Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 November; 6(1): 1161-1176

Influence Of Building Material On Building Performance In Institutional Building

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Abstract

The choice of building materials plays a vital role in determining the overall performance of educational buildings. This research paper aims to analyse the impact of building materials properties on the various aspects of building performance, encompassing energy efficiency and occupant comfort. By understanding these influences, the researcher endeavours to provide valuable insights for optimizing building material selection and construction strategies. The study adopts a mixed-methods approach, combining both quantitative and qualitative research methodologies. Data collection will involve extensive literature review, to identify the properties of potential alternative building materials. This review paper will discuss the following building performance factors - energy efficiency and thermal efficiency. Through the analysis of collected data, the review paper assesses the role of building materials in influencing energy performance patterns and thermal performance. The findings of this review highlight the most suitable materials properties for buildings to achieve superior performance. By addressing the interrelation between building materials and performance outcomes, this research paper contributes to the advancement of high-performance educational buildings.

Key Words: Building performance, building envelope, material selection, thermal-physical properties, material properties, construction techniques

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

The modern world is characterized by rapid urbanization, technological advancements, and a growing concern for optimizing building performance. Within this dynamic landscape, the design and construction of buildings have taken on a profound significance. Beyond mere physical structures, buildings serve as intricate systems that impact human well-being, resource utilization, energy consumption, and the quality of our surroundings (Rajivodevic, 2018). As societies strive for greater efficiency, comfort, and sustainability, the concept of building performance has emerged as a pivotal focal point. Building performance refers to the ability of a structure to effectively meet the needs of its occupants. It encompasses a multifaceted array of factors, including energy efficiency, thermal comfort, acoustic quality, indoor air quality. Achieving optimal building performance is not only a matter of functionality but also a testament to responsible design and construction practices that harmonize with the natural world.
Building material properties act as the foundation upon which building performance is built. These properties determine how a material responds to thermal, acoustic, and environmental stimuli, ultimately shaping its behaviour within a constructed environment. Material layer thickness, for instance, influences insulation effectiveness, affecting a building's ability to retain or dissipate heat. Thermal conductivity dictates how efficiently heat travels through a material, directly impacting energy consumption for heating and cooling. Specific heat capacity influences a material's ability to store and release thermal energy, contributing to temperature regulation. Density affects structural integrity, as well as the material's potential for heat absorption and retention (Johra, 2021). In the context of energy-efficient design, the properties of thermal resistance, thermal absorptance, solar absorptance, and visible absorptance play pivotal roles. Thermal resistance determines a material's ability to impede heat flow, crucial in minimizing energy loss through building envelopes. Absorptance properties influence how a material interacts with solar radiation, impacting thermal gains and losses and subsequently affecting indoor temperatures. These properties are particularly crucial for optimizing passive solar design and reducing the reliance on mechanical heating and cooling systems.
In light of these considerations, this paper embarks on an exploration of how building material properties ranging from material layer thickness to absorptance coefficients directly influence building performance. By delving into the nuances of each property and its impact on energy efficiency and thermal comfort. Aim is to contribute to a more comprehensive understanding of how material choices shape the trajectory of modern construction. Through this analysis, we aspire to

catalyze informed decisions, innovative approaches, and a more harmonious relationship between material properties and building performance.

CHAPTER 2: LITERATURE REVIEW

2.1 BUILDING ENVELOPE

The term "building envelope" describes the enclosure of a built environment, which includes the roof, skylights, doors, windows, and other openings for light and ventilation. The building envelope refers to the entire collection of (building) elements made up of parts that keep the building's interior environment separate from the outside world (Oral, 2004). The envelope shields the interior of the building and its occupants from weather and other outside factors. The visual and thermal comfort of building occupants, as well as energy consumption, are significantly influenced by an envelope's design features. Building form, building pattern, building scale, and building proportions all play a role in how a building's envelope design emerges. Typically, a building's envelope is designed with consideration for a variety of factors, including the environment, technology, society, culture, function, and aesthetics (Kumar, 2016).

