Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 11, No. 2, November : 2023

REDUCING OPERATIONAL ENERGY USAGE IN RESIDENTIAL BUILDINGS USING LOW THERMAL CONDUCTIVITY SUSTAINABLE MATERIALS

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ABSTRACT
During the act of sustainable development of the construction industry, green construction is an important means, however application having a limited ability to conduct heat sustainable materials reduces the operational energy. The energy analysis is carried out with the assistance of a simulation tool (insight), which is integrated with Revit BIM models. In this study, an attempt was made by the integration of BIM into sustainable designing of buildings to reduce operation energy and cost. The main objective of this study is to identify the available sustainable low thermal conductivity materials in Warangal, Telangana State (India). In survey it was observed that apart from normal clay bricks, only flay ash bricks and Autoclaved aerated concrete blocks (AAC blocks) are available in the Warangal area within 10 kms from National institute of technology Warangal. As a result, it was found that the price of constructing the building is 7% higher with normal clay brick and 18% higher with fly ash brick than with AAC blocks. In regards to operational energy the energy usage of normal clay brick is 29 % higher than fly ash brick and 31 % higher than AAC blocks of energy 399 kWh/m^2/year.

Keywords Sustainable materials, Building information modelling (BIM), Operational energy.

1.INTRODUCTION
Green technology is a fast developing and essential approach in today's construction sector. Green technology has received a lot of attention since the early 1990s, and there has been a major change towards efficient construction design implementation of eco-friendly activities that allow for sustainable technology. Sustainable technology, alternatively referred to as green technology is a type of construction technology that is environmentally friendly and focuses on long-term sustainability.
Among the foremost critical challenges surrounding green buildings is energy usage, which can have a considerable impact on operational expenses. As a result, a number of researchers have come to the conclusion that the demand for reduced energy consumption appears to be the most important aspect of the early stages of building design. Integrating promising innovative techniques employed in digital environments of data can provide great potential for identifying optimal solutions for the thermal load's energy trade-off in order to improve the early building design process. Simulation techniques for Building Information Modeling (BIM) has the potential for utilization in. anticipate energy performance.
The need of optimizing building performance, not only regarding energy usage but also in terms of resource utilisation, has been recognised by decision makers, planners, and investors. In order to attain sustainability, in the planning phase, an assessment of the environmental performance of buildings and various sub-components based on evaluation and optimization of both energies utilized for construction and ongoing operation and emission would be required.
The majority of operational energy savings are accomplished by using more materials (for example, insulation), which increases the energy input for production and manufacturing. Inefficient thermal performance of the building envelope is largely responsible for heat dissipation. The heat transfer coefficient (U) has become a key measure for evaluating the thermal quality of a building envelope, which is influenced by various material and structural factors. Fly ash, a pozzolanic substance derived from thermal power plants, has found application in the construction sector. Autoclaved aerated concrete (AAC) has gained popularity as a construction material. AAC is produced using raw materials such as quartz sand, cement, quicklime, anhydrite or gypsum, aluminum powder or paste, and water. Researchers worldwide have made significant advancements in creating alternative sustainable

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building materials and simplified techniques that lead to more environmentally friendly and cost-effective structures, addressing contemporary requirements.

To improve thermal performance, energy performance effectiveness and the quality of indoor air, resource efficiency, and artistically attractive exterior surface finishes, sustainable design methods call for the usage and selection of appropriate materials. Climate, strength, durability, cost-effectiveness, fire resistance, environmental friendliness, and local availability are all critical aspects while selecting materials. An analysis of commonly employed construction materials reveals that timber exhibits the least thermal conductivity, while single glazing exhibits the highest thermal conductivity. To mitigate solar heat gain in fenestrations, it is essential to consider factors like thermal conductance, the ratio of wall to window area, shading coefficient, and shading.

AAC blocks, an environmentally friendly material that offers a promising solution for building construction. To replace red bricks with environmentally friendly AAC blocks. The use of AAC blocks reduces the construction costs up to 20%. The use of AAC blocks also reduces the need for materials like cement and sand up to 50%.

