfortable for the occupants while lowering the total energy consumption. Selecting Strategic Materials to Ensure GRIHA Compliance: To assess how various materials affect solar radiation absorption and energy efficiency, use comparative material analysis, or CM Analysis. The objective of this investigation was to determine the best insulating materials (OIM) for current structures that meet GRIHA

certification requirements. Optimize GRIHA Certification ability: Determine whether Block-4 has the ability to achieve GRIHA's solar radiation and energy efficiency requirements by comparing the Study Average Insolation Value (SAIV) of OIM alternatives versus conventional materials (CM). Lower Building Energy Consumption and Costs: Assess how carefully chosen materials will affect the building's overall Energy Use Intensity (EUI) and energy costs. The aim was to exhibit a discernible decrease in energy usage and related expenses by means of sustainable material enhancements.
An essential component of this initiative was the data-driven analysis of energy (28). We started by gathering data regarding the building plans and materials currently in use in Block-4. Afterwards, simulations using Revit's Insight 360 plugin helped to comprehend how the building will react to solar heat gain all year long (28). An energy consumption baseline was created by this data. We then performed Comparative Material Analysis (CM Analysis) to evaluate the effects of various materials on energy efficiency and solar radiation absorption/insulation (28). The performance of the conventional materials (CM) now in use in Block-4 and the optimal insulating materials (OIM) was compared in this investigation (29). Throughout the analysis, the Study Average Insolation Value (SAIV) was a crucial statistic (28). To compare SAIV attained with various material combinations, simulations were run (28). We were able to identify important construction elements that had the most effects on the amount of solar radiation absorbed by analyzing SAIV (28). The elements with the biggest potential for energy savings—windows, walls, and floors—became the focal points for planned material upgrades. Based on the outcomes of the CM Analysis, the project then assessed Block-4's likelihood of meeting GRIHA's energy efficiency requirements (28). Creating a sustainable material replacement plan that gave priority to parts that would have the biggest effects on lowering energy usage and obtaining GRIHA compliance was one aspect of this (28). Lastly, an analysis was conducted to determine how these material replacements affected the building's Energy Use Intensity (EUI) (28). EUI was a key indicator used to show how well the suggested material changes worked to lower overall energy consumption (28).

2.Experimental program

2.1 General information

This research endeavors to delve into the complexities of enhancing the energy efficiency and thermal comfort levels of Block-IV, the Administrative Building at KITSW in Warangal. Leveraging state-of-the-art sustainability methodologies and Building Information Modeling (BIM) software, the study embarks on a multi-faceted journey aimed at significant improvements in the building's environmental performance. The initial phase involves an exhaustive data collection process, meticulously gathering crucial information regarding Block-IV from various sources [28, 31]. This includes detailed blueprints, dimensions, and structural compositions of the building, drawing upon insights gleaned from prior studies. Subsequently, armed with this comprehensive dataset, the research team undertakes the task of constructing a highly accurate 3D model of Block-IV within a BIM environment [28]. This phase is critical as it lays the foundation for the subsequent analytical stages by providing a detailed representation of the building's physical attributes.
Moving forward, the study embarks on a thorough investigation into the building's solar radiation exposure patterns throughout the year, a process informed by the findings of previous research endeavors [32, 33]. This analysis aims to shed light on how varying levels of sunlight impact the internal temperature dynamics of Block-IV. Moreover, insights from past studies on innovative insulation materials are incorporated, offering valuable guidance on potential solutions [2, 35]. In parallel, the research team

initiates an intricate energy usage simulation exercise for Block-IV, drawing upon the insights gleaned from prior energy modeling research endeavors [3, 39, 41]. By meticulously examining a myriad of factors such as building design elements and material compositions, the objective is to identify actionable strategies aimed at curbing energy consumption while simultaneously enhancing occupant comfort levels. By integrating these diverse approaches, the overarching aim of this research endeavor is to formulate pragmatic solutions geared towards bolstering the energy efficiency and thermal comfort attributes of Block-IV. Through a systematic and data-driven approach, the study seeks to unlock tangible opportunities for enhancing the overall environmental performance of the administrative building at KITSW.

2.2 Research plan

This project aims to implement a data-driven approach to improve the thermal comfort and energy efficiency of Block-4 at KITSW, Warangal. By leveraging advanced sustainability research tools and Building Information Modeling (BIM) software, the study endeavors to identify key design alterations that can significantly reduce energy consumption while enhancing occupant comfort. The research methodology consists of several integral stages, each contributing to a comprehensive analysis of Block-4's environmental performance. Firstly, detailed information regarding Block-4, including blueprints, size, composition, and arrangement, will be gathered to create an accurate 3D model using BIM software. Additionally, data on the building's location, surroundings, and existing materials will be collected to inform subsequent analyses. Next, a thorough solar radiation analysis will be conducted to understand how sunlight affects Block-4's heat intake and potential solar energy utilization. This analysis will consider factors such as the building's orientation and geometry to evaluate the year-round effects of solar exposure and identify thermal weaknesses. Simulations will be run in two scenarios: one using current building materials and another with optimized insulation choices.

Furthermore, an assessment of Block-4's daylighting and energy usage will be carried out using a digital energy model created in the BIM program. This model will accurately represent the building's shape, materials, and operational features, enabling simulations to evaluate energy efficiency and identify areas for improvement. The project's scope includes several key components. Firstly, a detailed solar radiation analysis will be conducted to understand its impact on Block-4's energy performance. Secondly, an assessment of the thermal characteristics of the building envelope materials will be conducted to identify optimal substitutes with higher insulation values. Thirdly, simulations in the Revit environment will simulate the effects of swapping out envelope materials to assess their impact on energy efficiency and thermal comfort. Additionally, the project will explore the possibility of obtaining GRIHA certification for pre-existing structures like Block-4, indicating KITSW's commitment to environmental responsibility. This certification could enhance the institution's reputation and attract environmentally conscious stakeholders. Overall, this study offers a comprehensive strategy for improving Block-4's thermal comfort and energy efficiency, with potential benefits including decreased energy usage, improved thermal comfort for occupants, and the possibility of GRIHA accreditation. The insights gained from this research will inform future decisions regarding Block-4's management and contribute to KITSW's sustainability efforts. Table 1 provides a concise compilation of abbreviations used throughout the case study, aiding in clarity and consistency of terminology.

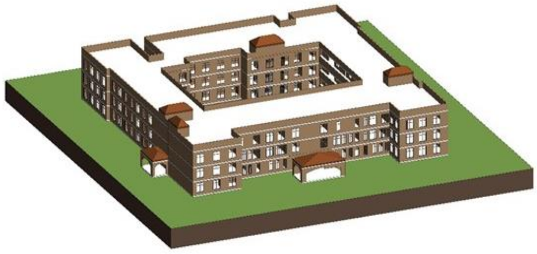

Fig. 1. 3D model of Block-4

Table 1 Abbreviations

Abbreviations	
CM	Conventional Materials
OIM	Optimal Insulating materials
S'F	Stilt Floor
GF	Ground Floor
FF	First Floor
SF	Second Floor
SAIV	Study Average Insolation Value

2.3 Materials

To evaluate the thermal properties of materials utilized in Block-IV of KITSW's Administrative Building, covering walls, roof, windows, and flooring, this study employs two tables (Tables 2 and 3). These tables delineate between optimal insulating materials recommended for enhanced thermal performance (OIM Analysis) and the current conventional materials employed in construction (CM Analysis). Table 2 outlines the characteristics of each material, including type, behavior (isotropic), density, emissivity, permeability, thermal conductivity, and specific heat. Thermal conductivity indicates how efficiently a material conducts heat, with lower values denoting better insulation. Specific heat represents the energy required to raise the temperature of a unit mass by a specific amount, while density reflects mass per unit volume. Permeability measures the ease of gas or liquid movement through a substance, and emissivity indicates the surface's heat radiation emission efficacy. Distinguishing between ordinary and ideal insulating materials for the same building component (e.g., Wall) reveals disparities. For instance, Fly Ash bricks (OIM Analysis) demonstrate considerably lower thermal conductivity for walls compared to Common bricks (CM Analysis), indicating superior insulation potential. Similarly, Double Glazed windows (OIM Analysis) exhibit lower thermal conductivity than Clear Glazed windows (CM Analysis). The comprehension of building envelope heat transfer characteristics and assessment of potential impacts from optimal insulating materials usage on thermal performance hinge on this solar radiation analysis.