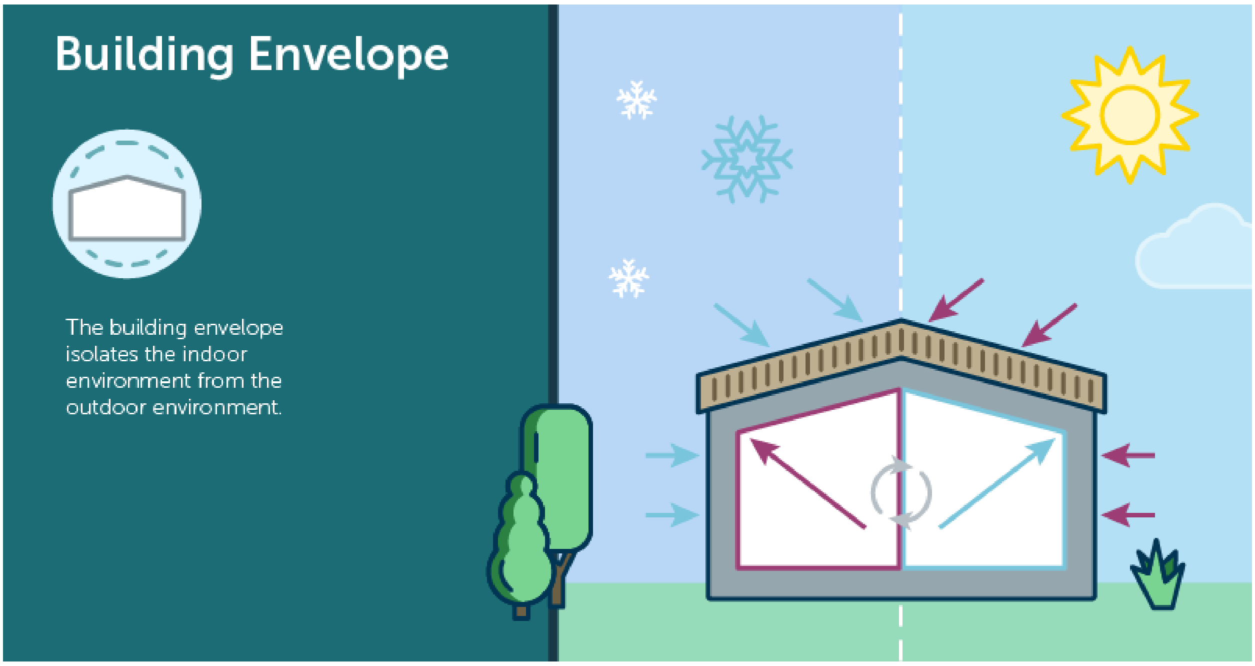

Figure 1: *Building Envelope*

Components that make up the building envelope can be categorized as opaque and transparent. Walls, roofs, slabs, basement walls, and opaque doors are among the opaque components. Windows, skylights, ventilators, doors with more than one half of glass, and glass block walls are examples of transparent building envelope components (fenestration system). Physical protection from weather and climate (comfort), indoor air quality (hygiene and public health), durability, and energy efficiency are common ways to assess the effectiveness of building envelope components. It should also satisfy the user psychologically and environmentally. Outside perspectives are crucial psychologically. How they react to solar radiation (both from the sun's heat and light), how ventilation is made possible, how heat loss is minimized, and how noise is controlled are some environmental concerns that need to be addressed (Thomas, 2002). The next ten to fifteen years are likely to see a rapid development of a building envelope or skin. Glass technology advancements will enable window systems to react to changing environmental conditions to achieve sustainability in built form (Kumar, 2016).

Table 1: *Parameters for Opaque and Transparent components of Envelope (Oral,2004)*

OPAQUE COMPONENTS (WALLS, ROOFS, SLABS, BASEMENTS WALLS AND OPAQUE DOORS)	TRANSPARENT COMPONENTS (FENESTRATION SYSTEM: WINDOWS, VENTILATORS, DOORS, GLASS WALL, GLAZING ETC)
Orientation of building, its form and size of external obstacles.	Orientation of fenestration components, and external obstacles.
Position of building relative to other buildings.	Dimensions of the transparent component.
Soil cover and nature of ground.	Heat transmission coefficient of the glazing.
Thickness, density, specific heat and conduction coefficients of materials.	Absorption, reflection and transmission coefficient of the glazing for solar radiation.
Light absorption and reflection coefficients of the surfaces.	Transmission coefficient of the glazing for diffuse sunlight.
Porosity and roughness of the surface.	Transmission coefficient of the glazing for direct sunlight.
Sound transmission and absorption coefficient of the surface.	Transmission coefficient of the glazing for sound.
Depth of the cavity between the layers.	Type of frame used for the transparent component.
Thickness and sound absorption of the insulating material used inside the cavity.	Maintenance factor of the glazing.
Kind of connection between layers of different materials, and their number.	Thermal properties of spacer and cavity in the glazing system.

