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Thermal and Energy Analysis of a Commercial Building: A Comparative Study of Construction Materials Using Revit Software

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Abstract: ***This paper presents a comprehensive thermal and energy analysis of a commercial building, focusing on the comparative study of different construction materials and window glass types using Revit software. The selection of appropriate building materials and window glass is crucial as they significantly impact the heating and cooling loads of the building. The study specifically targets a 5 - story commercial building with a carpet area of 20, 000 square feet. The analysis begins by modeling the building in Revit software, incorporating various construction materials and types. Different window glass materials, including single - glazed, double - glazed, and triple glazed glass are also considered. The thermal and energy performances of each material and glass type is evaluated and compared. The energy analysis is conducted to assess the heating and cooling loads of the building under different scenarios. This analysis helps identify the most energy - efficient combination of construction materials and window glass, aiming to optimize energy consumption while ensuring occupant comfort. Furthermore, the report explores the application of stone wall cladding as a potential strategy to reduce cooling loads. The findings of this study contribute to a better understanding of the influence of construction materials and window glass on the thermal behavior and energy performance of commercial buildings. The results provide valuable insights for architects, engineers, and building professionals in making informed decisions regarding material selection during the design and construction phases. Ultimately, the research aims to promote sustainable and energy - efficient practices in the building industry.***

Keywords: Thermal analysis, Energy analysis, Construction materials, Window glass materials, Revit software, Heating load, Cooling load, Building energy efficiency, Building information modeling, Concrete materials, Stone wall cladding, Sustainable building practices, Design and construction decisions

1. Introduction

In India, both commercial and residential buildings contribute significantly to the nation's energy consumption, accounting for 8% and 25% respectively. With the rising energy demands and environmental concerns, it becomes imperative to explore strategies that enhance energy efficiency in buildings. Among the various elements that comprise a building, the building enclosures, including walls, floors, roofs, and windows, play a pivotal role in controlling heat gain and loss. Heat gain in buildings can be effectively managed through the optimization of building enclosures. Among these elements, windows, which often consist of glass, hold particular importance due to their higher conductance coefficient compared to other building enclosures. Thus, it becomes crucial to study the thermal behavior of walls and window glasses in order to mitigate heat gain and enhance energy efficiency in buildings.

Whole building energy simulation emerges as a powerful tool in analyzing and predicting the energy use of a building. By considering the building's geometry, climate, building type, envelope properties, and active systems such as HVAC and lighting, this simulation captures the interdependencies of the building as a comprehensive system. Designers can leverage the analytical information obtained from whole building energy simulation to make informed and cost - effective decisions, ultimately improving building performance and reducing environmental impact.

The escalating environmental impact caused by human activities necessitates innovative approaches to reduce carbon footprints. It is our collective responsibility as global citizens to contribute towards healing and preserving our planet. Efficient utilization of energy and reduction of environmental impact should be at the forefront of our efforts. Unfortunately, certain energy - intensive industries often receive less attention when it comes to environmental considerations.

Therefore, this study aims to address the critical aspect of energy efficiency in buildings, specifically focusing on the thermal behavior of walls and window glasses. By exploring the thermal performance of these elements, we can identify strategies to minimize heat gain and improve energy efficiency in buildings. Through a comprehensive analysis using whole building energy simulation, we can provide valuable insights to designers and stakeholders, enabling them to make informed decisions towards energy - efficient and sustainable building practices.

By recognizing the importance of reducing environmental impact and optimizing energy consumption, we contribute to a better future for our planet. It is essential to continually explore innovative approaches and technologies that can enhance energy efficiency in overlooked sectors, ultimately working towards a more sustainable and environmentally conscious world.