2. METHODOLOGY:

2.1 Building information Modelling (BIM):

BIM is combination of 3D modelling, information database technology, and interoperable software in a computer application that design experts and contractors can use to design a facility and simulate construction. Building Information Modeling (BIM) is a 3-D, object-oriented CAD method utilized by architects and engineers. One of its most valuable attributes is the improvement it brings to coordination among various design disciplines, thereby reducing errors. BIM possesses the capability to fulfill an owner's requirements for cost predictability, quality, and timely delivery. BIM objects play a substantial role in effectively representing the entire lifespan of a constructed structure. This lifelike building model aids the project team in maintaining focus and facilitating straightforward communication when essential adjustments are needed. BIM is a detailed digital representation of a building that can be integrated with various energy modelling tools to create a sustainable design and energy consumption evaluation. Autodesk Revit, Sketchup, and ArchiCAD are examples of BIM-based software.

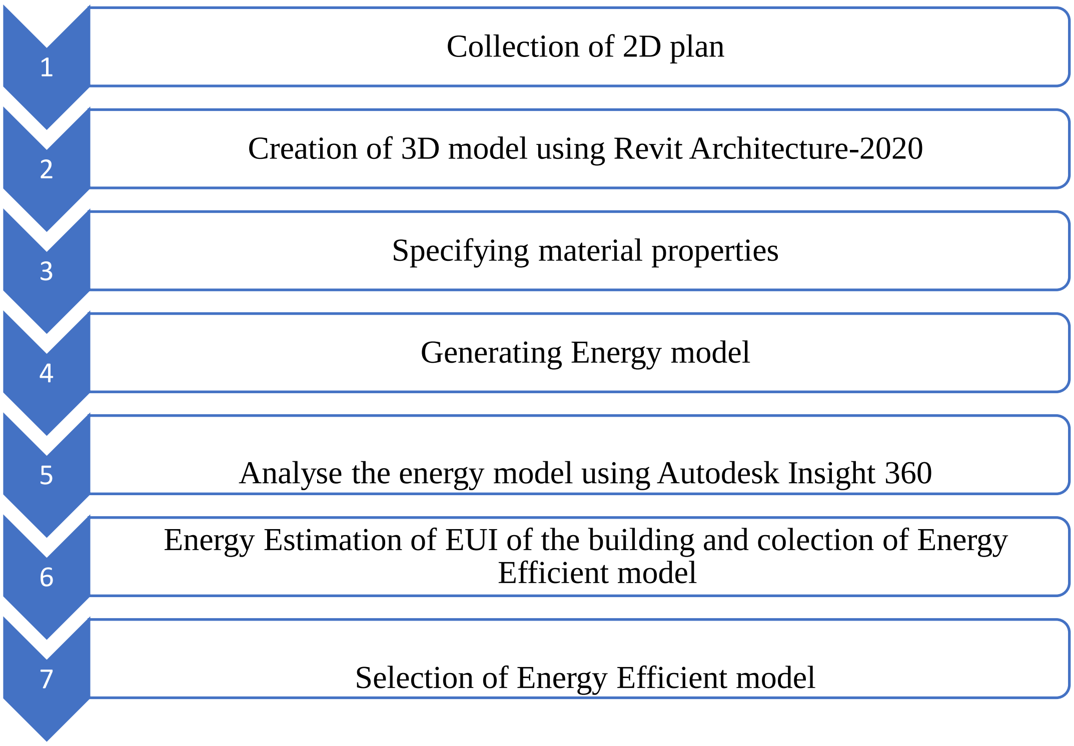


Figure 1: frame work for energy analysis

This study in Warangal, Telangana, simulated a single-story residential building (Built up Area-725 ft2 / 67.35 m2). Warangal is located in a semi-arid climate which is hot and dry (Average high of 102^{o} F in summers and a low of 62^{o} F in winters). The 3-D model of the building is created using Revit Architecture 2020 and 2-D AutoCAD drawings, and it is then tested for energy efficiency with Autodesk Insight. Autodesk Insight 360 is a Revit-based energy, lighting, and solar analysis tool. A cost estimation was made for each of the three components.