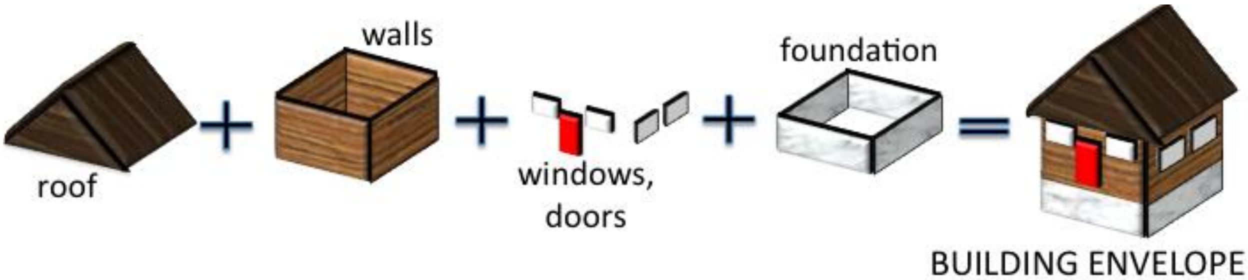

Figure 2: *Components of Building Envelope*

2.1.1 WALLS (EXTERIOR)

The vertical components that surround a building are its exterior walls. They contribute to thermal insulation, offer structural support, and provide protection from the elements. Concrete, brick, wood, and different cladding systems are frequently used for exterior walls. The energy efficiency of a building can be significantly impacted by these walls because they are exposed to outside temperatures. By preventing heat gain and loss in the summer and winter, proper wall insulation contributes to the maintenance of a comfortable indoor climate. The choice of wall materials can also impact a building's appearance, toughness, and weather resistance (Struabe, 2006).

2.1.2 ROOFS

Roofs are a building's topmost covering and provide protection from weather conditions like rain, snow, and sunlight. They are available in a variety of styles and components, such as metal, asphalt shingles, and green roofs. Particularly when it comes to heat gain, roofs can have a big impact on a building's energy efficiency. A dark-coloured or poorly insulated roof can result in an excessive amount of solar heat gain in the summer, raising cooling costs. On the other hand, a roof that is well insulated and reflective can help control interior temperatures, lower energy use, and enhance comfort levels. To stop water leaks and increase a building's lifespan, proper roof design and maintenance are crucial (Struabe, 2006).

2.1.3 SLAB (FLOORS, CEILING)
The horizontal surfaces known as slabs, which can be both floors and ceilings, separate the various levels of a building. They are essential for the integrity of the structure and can be made of materials like concrete or wood. Insulated slabs improve comfort and energy efficiency by reducing temperature transfer between floors. In colder months, properly insulated floors can stop heat from escaping to the ground, and in warmer months, they can reduce heat gain from the ground. In order to lessen noise transmission between various spaces in a building, sound insulation in slabs between floors is also crucial (Struabe, 2006).

2.1.4 BASEMENT WALLS
The foundation of a building is built on the structural support provided by basement walls. It's essential to insulate basement walls to stop heat loss to the ground and moisture intrusion. Uninsulated basement walls can cause a chilly, damp basement in colder climates, raising heating costs. In addition to improving energy efficiency, proper insulation and moisture management also guarantees a cosy and dry basement. Basements must have sufficient ventilation and waterproofing to prevent mould growth and maintain indoor air quality. The structural integrity and general environmental control of a building are greatly influenced by the basement walls (Struabe, 2006).

2.1.5 OPENINGS
Openings, such as doors and windows, are essential for a building's performance, impacting energy efficiency, aesthetics, security, and functionality. They contribute to thermal insulation, natural ventilation, daylighting, and indoor comfort. Well-insulated openings reduce energy consumption, improve indoor comfort, and enhance well-being. Low-emissivity (low-e) coatings and double- or triple-glazed windows with energy-efficient glass help control interior temperatures and lower heating and cooling expenses. Architects and builders must carefully select materials, design, and placement of openings to optimize performance, energy efficiency, aesthetics, and functionality. Overall, doors and windows are multifaceted components that contribute to sustainable and comfortable built environments (Struabe, 2006).

2.1.6 SKYLIGHTS
Skylights are windows that are mounted on the roof and are used to let natural light into interior spaces. Skylights, like regular windows, can contribute to heat gain and loss, so it's important to choose and design them carefully for energy efficiency. Skylights that are energy-efficient frequently have low-e coatings, double or triple glazing, and insulated frames. Maximizing natural daylighting while minimizing heat gain in the summer and heat loss in the winter can be accomplished with the right placement and sizing of skylights. Additionally, the installation of blinds or shading mechanisms can control how much sunlight enters a room, ensuring the comfort of the occupants and resulting in energy savings (Struabe, 2006).