Table 2 Thermal Properties of Envelope Materials-Conventional

	Slab	Wall	Window	Flooring	Roof	Units
Material (CM Analysis)	Concrete cast in place	Common bricks (Earthern)	Glass : Clear glazed Frame: Iron	Porcelain tiles	Concrete roof tiles	-
Behaviour	Isotropic	Isotropic	Isotropic	Isotropic	Isotropic	-
Thermal conductivity	0.6044	0.312	0.6356	0.6933	0.6044	btu/(hr.ft.°F)
Specific Heat	0.1569	0.2006	0.2006	0.203	0.1569	btu/(lb.°F)
Density	143.58	96.76	154.82	124.86	143.58	Pound per cubic foot
Emissivity	0.95	0.95	0.95	0.9	0.95	-
Permeability	3.1881	3.1881	0	0	3.1881	grain/(ft²·hr·inHg)

Table 3 Thermal Properties of Envelope Materials-Optimal Insulating Materials

	Slab	Wall	Window	Flooring	Roof	Units
Material (OIM Analysis)	Light weight Concrete	Fly Ash Bricks	Glass :Double glazed Frame: Aluminum	Ceramic tiles	Cool roof	-
Behaviour	Isotropic	Isotropic	Isotropic	Isotropic	Isotropic	-
Thermal conductivity	0.1208	0.5	0.7	1.2	0.0693	btu/(hr.ft.°F)
Specific Heat	0.1569	0.24	0.23	0.235	0.3009	btu/(lb.°F)
Density	59.31	75	154.82	130	31.84	Pound per cubic foot
Emissivity	0.95	0.85	0.85	0.87	0.85	-
Permeability	3.1881	3.1881	0	0	0.6117	grain/(ft²·hr·inHg)

In this study, the analysis of the building design's daylighting and thermal performance is conducted using the dynamic visualization capabilities of Insight 360, as elaborated by Wang et al. (2023) [27]. This advanced software tool enables a comprehensive evaluation of how daylighting and thermal aspects interact within the building environment, as highlighted in previous research [27]. Two main mechanisms are utilized to achieve this analysis. First, colour schemes are assigned to building surfaces, with dynamic changes reflecting projected surface temperatures, as proposed by Wang et al. (2023) [27]. These colour schemes serve as a visual representation of thermal conditions within the building, providing valuable insights into areas of potential thermal discomfort and highlighting regions prone to overheating. This approach facilitates strategic design decisions aimed at enhancing thermal comfort within the building, as emphasized by Wang et al. (2023) [27]. By providing an intuitive representation of thermal conditions,

designers can quickly identify areas requiring adjustments and optimize the building's design accordingly. The dynamic colour representation allows for easy interpretation of thermal performance, guiding the design process towards solutions that promote occupant comfort and energy efficiency, in line with the objectives outlined in previous studies [27]. The colours used to represent different energy quantities are illustrated in Figure 2, which depicts the Surface Colour Representation of Study Average Insulation Values in the Revit Simulation. This figure serves as a visual aid, demonstrating how different colours correspond to varying levels of thermal insulation across building surfaces. This visualization tool enables researchers and designers to gain a comprehensive understanding of thermal performance and make informed decisions to optimize building design for enhanced comfort and energy efficiency.
Furthermore, it's important to note that the simulation described above was conducted within the Insight 360 plugin of Revit software, as detailed by Wang et al. (2023) [27]. Insight 360 provides a powerful platform for performing detailed analyses of building performance, including daylighting and thermal characteristics, as highlighted in previous studies [27]. By leveraging the capabilities of Insight 360, researchers can accurately simulate various aspects of building behavior and assess the impact of design choices on energy efficiency and occupant comfort. The integration of Insight 360 within the Revit environment streamlines the analysis process and enables seamless collaboration between architects, engineers, and other stakeholders involved in the building design process. This simulation environment offers advanced visualization tools and intuitive interfaces, allowing users to explore complex data sets and evaluate design alternatives effectively. The utilization of Insight 360 within Revit enhances the efficiency and accuracy of building performance analysis, facilitating informed decision-making and enabling the creation of sustainable, high-performance buildings.

Fig. 2. Surface Colour Representation of Study Average Insulation Values in Revit Simulation

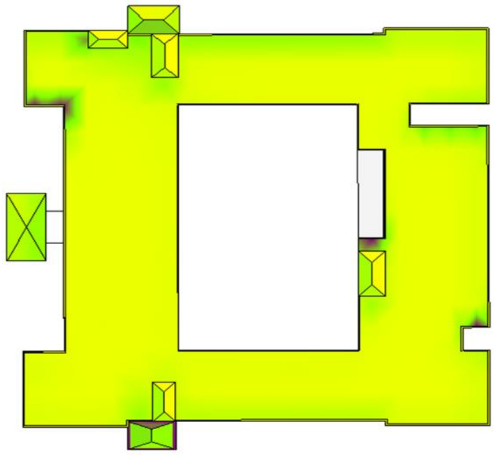

Fig. 3. Post CM Analysis Interface-Top View

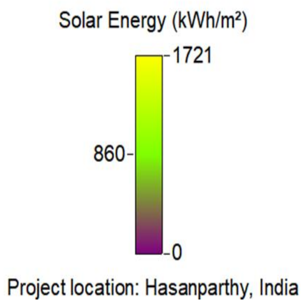

Fig. 4. Cumulative Insulation Indicator(CM Analysis)

2.4 Methodology

Getting 2D CAD drawings of the structure from the project office is the first stage. All four stories, including the ground floor, should have their layout and measurements accurately depicted in these drawings. It is needed to carefully go over the plans once we obtain them in order to extract important characteristics like the building's footprint, overall dimensions, sizes and positions of windows and doors, wall configurations with thicknesses, and roof specifics like pitch and orientation. Using Revit software, this gathered data will serve as the basis for producing an accurate 3D model of the building. Revit software is used to generate a 3D model of the KITSW Administrative Block using the data that was retrieved from the 2D CAD drawings. The geometry of the building, including all of the walls, floors, roof, windows, and doors, will be accurately portrayed in this model. The finished Revit model in .rvt format will be used as the main starting point for additional CM Analysis related to sustainability. To guarantee the correctness of the findings, more information must be gathered before performing a thorough CM Analysis using Autodesk Insight. Three primary categories apply to this data: materialistic conditions, thermal properties, and geographical data.

Geographical data contains the latitude and longitude of the construction site as well as local meteorological data, including annual patterns of solar radiation. The density, specific heat capacity, and thermal conductivity of the materials that make up the building envelope (windows, roof, and walls) are all considered thermal characteristics. Building codes or material specifications may include references to these characteristics. Last but not least, physical circumstances include information on the building envelope's current insulation levels and any nearby shade structures, including trees or overhangs.

Important details about the materials used in the building envelope can be found in the Revit model itself. From the model, we may extract tables with these materials' distinctive features. In the CM Analysis stage, this data—which is usually based on a pre-defined library of standard materials in Revit—will be essential for accurately assigning thermal values to the building elements as shown in the Table 2 and 3 above. In order to conduct an analysis of sustainability factors, including solar radiation, energy saved and received, and energy consumed by the four-story KITSW Administrative Building, also known as Block IV. The Figure model, which needs to be examined closely, depicts the area of the structure. The study's objectives are to evaluate KITSW's administrative block's potential for solar radiation and energy efficiency. We can carry out a thorough CM Analysis after finishing the modelling of the structure in the .rvt format as illustrated in Figure 1 and using an internal program called Insight, a component of the Autodesk 360 suite. This study employs Insight 360's dynamic visualization capabilities to conduct a thorough analysis of the building's Energy efficiency and solar radiation absorption or insulation will be two main mechanisms used. Colour schemes for building surfaces will be assigned, and they will change dynamically in response to projected surface temperatures. Strategic design decisions are guided towards greater thermal comfort by this easy-to-understand representation, which quickly reveals potential thermal hotspots and susceptible areas that could overheat. The colours that are being used for different energy quantities are shown in Figure 4. The Post Solar Radiation CM Analysis and the Overall 2 Analyses come first. The first analyzes the structure using the current, conventional materials utilized in Warangal, Telangana, and the second CM Analysis is carried out by substituting the materials with those listed in Table 2. The cumulative indicator for insulation values for the envelope components that were the subject of the CM Analysis is displayed in Figure 4. Similar to this, Figure 2, except the csv file that is extracted after the solar research is completed, depict the Post CM Analysis Interface and the colour scheme that is used to visually display the insulating values. Figures 2 depicts the Post Analysis Insulation Interface from every angle, demonstrating the same thing except for OIM Analysis, which is carried out following the ideal kind of material modification. The Export window, which appears after entering the necessary data set and allows the SAIV (Study Average Insulation Value) to be compared with individual cases, is shown in Fig. 5.

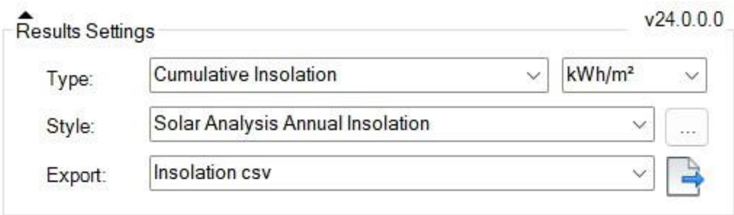

Fig. 5. SAIV Export Interface

This case study constitutes one of eleven cases considered, aiming to identify optimal materials and components for enhancing the heat gain or insulation of Block IV's envelope components. Each case undergoes similar methodology, utilizing data-driven insights to evaluate and optimize the building's thermal performance. Through comparative analysis and visualization tools, the study aims to provide actionable recommendations for enhancing the sustainability and energy efficiency of the KITSW Administrative Block.

Assessing a building model's energy performance is a necessary step in studying the energy CM Analysis in Revit. Making well-informed design choices to increase energy efficiency can benefit from this. KITSW Block IV's physical model was built to scale using the architectural drawings that the College

Project Office supplied. Strict attention to the blueprints guaranteed an accurate depiction of the building's dimensions. Using Autodesk Revit software, a digital energy model was created to examine KITSW Block IV's energy performance.