2. Literature Survey

K. Deepa, B. Suryarajan, and V. Nagaraj [1]conducted research on the energy consumption of buildings throughout their life cycle. Studying energy consumption at the conceptual stage is vital for selecting energy - efficient design alternatives. The authors highlighted the increasing significance of sustainable design and the use of analysis tools in architecture. They concluded that energy analysis using Autodesk Revit and Autodesk Insight is a modern and effective method for evaluating design options. This approach empowers designers to make informed decisions, enhance energy efficiency, and contribute to sustainable building practices.

I. S. N. V. R. Prashanth, V. Nikitha, B. Aravind, and N. Mahesh [2]conducted a project using Revit software to analyze cooling load calculations in commercial buildings. They compared window and split air conditioners with central air conditioning systems, emphasizing the importance of proper duct design to minimize issues like frictional loss, high costs, noise, and power consumption. Revit software was used to calculate cooling load from various sources, such as people, lighting, infiltration, and ventilation, including walls and roofs. Results were compared with industry standards. The study showcased the advantages of central air conditioning systems with well - designed ducts, promoting energy efficiency, cost - effectiveness, and improved aesthetics in commercial building design.

Pratik B. Ambalkar and Monika M. Borkar [3] focused on utilizing Autodesk Revit for energy analysis in a G+2 residential building. The study aimed to explore the capabilities of Revit and integrate its use in predicting the energy consumption of the building throughout its lifespan. A comparison was made between energy analysis results of a residential flat scheme using different materials, specifically normal brick and air - filled walls. The findings demonstrated that the second model with air - filled walls outperformed the first model. The authors employed Autodesk Revit's Green Building Studio, a cloud - based energy analysis program, for this purpose. The paper highlights the potential of Revit in facilitating energy analysis and aiding in design decisions for improved energy efficiency.

Abhilash Jangalve and VijayratnaKamble [4]conducted a study on energy analysis using Autodesk Energy analysis tools, focusing on residential building analysis through BIM technology. The research emphasized the benefits of energy simulation in understanding energy flow within building models, aiding designers in making cost - effective decisions to enhance building performance and reduce environmental impact. Whole building energy analysis considers various factors like building geometry, type, climate, envelope properties, and active systems such as HVAC and lighting to estimate energy consumption. The study highlights the significance of energy analysis in informing sustainable design practices and optimizing energy efficiency.

Gail S. Brager and Richard J. de Dear [5] explored the concept of thermal adaptation in the built environment and its implications for thermal comfort. The study emphasized the significance of considering adaptive approaches to modeling thermal comfort, taking into account the complexity of individuals' past thermal experiences. The authors identified three distinct processes: behavioral adjustment, physiological acclimatization, and psychological habituation. They found that while physiological acclimatization might not be as relevant in moderate building conditions, behavioral adjustment and expectations significantly influence thermal perception. The paper highlights the importance of focusing on these areas to enhance occupants' thermal comfort and design more responsive and comfortable built environments.

3. Architectural Design of the Building

The building model is created using Revit 2022 version. The building modeled is a corporate office, with a total square footage of 19, 789.28. The building features a storefront glass wall on its eastern face, allowing natural light to enter the workspace. The model includes a total of 335 windows and 112 doors, providing ventilation and access throughout the building. Additionally, there are 52 marked spaces within the office, potentially indicating separate areas or rooms for different functions. The modeled building is represented below.