2.2 BUILDING PERFORMANCE

2.2.1 DEFINITION AND CONCEPT OF BUILDING PERFORMANCE
A building is an asset that contributes to a secure environment if it is well maintained and leads to continuous improvement throughout its life cycle. Although they are expensive to acquire, having them has many advantages. Buildings are heterogeneous, according to (Douglas,1996), because each one is unique in its location, subsoil conditions, and access policies. Because each building's internal and external environments are different, each one has unique characteristics. (Khalil, 2013)
Generally, buildings require a set level of performance to provide a healthy and safe environment. (Bluyssen,2009) highlighted that the features for healthy buildings are free from hazardous materials and provide a healthy and comfortable environment for the building users throughout the building lifecycle. Therefore, this will influence both the image and value of a building. The main scope of building performance is to assure a quality asset that is able to integrate with user perceptions to achieve a desired lead of customer satisfaction. (McDougall etal,2002) mentioned that building performance has a strong relationship with building design and building occupants. Building performance is carried out by identifying user perspectives that can determine if the buildings perform well and it is an awareness to design the decision-making process (Vischer, 2009). In addition, (Vischer, 2009) mentioned that collaboration of human performance, building performance and social value is needed to assess the overall building performance. Building performance is a process that influences the value of a building by assessing how buildings work and the effectiveness towards the building users (Preiser and Schramm, 2005).(Douglas, 1996) defined building performance as a process to assess the overall progress of a building. Therefore, building performance is important because it needs to be well

maintained in order to fulfil the customer requirements and customer satisfaction to increase the work productivity (Wahab, 2011).

Table 2: *Definitions of Building Performance (Wahab, 2011)*

AUTHORS'	DEFINITIONS
Preiser & Schramm (2002)	Building performance includes notions of use and effect on human performance, because performance is assessed in terms of how buildings and building system affect the comfort, effectiveness and wellbeing of building users.
Keith (1996)	Overall performance of a building should assess by the combined performance of the building as it affected by technical capabilities of the building, technological environment and its process and perhaps most importantly the individual involve
Douglas (1996)	To assess how well a building is behaving overall and in the long term. It is important both in an inter building and intra building sense.
Becker (1996)	All buildings require, throughout their life, a level of performance and a standard of management that can provide and sustain conditions suitable for the well-being of their users. The approaches to building performance consist of built ability; flexibility; maintainability; adaptability; and marketability
Markus (1981)	It is obvious that buildings are for people; people pay for them, use them and design them. The design of a building consists of people making decisions on behalf of other people that affect another set of people.

2.2.2 PURPOSES OF EVALUATING BUILDING PERFORMANCE
Performance of buildings is assessed for a variety of objectives. The elements that should be carefully evaluated depend, ideally, on the goals of the evaluation. (Douglas, 1996) provided the following list of justifications for using building performance evaluation in buildings:

- For property portfolio review, acquisition or disposal purposes;
- To highlight where a building is lacking in performance;
- To help prioritize maintenance or remodelling works;
- To provide identification or early warning of obsolescence in buildings; and
- To assist in achieving value-for-money from building assets by aiding identification of performance achievements as well as failures.

The aforementioned factors make it more likely that buildings will be sustainable and that service operations will be optimized. (Preiser & Nasar, 2008) described that the key issues to cover in building performance also includes health, safety, security; issues addressed by building codes; functionality and guideline materials; and last, but not least, the social, psychological, cultural aspects of building performance.
The following table provides a summary of many literatures that explain the criteria for evaluating building performance, which are typically used for all types of structures, to make the notion of building performance and its needs easier to understand.

Table 3: *Summary of concept / requirements & purposes of BPE (Khalil, 2013)*

ASPECTS IN BPE	DESCRIPTION OF ASPECTS
Concept / Requirements in Building Performance Evaluation	• Building users / Occupants • Feedback from users or occupants
	• Clients' goal • Performance criteria • Performance measures / evaluation

	Efficiency and effectiveness
Purposes of Building Performance Evaluation	Help to fine tune building performance and reduce energy consumption
	Explore design changes that provide incremental improvement measured against single criteria such as reduced energy consumption and or improved thermal comfort.
	As an integral part of the planning and controlling cycle - it was among essential issues for the effective implementation of a facilities strategy.
	For better matching of supply and demand, improved productivity within the workplace, minimisation of occupancy costs, increased user satisfaction, certainty of management and design decision making, higher returns on investment in buildings and people.
	As negotiating instruments among stakeholders at various phases of the building procurement process.
	To solve problems on "real-world research" such as predicting effects, robust results and developing services towards client oriented.
	To credibly account on how well a building achieve its purpose at any time during its useful life

2.2.3 FACTORS OF BUILDING PERFORMANCE

- ENERGY EFFICIENCY
- THERMAL EFFICIENCY
- INDOOR AIR QUALITY
- LIGHTING

Building performance is influenced by energy efficiency, thermal efficiency, indoor air quality, and lighting. Energy efficiency reduces resource waste, lowering costs and having a smaller negative impact on the environment. By maximizing insulation and materials, thermal efficiency ensures comfort and lower energy consumption. Inhabitant health and productivity are enhanced by good indoor air quality. Energy savings and aesthetics are both improved by proper lighting. Together, these elements produce buildings that are eco-friendly, cozy, and cost-effective, promoting wellbeing while reducing their impact on the environment (Altan, 2016).