This model was created by taking advantage of the built-in features of the software to extract precise geometric data from the architectural plans of the building. To ensure a realistic portrayal of the physical structure, this comprises specifications for the roof assemblies, walls, and windows.Additionally, based

Total Walls area in Block IV of KITSW	**11220 m^2**
Walls area(Stilt floor) in Block IV of KITSW	**2891 m^2**
Walls area(Ground floor) in Block IV of KITSW	**2777 m^2**
Walls area (First floor) in Block IV of KITSW	**2771 m^2**
Walls area (Second floor) in Block IV of KITSW	**2781 m^2**
Total Slab area in Block IV of KITSW	**13398 m^2**
Total number of windows present in the building	**239**
Total Area of Windows in the building	**332 m^2**
Area of Block IV of KITSW	**3040 m^2**

on the project documents, pertinent material attributes and building details were assigned. This thorough model provides the required input data for specialized software tools and acts as the basis for later energy CM Analysis simulations. These resources make it easier to assess KITSW Block IV's daylighting and energy use in-depth, which helps to provide a comprehensive picture of the building's energy efficiency. The energy model of the block IV can be observed in fig(7) in which it is generated by Revit before starting analysis.

Setting boundaries for energy One crucial step in making sure the simulated performance faithfully depicts the real building and its surroundings in Autodesk Revit is CM Analysis. Ts close to the current Block IV of KITSW, which is Hasanparthy, Hanamkonda as observed in fig (6) , by providing important information regarding building location.

Table 4 (Area of Envelope Components of Block IV)

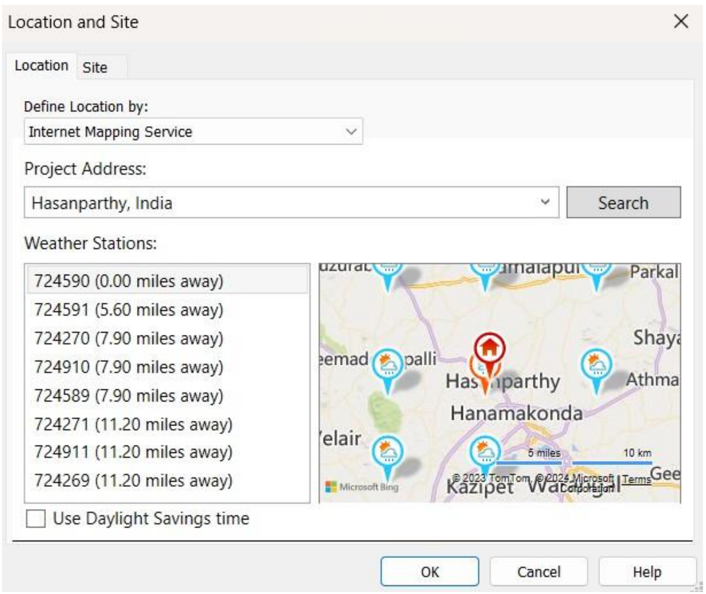

Fig.6.Selection of Location and site in Revit

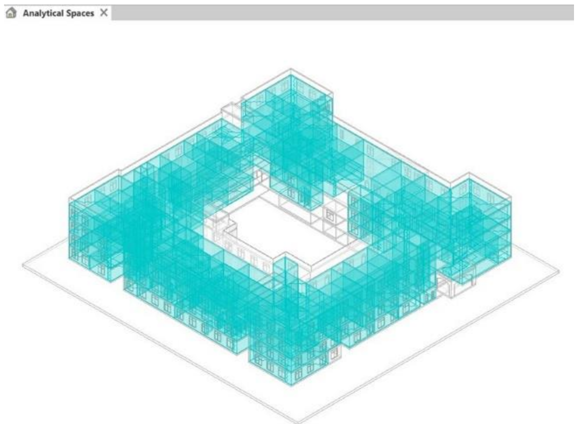

Fig.7.Energy model of KITSW BLOCK IV in Revit

In order to ensure that the CM Analysis is roughly accurate, the materials listed in the table are assigned to the building as precisely as possible based on the actual construction materials at the time. The materials for the panels and frames around the windows are chosen separately; the walls throughout the structure are made of mud bricks or roughly earth bricks; the flooring on the first, second, and roof floor is distinct, as shown in table 4. Executing energy CM Examining a college building in Autodesk Revit requires careful setup of several parameters to ensure a simulation that faithfully replicates the actual architecture. The project phase and building type must be specified during this process.The project phase selected for this research is "Existing Building," denoting a CM Analysis of a structure that has already been built. Moreover, the building type is designated as "School or University." Next, choose the energy settings and set the infiltration class to medium, meaning that air can enter the building through medium air openings. Next, choose the year-round school building operation schedule, which is appropriate for the building that is currently being analysed , allowing Revit to use pertinent default settings and parameters specific to educational facilities. Upon optimizing the subsequent building selection process for CM Analysis, the software proceeds to automatically navigate to the Autodesk Insight module. Comprehensive information about the building's energy performance, including annual cost evaluations and Energy Use Intensity statistics, is provided by this integrated dashboard.Normally Energy use intensity is calculated by multiplying No.of units with cost per unit in the region.

3 Results and discussion

3.1 Solar Radiation Analysis

After considering the modifications as indicated and conducting the simulation. The effect of using optimal insulating materials (OIM) over conventional materials (CM) on the building's thermal performance, as measured by the Study Average Insolation Value (SAIV), is summarized in this table. The acronym SAIV stands for the total building's average projected solar heat gain value. Better thermal performance is indicated by lower SAIV values, which may also result in less energy being used for cooling by lowering heat uptake from solar radiation. The SAIV for different building components built with CM or OIM is displayed in the table. The following are some important conclusions from each component's CM Analysis: Walls (Cases 2-5): SAIV can be greatly decreased by upgrading the walls on the stilt floor (S'F), ground floor (GF), first floor (FF), and second floor (SF) using the best insulation materials. Buildings with big sections of wall exposed to direct sunshine will especially benefit from this. Slabs (Case 6): A reduced total SAIV can be achieved by using appropriate insulation in slabs (floors) on all floors. This is particularly crucial for hot climates or structures where the ground floor slab allows heat to enter the building. Windows (Cases 7–10): A significant decrease in SAIV can be achieved by substituting better insulated options (OIM) for conventional windows on the stilt floor (S'F), ground floor (GF), first floor (FF), and second floor (SF). The amount of solar heat gain from windows can be substantial, and replacing them can greatly increase thermal comfort. Case 11: Flooring By lowering the amount of heat transmission into the building from the ground or lower floors, using the best insulating materials for flooring on all floors can improve thermal efficiency. This is especially important for structures in warm regions.

Table 4

Case Number	Component	Floor	Case	Material	Study Average Insolation Value (kWh/m²)
1	**CM**	**All Floors**	**Baseline**	Conventional Materials for All Components	567.79
	OIM	**All Floors**	**Target**	Optimal Insulating Materials for All Components	545.95
2	**Walls**	**S'F**	**CM**	Common bricks (Earthern)	564.24
	Walls	**S'F**	**OIM**	Flyash bricks	543.98
3	**Walls**	**GF**	**CM**	Common bricks (Earthern)	570.00
	Walls	**GF**	**OIM**	Flyash bricks	546.00
4	**Walls**	**FF**	**CM**	Common bricks (Earthern)	561.60
	Walls	**FF**	**OIM**	Flyash bricks	539.21
5	**Walls**	**SF**	**CM**	Common bricks (Earthern)	559.84
	Walls	**SF**	**OIM**	Flyash bricks	536.76
6	**Slabs**	**All Floors**	**CM**	Concrete cast in place	567.20
	Slabs	**All Floors**	**OIM**	Lightweight concrete	545.95
7	**Windows**	**S'F**	**CM**	Clear glazed	560.25
	Windows	**S'F**	**OIM**	Double glazed	537.70
8	**Windows**	**GF**	**CM**	Clear glazed	562.50
	Windows	**GF**	**OIM**	Double glazed	539.90
9	**Windows**	**FF**	**CM**	Clear glazed	557.75
	Windows	**FF**	**OIM**	Double glazed	534.40
10	**Windows**	**SF**	**CM**	Clear glazed	555.00
	Windows	**SF**	**OIM**	Double glazed	532.23

11	**Flooring**	**All Floors**	**CM**	Porcelain tiles	567.18
	Flooring	**All Floors**	**OIM**	Ceramic tiles	545.09

Case 1: CM vs OIM-All Floors (All Components)

CM (Conventional Materials): When all of the building's components—such as the walls, windows, floors, and other elements—are made of conventional materials, the average solar heat gain for the entire structure is represented by this value (567.79 kWh/m²). OIM (Optimal Insulating Materials): If all building components were constructed with optimal insulating materials, the average solar heat gain for the same building would be represented by this value (545.95 kWh/m²). The comparison of the aforementioned aspects is shown in Figure. We can understand the possible advantage of choosing the best insulation materials by comparing these numbers. The 21.84 kWh/m² discrepancy between CM (567.79 kWh/m²) and OIM (545.95 kWh/m²) indicates that utilizing the best insulating materials for every building component might considerably lower the overall solar heat gain. This decrease in heat gain may result in better occupant thermal comfort and possibly less energy use for building cooling.