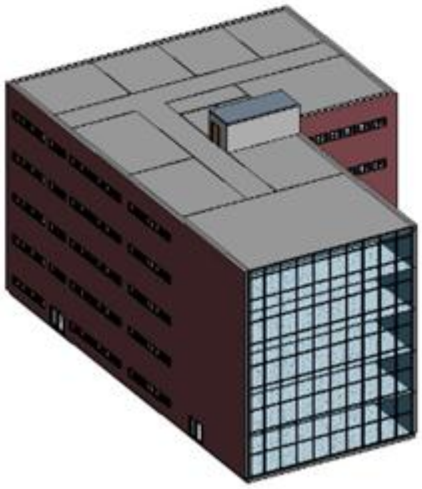

Figure 1: 3D view of the modeled building

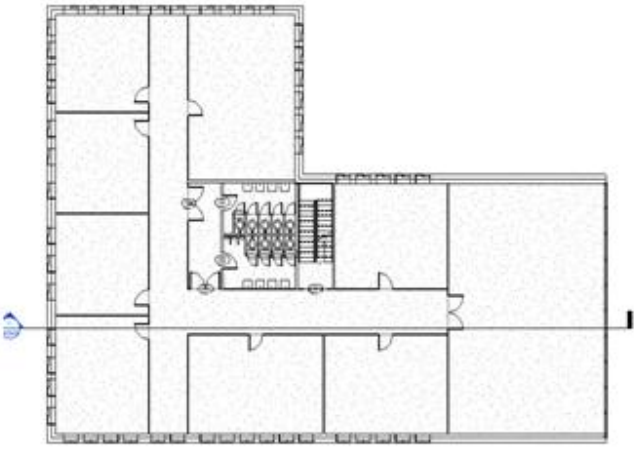

Figure 2: Level 1 floor plan

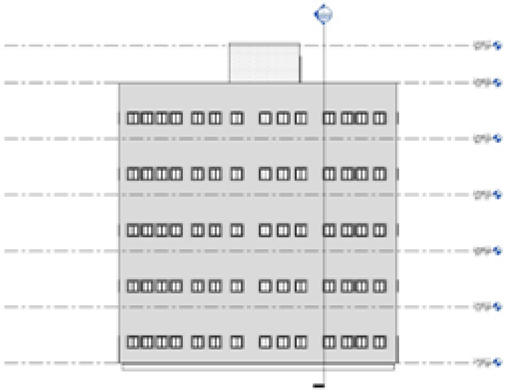

Figure 3: West view of the model

Figure 4: North view of the model

Figure 5: South view of the model

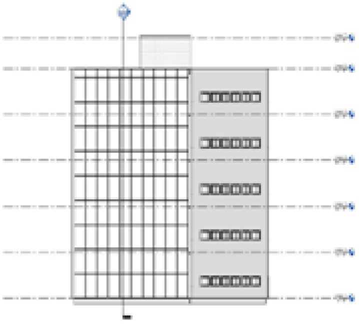

Figure 6: East view of the building

Table 1: Analytical surfaces

	Total	North	East	South	West
Gross Wall Area [ft2]	22157.09	6612.68	4263.31	6720.66	4560.45
Above Ground Wall Area [ft2]	22157.09	6612.68	4263.31	6720.66	4560.45
Window Opening Area [ft2]	4375.46	529.31	2752.26	599.88	494.02
Gross Window - Wall Ratio [%]	19.75	8.00	64.56	8.93	10.83
Above Ground Window - Wall Ratio [%]	19.75	8.00	64.56	8.93	10.83

4. Materials Selected for Analysis

The choice of materials is crucial as they have a significant impact on the thermal performance of the building. In this study, careful consideration was given to selecting materials with different thermal properties to perform a comparative analysis. The materials were chosen based on their commonly used applications in construction and their known thermal characteristics. The Revit software provides a comprehensive library of materials with predefined thermal properties, allowing for accurate representation and simulation of their behavior within the building model. By assigning these materials to different building elements such as walls, floors, and roofs, the thermal properties of each component can be accurately accounted for during the energy analysis. The materials used for simulation and their thermal properties are represented below.