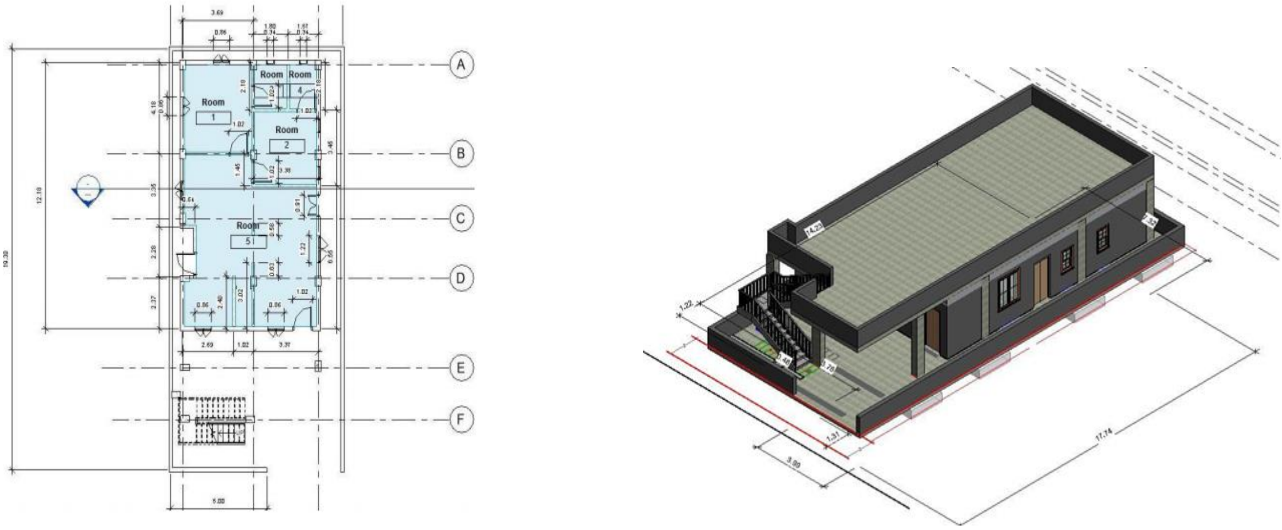
A model is made in Revit. The specifications and various sight views are shown below.

2.2 Specifications:

Table 3: Building plan specification

Description about model		
Total plan area(m)	19.30 × 8.94	
No of isolated footing	15	
Depth of footing (m)	1.5	
Size of footing	72" × 48" ×18"	
Size of columns	12" × 18"	
Thickness of outer wall	8"	
Thickness of inner wall	6"	
Height of outer and inner wall (m)	2.74	
Cross section of beam	10"	
Thickness of roof	9"	
Thickness of floor	5"	
Width of parapet wall	6"	
Width of compound wall	8"	
Size of doors (m)	1.02 × 2.24	
Size of windows (m)	1 × 1	
Staircase	Tread	Riser
Number	20	20
Length	0.2794m	0.1524m

2.3 Building floor plan and 3D View:



(a)Building floor plan (b) 3D model

Figure 2: Building floor plan and 3D view of model

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3. COST ANALYSIS

Cost analysis was done for three materials in the building namely
1. Normal clay brick
2. Fly ash brick
3. AAC blocks

Different dealers involved with the supply of construction materials were contracted and the most economical deal was chosen.

With considering the sizes of clay bricks 190×90×90, fly ash bricks 230×110×100 and AAC blocks 600×200×100, the total calculation is done using the center line method of estimation considering external walls, internal walls, floor, roof, Coping wall, foundations, pillars, perimeter walls, stairwell, and wall, beam, stairwell, and roof surface finishing. After getting the quantity of concrete, brickwork and mortar volume. The final quantities are calculated on the basis of considering Concrete as M20 and mortar ratio as 1:5.

The final calculations are tabulated for each type of wall made with Normal clay brick, fly ash brick and autoclave aerated concrete block.

Table 1: Table showing the cost calculations of walls with different bricks considered.

Parameters	**clay brick**	**Fly ash brick**	**AAC block**
Size (mm)	190×90×90	230×110×100	600×200×100
Volume of one brick without mortar (m^3)	0.0015	0.00253	0.012
Volume of one brick with mortar (m^3)	0.002	0.00316	0.014
Mortar required per m^3 of brickwork	0.2305	0.203	0.136
Number of bricks required	21010	13,236	3050
Concrete work (m^3)	72.775	72.775	72.775
Volume of coarse aggregate required (m^3)	48.177	48.117	48.177
Volume of sand required (m^3)	45.86	42.19	41.19
Bags of cement required	700	671	670
Cost of cement (Rs.)	2,45,000	2,34,850	2,34,500
Cost of sand (Rs.)	85,758	78,895	77,027
Cost of coarse aggregate (Rs.)	51,669	51,669	51,669
Cost of bricks (Rs.)	1,47,070	2,38,248	1,31,150
Total cost (Rs.)	**5,29,497**	**6,03,662**	**4,94,346**

4. PROCESS OF ENERGY ANALYSIS:

The building was simulated using Revit Architecture 2021, which operational energy consumption was calculated using insight. By employing various materials in the simulation, the case study structure was analyzed to conduct a comparison of energy consumption.