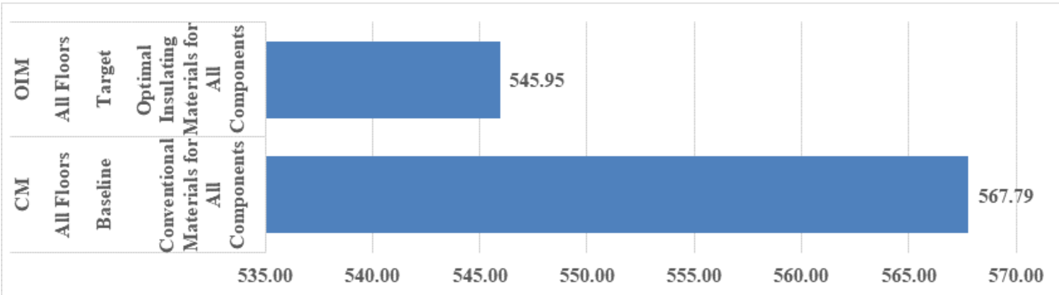

Fig. 10. Impact of OIM (All Floors) on SAIV - CM vs. OIM(KWh/m^2)

Case 2: CM vs OIM-S'F (Walls)

The impact of wall insulation on the Study Average Insolation Value (SAIV) for the building's Stilt Floor (S'F) is the main topic of this case study. Two situations are compared in the figure: CM (Conventional Materials): The estimated SAIV when just the walls on the S'F are built using conventional materials is represented by this value. Conventional materials are used for the roof, floors, and windows, among other parts. OIM (Optimal Insulating Materials): If the walls were built with the best insulating materials while all other elements stay the same, this value would indicate the predicted SAIV for the S'F. The graphic illustrates the SAIV difference between CM and OIM for walls, highlighting the possible advantage of choosing the best insulation materials specifically for the walls on the S'F. To determine whether concentrating on wall insulation is a desirable first step, even in the absence of improving other components, this CM Analysis can be useful. Due to their lower location relative to upper floors, stilt floors are frequently more exposed to direct sunlight; hence, improving wall insulation on the S'F might be advantageous. On a single floor, walls often have a bigger area than windows or floors. Thus, concentrating on wall insulation on the S'F may result in a notable decrease in solar heat gain on that particular floor.

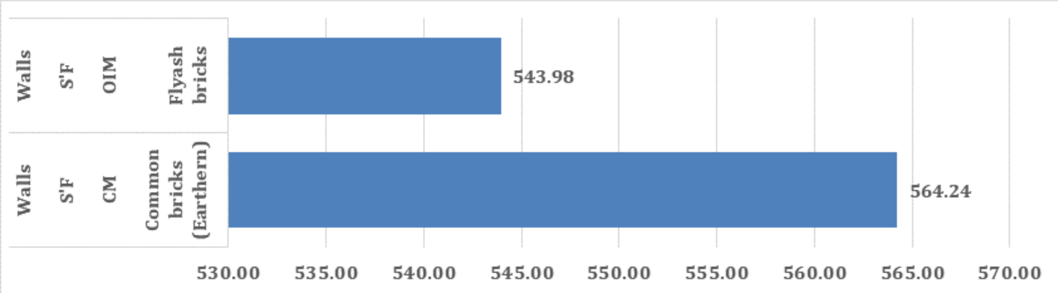

Fig. 11. Impact of Wall Insulation (Stilt Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 3: CM vs OIM-GF (Walls)

CM (Conventional Materials): This figure shows the approximate SAIV when conventional materials are used exclusively for the ground floor walls and not for any other components. OIM (Optimal Insulating Materials): If the walls were built using the best insulating materials possible, this value would indicate the predicted SAIV for the ground floor. We may evaluate how well enhanced wall insulation reduces solar heat gain, particularly for the bottom level, by comparing the CM and OIM values for walls (as indicated in the picture). Even if other components haven't been updated yet, our CM Analysis helps decide whether concentrating on wall insulation on the ground floor is a beneficial move for increasing thermal comfort and maybe lowering cooling energy use. Particularly in warm areas, ground floors may be vulnerable to heat accumulation from the surrounding earth. In addition to lowering solar heat input via the walls themselves, wall insulation can assist attenuate this heat gain.

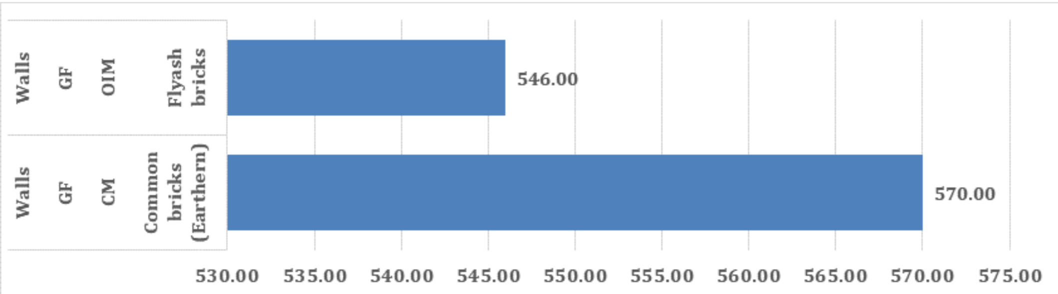

Fig. 12. Impact of Wall Insulation (Ground Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 4: CM vs OIM-FF (Walls)

Case 4 focuses on how wall insulation affects the building's First Floor (FF) Study Average Insolation Value (SAIV). As in other instances, "OIM" stands for optimal insulating materials and "CM" for conventional materials. Two situations are compared in the figure: CM (typical Materials): When the first story walls are built using typical materials, this bar indicates the approximate SAIV. Conventional materials are used for other parts of the building envelope, such as the windows and walls on other stories. OIM (Optimal Insulating Materials): If the walls were built using the best insulating materials and all other elements stay the same, this bar would show the predicted SAIV for the first level. Solar heat gain can have a big effect on first floors, especially in multi-story structures when they get direct sunshine from windows above. Wall space is frequently larger than windows or single-story floors. Improving the insulation of first-floor walls may result in a notable decrease in solar heat gain on that particular floor.

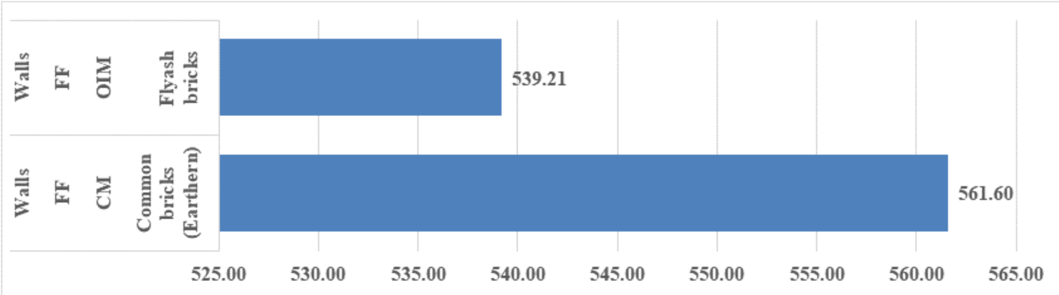

Fig. 13. Impact of Wall Insulation (First Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 5: CM vs OIM-SF (Walls)

In Case 5, the impact of wall insulation on the building's second floor's Study Average Insolation Value (SAIV) is investigated. As previously mentioned, "OIM" stands for Optimal Insulating Materials, whereas "CM" stands for Conventional Materials. Most likely, the chart you supplied contrasts two situations: CM (Conventional Materials): This bar shows the approximate SAIV in the event that conventional materials are used to build the second floor's walls. Depending on the study, further elements of the building envelope (such as windows, walls on other floors, the roof, etc.) may be constructed with standard or ideal materials. OIM (Optimal Insulating Materials): This bar shows the predicted SAIV for the second level assuming that, while other components may stay the same, the walls were built using the best insulating materials. Due to possible shadowing from the first level, the effect of solar heat gain may be less severe on the second story than on lower floors, but it's still something to think about. Improving the insulation in the walls of the second level can help lower the building's overall heat gain.

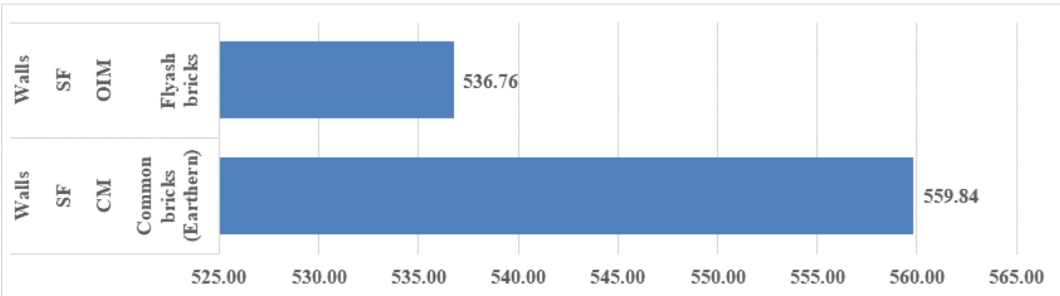

Fig. 14. Impact of Wall Insulation (Second Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 6: CM vs OIM-Slabs (All floors)

Case 6 focuses on how the building's overall Study Average Insolation Value (SAIV) is affected by the insulation in the slabs (floors). As in other instances, "OIM" stands for optimal insulating materials and "CM" for conventional materials. Two situations are compared in the figure: CM (Conventional Materials): This figure shows the approximate SAIV in the case where all floors' slabs are built using conventional materials. Conventional materials are used for the walls, windows, flooring, and other parts of the building envelope. OIM (Optimal Insulating Materials): If all floor slabs were built with the best insulating materials and all other building components stay the same, this value would indicate the predicted SAIV for the entire structure. Heat can be transferred from lower levels or the ground to slabs, particularly in structures without crawl spaces or basements. In hot climates, well-insulated slabs can help prevent heat from radiating upwards into the occupied space.