Table 2: Materials/wall types used for construction of interior

Sr. No.	Wall Type	Function	Heat Transfer Coefficient (BTU/ (h. ft^2. °f))	Thermal Resistance ((h. ft^2. °f) /BTU)	Thermal Mass (BTU/ (ft^2. °f))
1	partition 5 ½”	Interior	0.0469	21.329	2.15
2	soffit - 1/2” GWB and Metal Stud	Interior	8.6392	0.115	7.59

Table 3: Materials/wall types used for construction of exterior walls

Sr No.	Wall Type	Function	Heat Transfer Coefficient (BTU/ (h. ft^2. °f))	Thermal Resistance ((h. ft^2. °f) /BTU)	Thermal Mass (BTU/ (ft^2. °f))
1	Brick and CMU on Metal Stud	Exterior	0.0184	54.423	13.99
2	Brick on CMU	Exterior	0.0316	31.625	28.64
3	Brick on Metal Stud	Exterior	0.0185	54.023	7.185
4	CMU Insulated	Exterior	0.0320	26.184	44.62
5	CMU on Metal Stud	Exterior	0.0186	53.890	15.64
6	EFIS on Metal Stud	Exterior	0.0151	66.090	1.45
7	Red Brick	Exterior	0.9360	1.068	6.427
8	CMU	Exterior	1.1821	0.840	14.32
9	Aerated Concrete	Exterior	0.1213	8.241	7.2664

10	Clay	Exterior	0.5489	1.821	23.79
11	Stone	Exterior	1.6756	0.5968	34.443

Table 4: Materials/Glass types used for construction of exterior walls

Sr No.	Glass types	Function	Heat Transfer Coefficient (BTU/ (h. ft^2. °f))	Thermal Resistance ((h. ft^2. °f) /BTU)	Solar Heat Gain Coefficient
1	1/4 in Pilkington single glazing	Exterior	1.1803	0.847	0.86
2	Double glazing - 1/4 in thick - low - E/clear (e = 0.2) glass	Exterior	0.3500	2.835	0.60
3	Triple glazing - 1/4 in thick - low - E/low - E/clear (e = 0.05) glass	Exterior	0.2700	3.704	0.2600

a diverse range of materials was selected to ensure a comprehensive analysis and obtain a varied dataset. Each material was chosen based on its distinct thermal properties, allowing for a thorough examination of their impact on the building's thermal performance. By incorporating materials with different thermal conductivities, heat capacities, and insulation properties, the study aimed to capture a wide spectrum of scenarios and evaluate the sensitivity of the building's energy performance to material selection. This approach enabled a more holistic understanding of how various materials contribute to the overall thermal behavior of the building.

5. Analysis and Results

The first step in conducting the thermal and energy analysis is to assign analytical spaces in the design. These spaces represent areas where HVAC systems will be installed. In the model used for this study, a total of 52 analytical spaces were identified and defined within the building layout. Once the analytical spaces are established, the next step is to assign appropriate construction materials to the building model. Different materials with their respective thermal properties are selected and assigned to the corresponding elements of the building, such as walls, roofs, and floors. This step ensures that the model accurately represents the thermal behavior of the actual building. To simulate the building's energy performance in a specific location, the geographical location needs to be specified within the software. For this study, the city of Mumbai was chosen as the location. Autodesk Revit software retrieves weather data from the nearest weather station to Mumbai for its energy analysis calculations. This ensures that the simulation takes into account the local climate conditions and their impact on the building's energy consumption. With the location and materials assigned, an energy model is created within the software. The energy model incorporates all the relevant elements, including the building geometry, construction materials, window types, HVAC systems, and lighting fixtures. This model serves as the basis for the subsequent energy analysis. The detailed energy analysis is then performed using the energy model. The software calculates various parameters, such as heating and cooling loads, energy consumption, and thermal comfort metrics, based on the inputs provided.

To investigate the impact of external wall types and materials on the thermal load of the building, a series of analyses were conducted by altering the external walls while keeping all other elements constant. This approach allowed for a comparative study to assess the thermal performance and energy consumption associated with different wall configurations. In each analysis, the external walls were modified to incorporate various types and materials, such as concrete, brick, insulated panels, or composite materials. The thermal properties of these materials, including conductivity, heat capacity, and insulation values, were taken into account during the analysis. By changing the wall composition while maintaining consistent interior spaces, HVAC systems, and weather conditions, the sole influence of the external walls on the building's thermal load could be isolated. Results are represented in the table below.