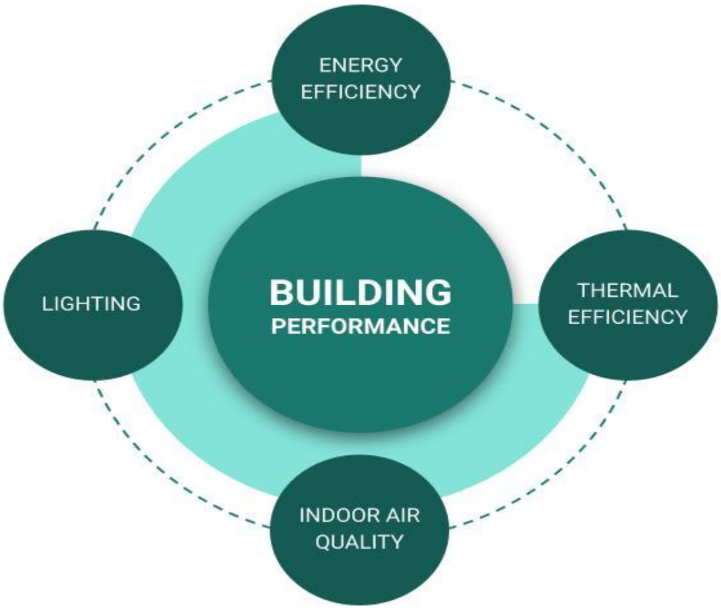

Figure 3*:Factors of Building Performance*

2.2.3.1 ENERGY EFFICIENCY

Building performance is based on energy efficiency. It entails utilizing energy resources wisely in order to minimize consumption and the impact on the environment. Buildings with efficient energy-use practices use less energy for equipment operation, lighting, heating, and cooling, which lowers energy costs and lowers carbon emissions. (Abokhalil, 2013)

- **Metrics :** Energy consumption (measured in kilowatt-hours or megajoules), energy use intensity (EUI), energy performance index (EPI).

Energy Performance Index : EPI is a metric commonly used to assess and benchmark the overall energy performance of a building or facility, typically on an annual basis. It provides a quantitative measure of a building's energy efficiency relative to its size and function. EPI is expressed in terms of energy use per unit of floor area or other relevant metrics. Here's how EPI is calculated:

EPI = Total Energy Consumption (e.g., in kWh or MMBtu) / Building Floor Area (e.g., in square feet or square meters)

Energy Use Intensity : EUI is another widely used metric for evaluating and benchmarking the energy performance of buildings. Like EPI, it quantifies energy consumption but focuses specifically on energy use per unit of floor area, typically on an annual basis. EUI is expressed in units such as kWh per square foot or MMBtu per square meter. Here's how EUI is calculated:

EUI = Total Energy Consumption (e.g., in kWh or MMBtu) / Building Floor Area (e.g., in square feet or square meters)

EPI is primarily used to assess and benchmark the overall energy performance of a building or facility. EUI, on the other hand, focuses specifically on energy use per unit of floor area.

- **Factors and Properties**

HVAC Systems: Efficient heating, ventilation, and air conditioning systems minimize energy use while maintaining occupant comfort.

Appliances and Equipment: Selection of energy-efficient appliances, computers, and other equipment lowers overall energy demand.

Renewable Energy: Integration of solar panels, wind turbines, or other renewable energy sources to generate on-site electricity.