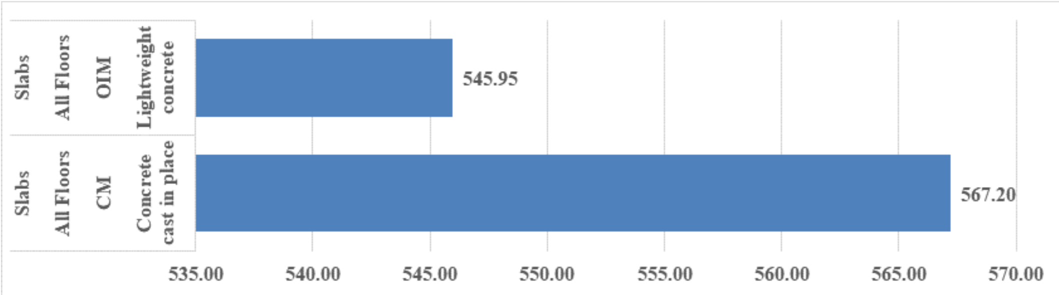

Fig. 15. Impact of Slab Insulation (All Floors) on SAIV - CM vs. OIM(KWh/m^2)

Case 7: CM vs OIM-S'F (Windows)

The impact of window upgrades on the building's Stilt Floor (S'F) Study Average Insolation Value (SAIV) is the main topic of Case 7. As previously mentioned, "OIM" stands for Optimal Insulating Materials, whereas "CM" stands for Conventional Materials. Two situations are compared in the figure: CM (Conventional Materials): This bar shows the approximate SAIV in the event that conventional materials are used in the construction of the stilt floor windows. Conventional materials are used for the walls, windows on other floors, flooring, and other parts of the building envelope. OIM (Optimal Insulating Materials): If the windows were replaced with the best insulating materials while all other parts stay the same, this bar shows the expected SAIV for the stilt floor. Because they are positioned lower than upper floors, stilt floors are frequently subject to greater direct sunlight exposure. When windows are single-glazed or improperly insulated, they can be a major source of solar heat gain.

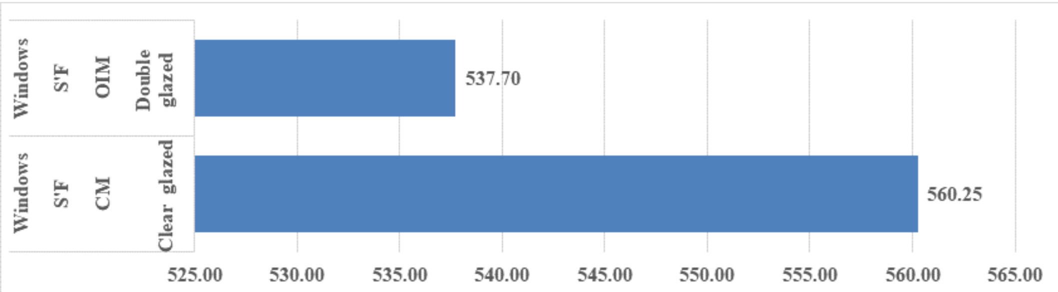

Fig. 16. Impact of Window Insulation (Stilt Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 8: CM vs OIM-GF (Windows)

This case looks at how replacing the windows affects the ground floor (GF) of the building's Study Average Insolation Value (SAIV). As in other instances, "OIM" stands for optimal insulating materials and "CM" for conventional materials. Two situations are compared in the figure:

CM (Conventional Materials): This figure indicates the approximate SAIV in the event that conventional materials are used in the construction of the ground floor windows. The figure indicates that conventional materials are used for other parts of the building envelope, such as the walls, windows on other floors, flooring, etc. OIM (Optimal Insulating Materials): If the windows were changed out for better insulating materials, like double-glazed windows, but the other elements stay the same, this value would indicate the expected SAIV for the bottom floor. Particularly in warm areas, ground floors may be vulnerable to heat accumulation from the earth's surface as well as solar radiation. Windows, especially those with single glazing or inadequate insulation, can contribute significantly to solar heat gain. Consequently, updating the ground floor's windows might be a calculated move to: Lower solar heat gain through windows. could reduce the amount of heat transferred from the warm earth.

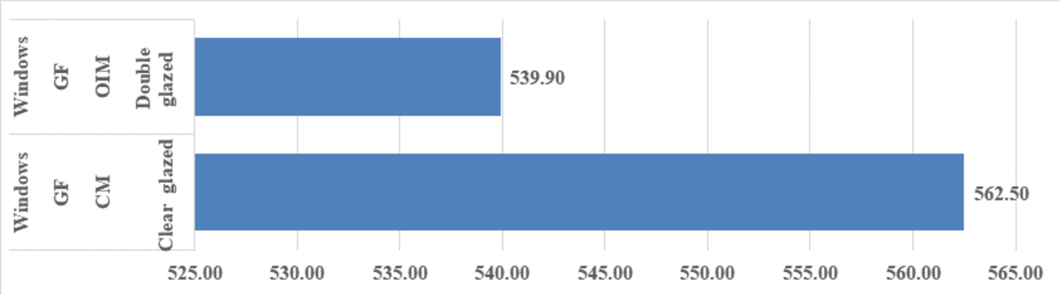

Fig. 16. Impact of Window Insulation (Ground Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 9: CM vs OIM-FF (Windows)

The impact of replacing the windows on the Study Average Insolation Value (SAIV) for the building's First Floor (FF) is the main topic of Case 9. As previously mentioned, "OIM" stands for Optimal Insulating Materials, whereas "CM" stands for Conventional Materials. Two situations are compared in the figure: CM (Conventional Materials): This bar shows the projected SAIV in the event that conventional materials are used in the construction of the first story windows. Conventional materials are used for the walls, windows on other floors, flooring, and other parts of the building envelope. OIM (Optimal Insulating Materials): This bar shows the predicted SAIV for the first floor in the event that all other components stay the same and windows are replaced with optimal insulating materials, like double-glazed windows. Solar heat gain can have a big effect on first floors, especially in multi-story structures when they get direct sunshine from windows above. Windows, particularly those with single glazing or inadequate insulation, can be a significant source of heat gain. Modernizing the first level's windows may result in a notable decrease in solar heat gain on that particular floor.

Fig. 17. Impact of Window Insulation (First Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 10: CM vs OIM-SF (Windows)

This example looks at how replacing windows affects the building's second floor's Study Average Insolation Value (SAIV). As in other instances, "OIM" stands for optimal insulating materials and "CM" for conventional materials. Two situations are compared in the figure: CM (Conventional Materials): When the windows on the second story are built using conventional materials, this value indicates the expected SAIV. According to the chart, typical materials are used for other building envelope components, such as the walls, flooring, windows on other floors, and so on. OIM (Optimal Insulating Materials): This figure shows the predicted SAIV for the second story in the event that all other components stay the same and windows are replaced with optimal insulating materials, like double-glazed windows. Due to possible shadowing from the first level, the effect of solar heat gain may be less severe on the second story than on lower floors, but it's still something to think about. When windows are single-glazed or improperly insulated, they can be a major source of solar heat gain. If a building has a lot of windows on the upper floors, replacing the windows on the second story can help lower the building's overall heat gain.

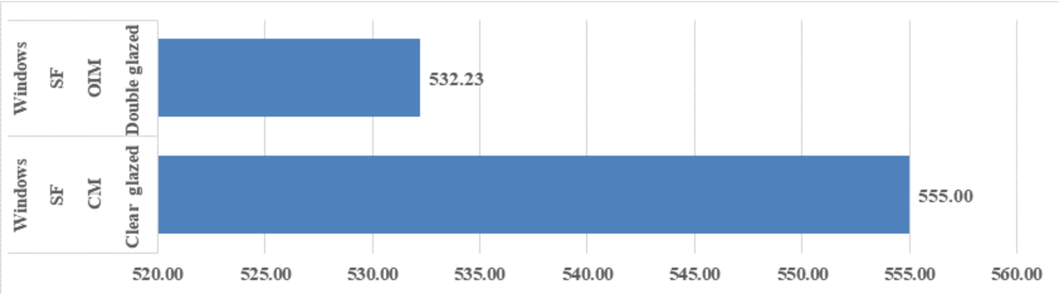

Fig. 18. Impact of Window Insulation (Second Floor) on SAIV - CM vs. OIM(KWh/m^2)

Case 11: CM vs OIM- Flooring (All floors)

In Case 11, the impact of flooring materials on the building's total Study Average Insolation Value (SAIV) is investigated. As previously mentioned, "OIM" stands for Optimal Insulating Materials, whereas "CM" stands for Conventional Materials. Two situations are compared in the figure: CM (Conventional Materials): When all floors have conventional materials used in the construction of their flooring, this value indicates the anticipated SAIV. Conventional materials are used for the walls, windows, and other parts of the building envelope. OIM (Optimal Insulating Materials): If windows were replaced with optimal insulating materials (double-glazed, for example), and other components stay the same, this value would indicate the estimated SAIV for all levels. High thermal conductivity flooring materials make an occupied space feel warmer by rapidly transferring heat from the ground or lower floors. Well-insulated flooring can aid in preventing heat from rising into the inside of buildings in hot climes.