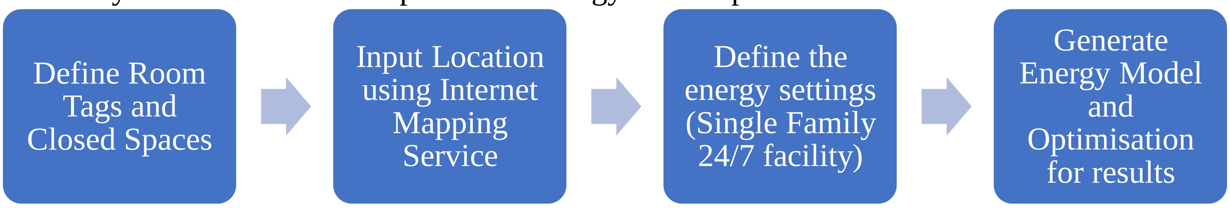

Figure 3: Process for energy analysis

5. ENERGY ANALYSIS IN REVIT (INSIGHT):

- The Energy analysis results were obtained from Autodesk Insight 360 website.

- The results indicate the energy assessment model, EUI (energy usage intensity), and various combinations of important criteria such as building orientation, window wall ratio (WWR), window shades, window glass, and wall and roof construction properties.
- By switching between the provided alternatives, you can adjust the energy cost value in USD/m2/year, enabling the selection of the most efficient model.
- Insights estimates the cost of energy per unit of area for a year in USD/m^2/year, and costs for kWh usage of electricity are estimated based on the location using standard conversion rates.

6. RESULTS AND DISCUSSION:

6.1 Comparison of materials:

Table 2: Material comparison

Parameters	Clay brick	Fly ash brick	AAC block
No of bricks required	21,010	13,236	3,050
Concrete work(m^3)	72.775	72.775	72.775
Volume of coarse aggregate required (m^3)	48.177	48.117	48.177
Volume of sand required(m^3)	45.86	42.19	41.19
Bags of cement required	700	671	670

- The quantity of coarse aggregate needed remains consistent across all three scenarios. AAC blocks require 85% fewer bricks, and Brick made from fly ash need 37% fewer bricks compared to regular clay bricks due to their larger dimensions.
- Volume of sand required for Brick made from fly ash is 8 % less and for AAC block is 10 % less than the normal clay brick.
- Volume of total mortar required is 21.64 % less for AAC blocks and 6.29 % less for Brick made from fly ash than the normal clay brick.
- Bags of cement required is approximately equal for Brick made from fly ash and AAC block is 4.28 % less than the normal clay brick.

6.2 Cost savings:

Table 3: Final cost savings

Parameters	Clay brick	Fly ash brick	AAC block
Cost of cement (Rs.)	2,45,000	2,34,850	2,34,500
Cost of sand (Rs.)	85,758	78,895	77,027
Cost of coarse aggregate (Rs.)	51,669	51,669	51,669
Cost of brick (Rs.)	1,47,070	2,38,248	1,31,150
Total cost (Rs.)	**5,29,497**	**6,03,662**	**4,94,346**

6.3 Energy composition:

Table 4: Energy Comparison

	Clay brick	Fly ash brick	AAC blocks
Energy Use Intensity (kWh/m^2/year)	**576**	**409**	**399**

7.CONCLUSION:

Materials play a crucial role in determining the construction costs of a building, and these costs can significantly vary between regions. Building orientation and material characteristics also influence a building's operational energy requirements. It was observed that constructing a building with normal clay bricks incurs a 6.6% higher cost compared to AAC blocks, while using fly ash bricks results in an 18% higher cost. In terms of energy consumption, the Energy Use Intensity (EUI) values are 576 kWh/m2/year for normal clay bricks, 409 kWh/m2/year for fly ash bricks, and 399 kWh/m2/year for AAC blocks. Normal clay bricks consume 29% more energy than fly ash bricks and 31% more energy than AAC blocks. This study's findings indicate that in the Warangal region, for residential construction, the use of AAC blocks or fly ash bricks is advantageous.

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