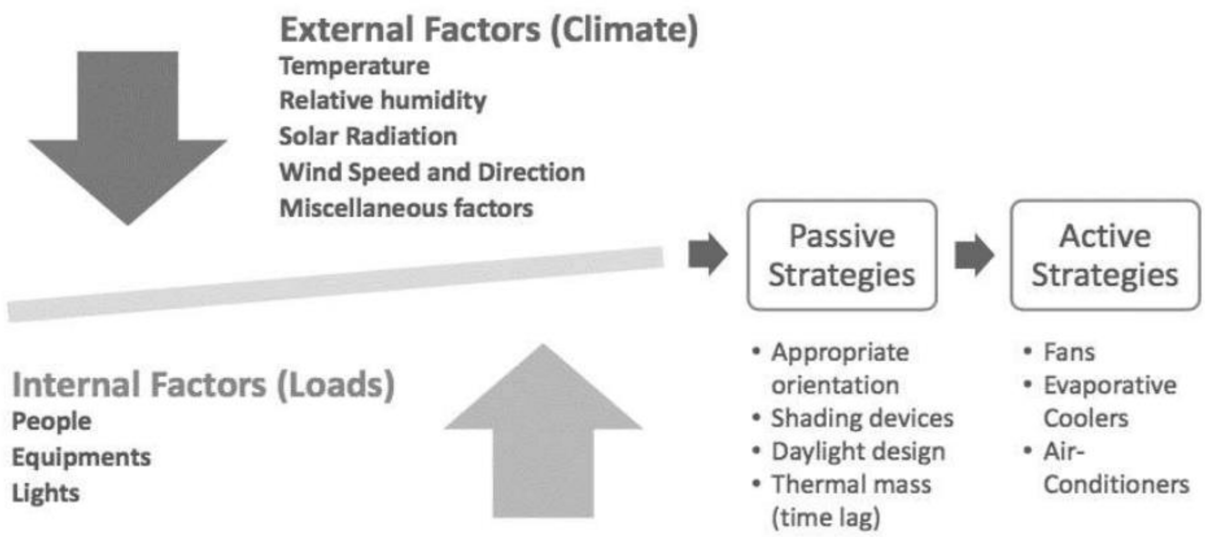

Figure 4: *Optimizing Energy Use for Thermal Comfort*

2.2.3.2 THERMAL EFFICIENCY / PERFORMANCE

Thermal efficiency is closely tied to energy efficiency. It focuses on how well a building's envelope (walls, windows, roof) insulates against heat transfer. A thermally efficient building maintains a comfortable indoor temperature while minimizing the need for excessive heating or cooling. Proper insulation, windows with good thermal properties, and airtight construction contribute to thermal efficiency. Thermal comfort is understood as "the condition of mind that expresses satisfaction with the thermal environment" (Altan, 2016) (Szokolay, 2014).

- **Metrics :** U-value (thermal transmittance), R-value (thermal resistance), thermal bridging coefficient, SHGC (solar heat gain coefficient), specific heat.

U-Value (or Thermal Transmittance): The U-value measures the rate of heat transfer through a building material or assembly, such as walls, windows, or roofs. It quantifies how well a material or structure conducts heat. A lower U-value indicates better insulating properties, meaning less heat is lost or gained through the material or assembly.

In cold climates, a low U-value is desirable to minimize heat loss from the interior, helping to maintain a comfortable indoor temperature and reduce heating costs. In hot climates, it's important for windows and roofs to have a low U-value to prevent excess heat from entering the building, reducing cooling energy consumption.

R-Value (Thermal Resistance): The R-value is the reciprocal of the U-value. It measures the resistance of a material or assembly to heat flow. A higher R-value indicates better insulation. It's often used to evaluate the thermal performance of insulation materials.

In cold climates, higher R-values are preferred for insulation materials to reduce heat loss and maintain warmth indoors. In hot climates, R-values are still relevant for controlling indoor temperature, as they help keep outdoor heat from infiltrating the building.

SHGC (Solar Heat Gain Coefficient): SHGC measures how much solar radiation (heat) passes through windows or glazed surfaces. It is expressed as a fraction or percentage. A lower SHGC means less solar heat is transmitted through the window, reducing cooling loads.

In hot climates with intense sun exposure, a lower SHGC is desirable to minimize solar heat gain, which helps keep indoor spaces cooler and reduces the need for air conditioning. In colder climates, a higher SHGC can be beneficial to capture more solar heat for passive heating during the winter.

Specific Heat (or Heat Capacity): Specific heat represents the amount of heat energy required to raise the temperature of a unit mass (usually 1 gram or 1 kilogram) of a substance by 1 degree Celsius (or 1 Kelvin). Different materials have different specific heat values, which can affect their ability to store and release heat.

Materials with high specific heat values, like water and some construction materials, can store a significant amount of heat. In nature, bodies of water with high specific heat, such as oceans and lakes, have a moderating effect on temperature, helping to keep nearby areas cooler in the summer and warmer in the winter.

- **Factors and Properties**

Insulation Materials: The type and quality of insulation materials used in walls, roofs, and floors impact their ability to resist heat transfer.

Windows and Glazing: Energy-efficient windows with low U-values and appropriate solar heat gain coefficients reduce heat loss and gain.
Thermal Bridging: Avoiding areas where heat can easily flow through the building envelope, which minimizes energy losses.
Building Envelope: Well-designed windows, doors, and thermal bridges reduce heat loss and gain.