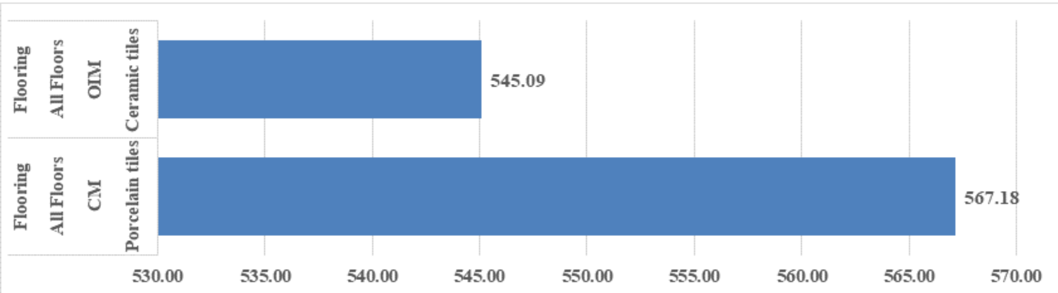

Fig. 19. Impact of Floor Insulation (All Floors) on SAIV - CM vs. OIM(KWh/m^2)

3.2 Energy Analysis

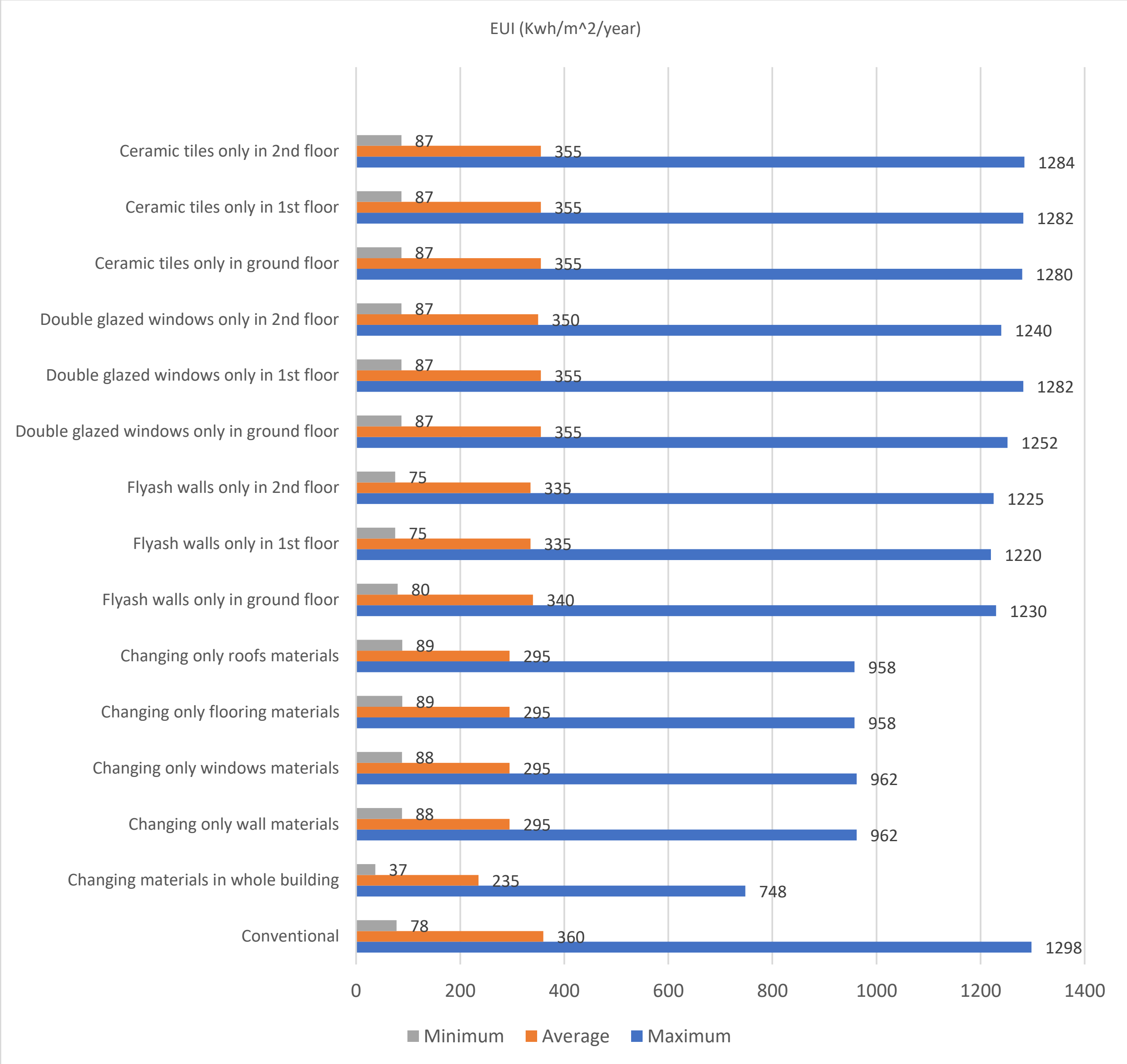

Fig.20.Comparitive analysis graph of Energy use intensity of all cases in BLOCK IV KITSW

The fig(20) is a visual representation of the maximum, average, and minimum energy use intensity (EUI) for various cases within block IV of KITSW. EUI is measured in kilowatt-hours per square meter per year (kWh/m²/year) and serves as a metric for evaluating energy efficiency in buildings. This graph facilitates comparison of energy performance across different scenarios within block IV, enabling identification of the most energy-efficient case.

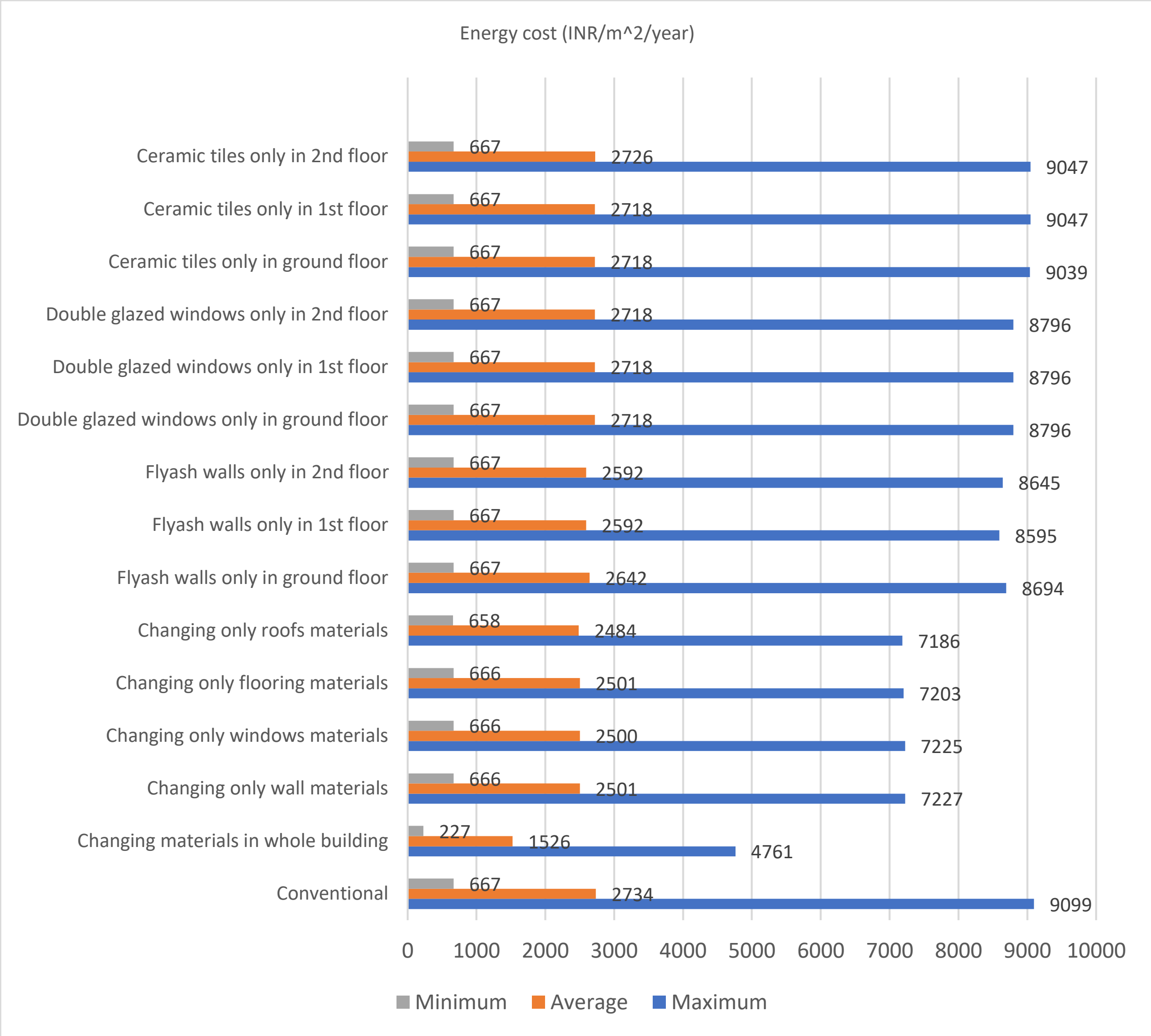

Fig.21.Comparitive analysis graph of Energy costs of all cases in BLOCK IV KITSW

The fig(21) depicts a comparison between the maximum, average, and minimum energy costs for various cases within block IV of KITSW. The cost is represented in Indian Rupees per square meter per year (INR/m²/year). This visualization allows for a clear understanding of the range of energy expenditures across different scenarios in block IV. It helps identifying the cases with the lowest energy costs.