Table 5: Results of energy analysis obtained by changing external walls

Sr No.	External wall type used for analysis	Annual consumptipn of energy for cooling (kBtu)	Total Energy Usage (Kbtu)	Energy Per Total Building Area (kBtu/ft2)
1	Brick and CMU on Metal Stud	2, 416, 773	2830410.52	143.03
2	Brick on CMU	2, 5845, 21	2, 945, 634	148.76
3	Brick on Metal Stud	2, 465, 428	2, 897, 564	146.34
4	CMU Insulated	2, 527, 559	2941207.02	148.45
5	CMU on Metal Stud	2, 447, 169	2860824.79	144.56
6	EFIS on Metal Stud	2, 416, 754	2830396.02	143.03
7	Red Brick	2, 929, 494	3343477.47	168.95
8	CMU	3, 149, 875	3, 598, 143	181.72
9	Aerated Concrete	2, 784, 951	3, 184, 565	160.83
10	Clay	2, 786, 475	3, 798, 412	156.14
11	Stone	2, 677, 915	3091730.16	156.23

Upon comparing the results, it can be observed that the different wall types exhibit varying energy consumption patterns. For instance, the exterior walls with brick on CMU (Concrete Masonry Unit) construction, including CMU Insulated and CMU on Metal Stud, demonstrate relatively lower annual energy consumption for cooling and energy per total building area. These wall types possess higher thermal resistance, which contributes to their improved energy efficiency. In contrast, wall types such as Red Brick and Stone display higher annual energy consumption for cooling and energy per total building area. These materials exhibit lower thermal resistance and higher thermal mass, which can result in increased heat transfer and higher energy demands for cooling. Results also indicate that wall types like EFIS (Exterior Insulation and Finish System) on Metal Stud and Brick on Metal Stud show lower annual energy consumption for cooling and energy per total building area. These wall types exhibit relatively higher thermal resistance and lower thermal mass, contributing to their improved energy performance.

By considering the material properties and analyzing the corresponding energy consumption values, it becomes evident that the choice of exterior wall type plays a significant role in the overall energy efficiency of the building. Wall types with higher thermal resistance and lower thermal mass tend to demonstrate better energy performance, while those with lower thermal resistance and higher thermal mass may lead to increased energy consumption.

After completing the analysis on the external wall types and materials, the study proceeded to investigate the impact of interior wall materials and types on the thermal load of the building. Similarly, multiple analyses were conducted by modifying the interior walls while keeping all other elements unchanged. In this phase of the study, 2 types of interior wall configurations were explored. Results are represented in the table below.

Table 6: Results of energy analysis obtained by changing internal walls

Sr No.	Interior wall type used in analysis	Annual consumption of energy for cooling (kBtu)	Total Energy Usage (Kbtu)	Energy Per Total Building Area (kBtu/ft2)
1	partition 5 ½”	2, 416, 773	2830410.52	143.03
2	soffit - 1/2” GWB and Metal Stud	2, 450, 828	2862315.87	145.41

The results obtained demonstrate that the change in cooling load between the different interior wall types is minimal. Despite selecting materials with extreme material properties, the variation in cooling load is relatively insignificant. This is primarily due to the HVAC zoning within the interior spaces of the building. Since most of the building's interior spaces are equipped with HVAC systems, the choice of interior wall materials has a relatively small impact on the overall cooling load.

Following the analysis of external and interior wall materials, the study proceeded to investigate the influence of window glass materials on the thermal load of the building. By modifying the window glass types while keeping all other elements constant, a series of analyses were conducted to assess their impact on thermal performance.