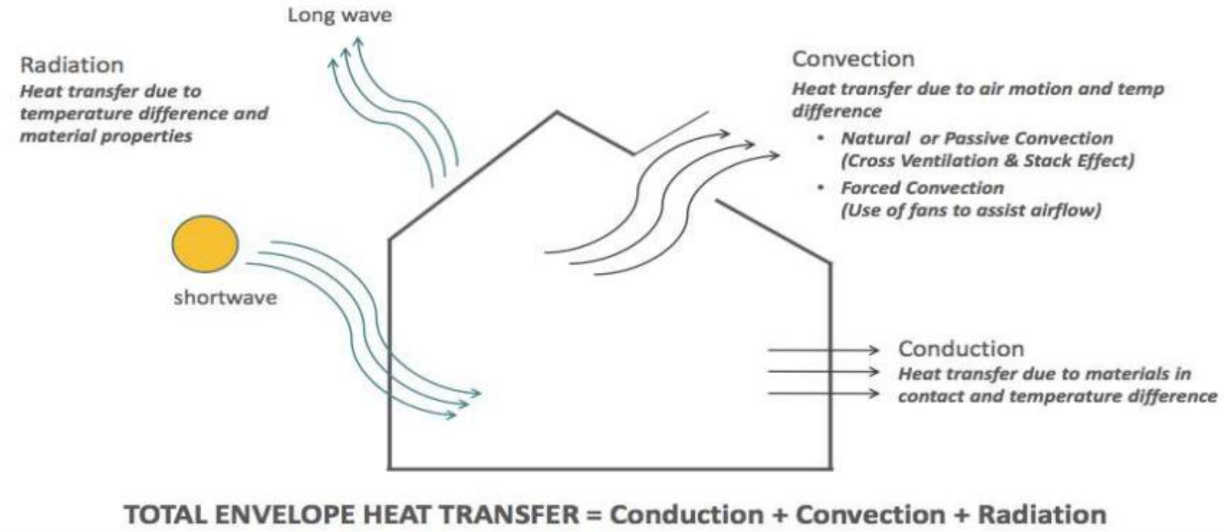

Figure 5: *Building heat transfer*

2.2.3.3 INDOOR AIR QUALITY
IAQ refers to the quality of the air within a building and its impact on occupants' health and comfort. Good IAQ involves proper ventilation, filtration, and control of pollutants such as allergens, chemicals, and mold. A building with excellent IAQ promotes a healthier indoor environment and enhances occupant well-being. (Altan, 2016)
Metrics: Air exchange rate, concentration of pollutants (particulate matter, volatile organic compounds), CO2 levels.
Factors and Properties:
Ventilation: Proper mechanical and/or natural ventilation systems provide fresh air while exhausting indoor pollutants.
Filtration: High-efficiency air filters remove allergens, dust, and particulates from the indoor air.
Control of Pollutants: Limiting or eliminating indoor sources of pollutants such as cleaning products, paints, and volatile chemicals.
Humidity Control: Maintaining appropriate indoor humidity levels to prevent mold growth and enhance comfort.
2.2.3.4 LIGHTING
Adequate lighting is crucial for occupant comfort and productivity. Effective lighting design considers both natural daylight and artificial lighting sources. Efficient lighting systems that provide appropriate light levels while minimizing energy use contribute to building performance(Altan, 2016).
Metrics: Illuminance (lux), luminance (candela per square meter), color temperature (Kelvin), lighting power density (LPD).
Factors and Properties:
Daylighting: Maximizing the use of natural daylight through well-placed windows and skylights to reduce the need for artificial lighting.
Lighting Fixtures: Efficient light fixtures that provide the desired illuminance levels with minimal energy consumption.
Lighting Controls: Dimming, occupancy sensors, and daylight-responsive controls to adjust lighting levels based on occupancy and available daylight.
Color Rendering: Selecting light sources that accurately render colors for improved visual comfort and aesthetics.

2.3 HIGH PERFORMANCE BUILDING IN EDUCATION SECTOR

Higher education institutions (HEIs) contribute significantly to the economic growth of any society through the creation and sharing of knowledge that fosters the development of human capital and innovation (Mowery, 2004). Buildings for higher education are designed to accommodate and support academic-related activities including teaching, learning, and research. These structures typically house a variety of faculties with various specializations. In addition, they have a range of rooms, including offices, lecture halls, classrooms, open areas, cafeterias, libraries, studios, workshops, and labs

(Oblinger, 2005). asserts that these areas exhibit the HEIs' pedagogical image. The effectiveness of these spaces affects the staff and students' behaviour, health, and production. Therefore, it is crucial for HEIs to offer sufficient facilities and places that satisfy the needs of its users - students and staff (Abisuga, 2019).