Table 5 Maximum energy use intensity (EUI) and Energy cost in all cases of Block IV KITSW

Case	Energy use intensity (KWh/m^2/year)	Energy cost (INR/m^2/year)	Percentage decrease EUI compared to conventional materials	Percentage decrease Energy cost compared to conventional materials
Conventional	1298	9099	-	-

Changing materials in whole building	746	4761	42.5%	47.5%
Changing only wall materials	962	7227	26.1%	20.4%
Changing only windows materials	962	7225	26.1%	20.4%
Changing only flooring materials	958	7203	26.3%	20.7%
Changing only roofs materials	958	7186	26.3%	21.1%
Changing wall materials only in ground floor	1230	8694	6.6%	4.4%
Changing wall materials only in 1st floor	1220	8595	6%	5.5%
Changing wall materials only in 2nd floor	1225	8645	5.6%	5%
Changing window materials only in ground floor	1252	8796	3.6%	3.3%
Changing window materials only in 1st floor	1282	8796	1.2%	3.3%
Changing window materials only in 2nd floor	1240	8796	4.4%	3.3%
Changing Flooring materials only in ground floor	1280	9039	1.4%	0.7%

Changing Flooring materials only in 1st floor	1282	9047	1.2%	0.6%
Changing Flooring materials only in 2nd floor	1284	9047	1.1%	0.6%

Table 6 Average energy use intensity (EUI) and Energy cost in all cases of Block IV KITSW

Case	**Energy use intensity (KWh/m^2/year)**	**Energy cost (INR/m^2/year)**	**Percentage decrease EUI compared to conventional materials**	**Percentage decrease Energy cost compared to conventional materials**
Conventional	360	2734	-	-
Changing materials in whole building	235	1526	34.7%	44.2%
Changing only wall materials	295	2501	18.1%	8.5%
Changing only windows materials	295	2500	18.1%	8.5%
Changing only flooring materials	295	2501	18.1%	8.5%
Changing only roofs materials	295	2484	18.1%	9.1%
Changing wall materials only in ground floor	340	2642	5.6%	3.3%
Changing wall materials only in 1st floor	335	2592	7%	5.2%
Changing wall materials only in 2nd floor	335	2592	7%	5.2%
Changing window materials only in ground floor	355	2718	4%	0.5%
Changing window materials only in 1st floor	355	2718	1.4%	0.5%
Changing window materials only in 2nd floor	350	2718	2.8%	0.5%
Changing Flooring materials only in ground floor	355	2718	1.4%	0.5%
Changing Flooring materials only in 1st floor	355	2718	1.4%	0.5%

Changing Flooring materials only in 2nd floor	355	2726	1.4%	0.3%

Table 7 Average energy use intensity (EUI) and Energy cost in all cases of Block IV KITSW

Case	**Energy use intensity (KWh/m^2/year)**	**Energy cost (INR/m^2/year)**	**Percentage decrease EUI compared to conventional materials**	**Percentage decrease Energy cost compared to conventional materials**
Conventional	78	667	-	-
Changing materials in whole building	37	227	52.6%	66.5%
Changing only wall materials	88	666	-	-
Changing only windows materials	88	666	-	-
Changing only flooring materials	89	666	-	-
Changing only roofs materials	89	658	-	1.3%
Changing wall materials only in ground floor	80	667	-	-
Changing wall materials only in 1st floor	75	667	3.8%	-
Changing wall materials only in 2nd floor	75	667	3.8%	-
Changing window materials only in ground floor	87	667	-	-
Changing window materials only in 1st floor	87	667	-	-
Changing window materials only in 2nd floor	87	667	-	-
Changing Flooring materials only in ground floor	87	667	-	-
Changing Flooring materials only in 1st floor	87	667	-	-
Changing Flooring materials only in 2nd floor	87	667	-	-

According to Tables (5,6,7) In case-2 where all the building materials are changed the maximum EUI was drastically reduced , It went from 1298 kWh/m² annually to 746 kWh/m² annually. This indicates a drop of 42.5%. The maximum energy cost decreased significantly as well, from 9099 INR/m² per year to 4761 INR/m² per year. The average EUI, which decreased by 34.7% from 360 kWh/m² year to 235 kWh/m² annually. The average energy cost also saw a significant improvement, falling from 2733 INR/m² per year to 1526 INR/m² per year, reflecting a 44.2% decrease. The minimal EUI saw the most reduction, falling from 78 kWh/m² annually to a meager 37 kWh/m² annually. This is an astounding 52.6% reduction. The minimum energy cost showed the most significant improvement, falling from 667 INR/m² per year to 227 INR/m² per year. This translates to a 47.5% decrease. In case-3 where only walls were changed into flyash walls in the whole building the maximum EUI decreased from 1298 kWh/m² per year to 958 kWh/m² per year, representing a 26.3% reduction , the highest energy cost decreased by 20.4%, from 9099 INR/m² annually to 7227 INR/m² annually.The average EUI improved slightly, from 360 kWh/m² per year to 296 kWh/m² per year, indicating an 18.1% decrease , the average energy cost improved slightly as well, falling from 2733 INR/m² per year to 2501 INR/m² per year, or an 8.5% decrease. The minimum EUI, which went from 78 kWh/m² year to 89 kWh/m² annually. This indicates a slight incline of 14.1%. The minimal energy cost stayed nearly the same at 667 INR/m² per year. In case-4 where only windows were changed into double glazed windows in the whole building the maximum EUI dropped by 26.1%, from 1298 kWh/m³ annually to 962 kWh/m² annually. There was a notable 20.4% drop in the maximum energy cost, from 9099 INR/m³/year to 7225 INR/m²/year.The average EUI also experienced a slight improvement, moving from 360 kWh/m² per year to 295 kWh/m² per year, reflecting an 18.1% decrease. The average annual energy cost decreased by 8.5%, from 2734 INR/m² to 2500 INR/m².

The minimum EUI saw a little increase, rising from 78 kWh/m² per year to 88 kWh/m² per year, representing a modest 12.8% gain. A small decrease in the minimum energy cost was attained, going from 667 INR/m²/year to 666 INR/m²/year. In case-5 where only flooring was changed into ceramic tiles in the whole building the maximum EUI dropped from 1298 kWh/m³/year to 958 kWh/m²/year, a 26.3% decrease , a notable 21.1% drop in the maximum energy cost, from 9099 INR/m³/year to 7186 INR/m²/year.

The annual average EUI decreased by 18.1%, from 360 kWh/m³ to 295 kWh/m² , The mean annual energy expense decreased by 8.5%, rising from 2734 INR/m² to 2484 INR/m².There was an increase in the minimum EUI (going from 78 kWh/m²/year to 89 kWh/m²/year.

A notable 1.3% decrease in the minimum energy cost was attained (going from 665 INR/m²/year to 658 INR/m²/year). In case-6 where only roof was changed into cool roofs in the whole building the highest EUI shown a notable decline, falling from 1298 kWh/m² annually to 958 kWh/m² annually, or a decrease of 26.3%. the highest energy cost decreased by 20.7%, from 9099 INR/m² per year to 7203 INR/m² per year.There was a minor improvement in the average EUI, which decreased by 18.1% from 360 kWh/m² per year to 295 kWh/m² per year , the average energy cost, which decreased by 8.8% from 2733 INR/m² per year to 2484 INR/m² per year. The minimum EUI only slightly changed, increasing from 78 kWh/m² year to 89 kWh/m² annually, or an 14.1% increase , the minimum energy cost decreased by a mere 1.3%, from 667 INR/m² per year to 658 INR/m² per year. In case-7 where wall materials were changed to flyash walls only in ground floor the maximum EUI dropped by 6.6% to 1230 kWh/m² annually. the maximum energy cost declined by 4.4% to 8694 INR/m² per year as The average EUI decreased by 5.6%, to 340 kWh/m² annually , The average energy cost reduced by 3.3% to 2642 INR/m² per year.The minimum EUI went up to 80 kWh/m² annually , the annual minimum energy cost of 667 INR/m² stayed mostly unchanged.