Table 7: Results of energy analysis obtained by changing Glass types

S. No.	Glass type used in analysis	Annual consumption of energy for cooling (kBtu)	Total Energy Usage (Kbtu)	Energy Per Total Building Area (kBtu/ft2)
1	1/4 in Pilkington single glazing	2, 490, 788	2902307.63	147.44
2	Double glazing- 1/4 in thick - low - E/clear (e = 0.2) glass	2, 130, 115	2541390.92	129.10
3	Triple glazing- 1/4 in thick- low- E/low- E/clear (e= 0.05) glass	1, 693, 256	2104245.08	106.90

Analyzing the results, we observe a significant difference in the energy consumption for cooling and energy per total building area among the different window glass types. When comparing the single glazing to the double glazing, there is a percentage reduction of approximately 14.60% in energy consumption for cooling and a decrease of around 12.10% in energy per total building area. Similarly, comparing the single glazing to the triple glazing, there is a percentage reduction of roughly 32.08% in energy consumption for coolingand a decrease of approximately 27.49% in energy per total building area. However, it is worth mentioning that the large exterior surface area of the building covered by a glass facade contributes to these results.

In addition to analyzing the impact of external and interior wall materials, as well as window glass types, the study further investigated the potential benefits of incorporating stone wall cladding into the design. Stone wall cladding, known for its thermal insulation properties, was added to the external walls of the initial model, and a subsequent analysis was conducted to evaluate its effect on the thermal load of the building. In addition to analyzing the impact of external and interior wall materials, as well as window glass types, the study further investigated the potential benefits of incorporating stone wall cladding into the design. Stone wall cladding, known for its thermal insulation properties, was added to the external walls of the initial model, and a subsequent analysis was conducted to evaluate its effect on the thermal load of the building. A stone wall cladding of 20mm thickness was added onto the exterior walls (Heat Transfer Coefficient 0.0112 BTU/ (h. ft2. °f)). Annual cooling energy required reduced from 2, 416, 773 Kbtu to 2320063 Kbtu signifying a 4% decrease.

6. Conclusion

In conclusion, this study conducted a comprehensive thermal and energy analysis of a commercial building using Autodesk Revit software. The findings of this research emphasize the importance of material selection and design considerations in optimizing the thermal performance and energy efficiency of buildings. By exploring the impact of different external and interior wall materials, window glass types, and the addition of stone wall cladding, valuable insights were obtained for designers in the field. The study demonstrated that the choice of external wall materials can significantly influence the thermal load and energy consumption of a building. It was observed that materials with higher thermal resistance and lower heat transfer coefficients resulted in reduced cooling energy requirements. Similarly, analyzing different window glass types revealed that the use of double or triple glazing with low - E coatings can substantially improve energy performance by minimizing heat transfer. Furthermore, the addition of stone wall cladding was found to enhance the thermal insulation of the building. For designers in the field, these findings provide valuable guidelines and considerations. Firstly, careful selection of external wall materials and window glass types can significantly impact the overall energy efficiency of a building. Choosing materials with optimal thermal properties and insulation characteristics can lead to reduced energy consumption and improved occupant comfort.

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References

[1] Kumar, Ajeet, et al. "Analysis Of Energy Conservation for A Building Model Of Research Institute, (Using Design Builder Simulation Software). " International Journal of Applied Engineering Research 12.18 (2017): 7630 - 7637.
[2] Prashanth, I. S. N. V. R., et al. "Estimation of Cooling Load Calculations for a Commercial Complex. " (2019).
[3] Pathan, Md Gulfam, et al. "Comparitive study of energy analysis on residential building in revit software. " International Journal of Advance Research and Innovative Ideas in Education 2 (2019): 1182 - 1189.
[4] Jangalve, Abhilash, et al. "Energy analysis of residential building using BIM. " Int. J. Emerg. Eng. Technol. Sci 108 (2016): 15 - 19.
[5] Brager, Gail S., and Richard J. De Dear. "Thermal adaptation in the built environment: a literature review. " Energy and buildings 27.1 (1998): 83 - 96.