In case-8 where wall materials were changed to flyash walls only in 1st floor the the maximum EUI dropped by 6.0% to 1220 kWh/m² annually. the maximum energy cost decreased by 5.5% to 8595 INR/m² annually.The average EUI decreased by 7.0%, coming in at 335 kWh/m² annually. the average energy cost

decreased by 5.2% to 2592 INR/m² annually.The minimal EUI, which dropped by 3.8% to 75 kWh/m² annually. The annual minimum energy cost stayed fixed at 667 INR/m². In case-9 where wall materials were changed to flyash walls only in 2nd floor the maximum EUI dropped by 5.6% to 1225 kWh/m², the maximum energy cost decreased by 5.0% to 8645 INR/m² per year.The average EUI decreased by 7.0%, coming in at 335 kWh/m² annually , the average energy cost declined by 5.2% to 2592 INR/m² per year.
The minimum EUI changed more significantly, falling by 3.8% to 75 kWh/m² annually. The annual minimum energy cost stayed fixed at 667 INR/m². In case-10 where window materials were changed to double glazed windows only in ground floor The maximum EUI reduction, which dropped by 3.6% to 1252 kWh/m² annually, The highest energy cost dropped by 3.3%, to 8796 INR/m² annually.The average EUI experienced a positive influence, declining by 4.0% year to 335 kWh/m². the average annual energy cost decreased by 0.5% to 2718 INR/m²The minimum EUI increased to 87 kWh/m² annually , The annual minimum energy cost of 667 INR/m² stayed the same. In case-11 where window materials were changed to double glazed windows only in 1st floor the maximum EUI dropped to 1282 kWh/m² annually, a 1.2% decrease , the maximum energy cost decreased by 3.3% to 8796 INR/m² per year.The average EUI decreased by a small 1.4% to 355 kWh/m² annually , the average energy cost declined by 0.5% to 2718 INR/m²year ,the minimal EUI rising to 87 kWh/m² year , The annual minimum energy cost stayed fixed at 667 INR/m².

In case-12 where window materials were changed to double glazed windows only in 2nd floor the maximum EUI dropped by 4.4% to 1240 kWh/m² annually , the maximum energy cost decreased by 3.3% to 8796 INR/m² per year. The average EUI also experienced a decrease of 2.8%, reaching 350 kWh/m² annually. The average energy cost decreased by 0.5% to 2718 INR/m² per year.the lowest EUI showed a increase to 87 kWh/m² per year, The annual minimum energy cost stayed fixed at 667 INR/m². In case-13 where flooring materials were changed to ceramic tiles only in ground floor the maximum EUI was negligible, declining by just 1.4% annually to 1280 kWh/m². the maximum energy cost decreased by 0.7% to 9039 INR/m² per year. There was a 1.4% annual decline in the average EUI, bringing it down to 355 kWh/m². the average energy cost was constant at 2718 INR/m² annually.The minimal EUI showed a increase to 87 kWh/m² annually. the minimal energy cost per year stayed at 667 INR/m². In case-14 where flooring materials were changed to ceramic tiles only in 1st floor the maximum EUI, which came down to 1282 kWh/m² annually ,The highest annual energy cost showed a little decline of 0.6% to 9047 INR/m².The average EUI in had declined by 1.4% year to 355 kWh/m². the annual average energy cost stayed steady at 2718 INR/m².The minimal EUI showed a increase to 87 kWh/m² annually , the minimum energy cost remained constant at 667 INR/m² annually. In case-15 where flooring materials were changed to ceramic tiles only in 2nd floor the maximum EUI dropped by 1.1% to 1284 kWh/m² annually , the maximum energy cost decreased by 0.6% to 9047 INR/m² annually.The average EUI dropped by 1.4% to 355 kWh/m² annually , the average energy cost decreased by 0.3% to 2726 INR/m² per year.
The minimum EUI increased to 87 kWh/m² annually, The annual minimum energy cost stayed fixed at 667 INR/m².

4 Conclusions

This case study concentrated on using solar radiation CM Analysis and strategic material selection to maximize thermal comfort and energy efficiency in Block 4 KITSW for GRIHA certification. Through a comparison of the Study Average Insolation Value (SAIV) between optimal insulating materials (OIM) and conventional materials (CM) in different building components, as displayed in the table, the CM

Analysis offered significant insights on meeting the solar radiation and energy efficiency standards of GRIHA. SAIV savings of up to 39.48 kWh/m² can be achieved by substituting conventional windows with OIM alternatives, especially on the stilt floor (S'F), ground floor (GF), and first floor (FF). This indicates that lowering solar heat gain and the associated cooling energy demand can be achieved by giving priority to window renovations. This is a win-win situation because using energy-efficient fenestration materials generally earns points toward GRIHA certification. All floors (S'F, GF, FF, and SF) can benefit greatly from upgrading their wall insulation with OIM materials, which can increase SAIV by 2.76 to 7.74 kWh/m². This highlights how crucial it is to reduce heat gain through walls, particularly those that have substantial uncovered sections that face the sun. Improved wall insulation has a positive effect on lowering building energy consumption, which is acknowledged by GRIHA. By installing OIM insulation in slabs (floors) on every floor, you can enhance the overall SAIV by 8.78 kWh/m². In warmer areas or for structures where heat gain via the ground floor slab is common, this can be especially helpful. Using thermal insulation in building components, such as floors, earns points in GRIHA. By lowering heat transmission from the ground or lower floors, choosing the best insulating materials for flooring on all floors can enhance thermal efficiency by 1.69 kWh/m². Even though it might not have as much of an impact as walls or windows, it can nevertheless help GRIHA meet its energy efficiency targets. Our study looked at the KITSW Administrative Block's potential for better solar panel installation and insulating materials. We used a number of techniques, such as material property extraction, thermal performance simulations, energy consumption CM Analysis, and data collection from building plans and software.

In Case 2, changing all building materials led to a significant decrease in maximum EUI from 1298 kWh/m² to 746 kWh/m² annually, a 42.5% drop. Maximum energy cost also decreased from 9099 INR/m² to 4761 INR/m² annually, a 47.5% decrease. Average EUI decreased by 34.7% to 235 kWh/m² annually, and average energy cost decreased by 44.2% to 1526 INR/m² annually. In Case 3, only changing walls to flyash led to a 26.3% reduction in maximum EUI and a 20.4% reduction in maximum energy cost. Average EUI improved slightly by 18.1%, and average energy cost decreased by 8.5%. In Case 4, changing only windows to double glazed windows resulted in a 26.1% decrease in maximum EUI and a 20.4% decrease in maximum energy cost. Average EUI decreased by 18.1%, and average energy cost decreased by 8.5%. In Case 5, changing only flooring to ceramic tiles led to a 26.3% decrease in maximum EUI and a 21.1% decrease in maximum energy cost. Average EUI decreased by 18.1%, and average energy cost decreased by 8.5%. In Case 6, changing only the roof to cool roofs resulted in a 26.3% decrease in maximum EUI and a 20.7% decrease in maximum energy cost. Average EUI decreased by 18.1%, and average energy cost decreased by 8.8%. Cases 7 to 15 involve specific changes to wall materials, windows, and flooring in different parts of the building, resulting in varied decreases in EUI and energy costs. In addition to solar radiation and energy efficiency, which are critical GRIHA certification criteria, the following other GRIHA factors are relevant to this project and should be taken into account:

Examine whether adding external shade elements to windows and walls that receive a lot of sun exposure—such as overhangs or louvers—is feasible. This can cut down on direct solar heat gain considerably without sacrificing natural light. The advantages of passive shading techniques are acknowledged by GRIHA. Look into ways to increase the amount of natural light that enters the building. This may lessen the need for artificial illumination and the energy it uses, which would help meet GRIHA's requirements for daylight utilization.Think about putting in place building automation systems that adjust HVAC and lighting to best suit occupancy and current conditions. In the GRIHA's energy management category, this can score points and drastically cut energy waste. Last but not least, Block 4 KITSW can potentially receive GRIHA certification by putting the aforementioned recommendations into practice and attending to additional GRIHA criteria pertinent to the project scope. This would result in considerable improvements in thermal comfort and energy efficiency. In addition to lowering operating expenses, this will support the creation of a more sustainable built environment and help GRIHA accomplish its overall goals for green building. In order to improve Block 4 KITSW's thermal comfort and energy efficiency for GRIHA certification, this case study offered insightful information. Nonetheless, the information provided here can serve as a basis for additional research in a number of areas: Although the simulations yielded useful information, real-world validation and the possibility to pinpoint areas for more optimization could only be achieved by putting the suggested upgrades into practice and keeping a close eye on the building's energy usage and thermal performance over time. A thorough cost-benefit analysis A more comprehensive understanding of the project's financial feasibility and return on investment could be obtained through analysis that takes into account material costs, installation costs, operating savings, and potential GRIHA certification incentives. A Life Cycle Assessment (LCA), which would be added to the research, would assess the project's overall environmental impact, taking into account resource extraction, transportation, building, operation, and end-of-life concerns. Pre- and post-upgrade occupant surveys could yield important information on the true effects of the modifications on user happiness, thermal comfort, and possible behavioral changes linked to energy use. To attain even greater energy independence and sustainability, future study could examine the viability of incorporating renewable energy sources other than solar panels, such as wind turbines or micro-hydro systems. More efficiency improvements may result from looking into how to best optimize the building management system to incorporate occupancy sensors, real-time weather data, and energy consumption patterns.This case study can be a useful starting point for future research in these areas, which will help advance sustainable construction practices both locally and globally. This will help Block 4 KITSW achieve GRIHA certification.

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