2.3.1 USER-CENTERED FACILITIES PERFORMANCE ATTRIBUTE

In contrast to research concentrating on other types of buildings, such as residential, commercial, and office buildings, a literature search on higher education building performance evaluation reveals that few have established user satisfaction needs in this context. Several buildings in the higher education setting are covered in these few studies, including student housing, classrooms, libraries, department buildings, and so on. Depending on the kind of building that is being evaluated, different performance attributes are also used. As previously mentioned, user requirements vary depending on the roles of the buildings and may alter over time. Due to this, several scholars have attempted to analyse some parameters in higher education buildings, as stated below:

2.3.1.1 DAYLIGHTING

Daylighting is a process that makes use of sunlight to create a normal lighting effect in buildings. According to (Tanner, 2009), daylighting has a large impact on the variance in students' science and reading vocabulary scores but has less of an effect on the variance in their mathematics results. Additionally, daylighting has a big impact on how comfortable users are in learning rooms. Light has an impact on a space's environmental performance. Natural light direction and luminance are important factors that affect users' choice of space. As a result, students evaluate learning environments based on the level of daylighting that supports their activities (Abisuga, 2019).

2.3.1.2 THERMAL COMFORT

Temperature has an impact on space environmental performance. According to (Yang, 2013), "heat from the sun" is the main element determining thermal comfort, which in turn affects student preferences for the classroom. A learning environment's temperature has a significant impact on students' comfort. Thermal comfort varies amongst buildings used for higher education. Additionally, (Hughes, 2002) noted that faculty buildings require improved temperature management within the individual rooms. (Lau, 2018) evaluated the degrees of thermal satisfaction in three distinct learning settings, building on the theories of (Kim, 2018), and discovered that users were somewhat more satisfied with the temperature in a hybrid ventilated area, followed by the air-conditioned and naturally ventilated space.

2.3.1.3 INDOOR AIR QUALITY

Indoor air quality has an impact on a space's ability to be environmentally friendly, according to (Kim, 2018). (Yang, 2013) analysed the air quality in classrooms and discovered that "stuffy air," which was ranked above "dirty air," "odorous air," and "humid air," is the most detrimental condition to air quality preference. (Hughes, 2002) also pointed out the need for improved air quality in learning environments. Therefore, ventilation can considerably impact users' overall pleasure, (Zhang, 2019) confirmed the impact of ventilation and indoor air quality on user satisfaction.

2.4 BUILDING MATERIAL

Building materials are a large category of materials, goods, and components used in infrastructure and construction projects to build physical structures. Based on their unique qualities, attributes, and adaptability for various construction tasks, these materials have been carefully selected.

Wood, stone, clay, and sand are examples of natural building materials. Concrete, steel, glass, and plastics are examples of produced or synthetic building materials. Reinforced concrete and fiber-reinforced plastics are examples of composite building materials. Within a building or construction, these materials may be used for structural, thermal, electrical, mechanical, or aesthetic purposes.

A key component of construction is the choice of building materials, which has an impact on aspects including structural integrity, durability, energy efficiency, aesthetics, and sustainability. To make sure that these materials satisfy the particular requirements and objectives of a construction project, architects, engineers, and builders carefully analyze the qualities, performance, and environmental impact of these materials (Mishra, 2014).

Figure 6: *Building Construction Materials*

2.4.1 IMPACT ON BUILDING PERFORMANCE

Modern architecture and construction focus on creating buildings that are aesthetically pleasing, functionally superior, energy-efficient, and maintain human comfort. Building materials play a crucial role in shaping and determining building performance, which encompasses a structure's efficiency, comfort, durability, and overall impact on its surroundings.

Building performance seeks to optimize a structure's ability to meet the diverse needs of its occupants while minimizing its environmental footprint. The selection of appropriate building materials underpins each of these goals, with the profound influence of building materials on several key dimensions (Rajivodevic, 2018).

2.4.1.1 Energy Efficiency: Building materials play a crucial role in determining the energy demand of a building, affecting heating and cooling requirements. Materials with high thermal resistance, low thermal conductivity, and excellent insulation properties contribute to reduced energy consumption for temperature regulation.

2.4.1.2 Thermal Comfort: Building materials significantly impact occupant comfort, with high thermal mass allowing for stable indoor temperatures and poor insulation causing discomfort.

2.4.1.3 Structural Integrity: Building materials with appropriate load-bearing capacities and resistance to environmental factors ensure the safety and longevity of a structure (Johra, 2021).

2.4.1.4 Indoor Air Quality and Health: Certain building materials emit volatile organic compounds (VOCs), which can degrade indoor air quality and negatively affect occupants' health. By selecting materials with low VOC emissions and minimal environmental impact, building professionals can create healthier indoor environments.

2.4.1.5 Aesthetic and Functional Considerations: Building materials contribute to the visual appeal and functionality of a space, offering diverse textures, colors, and finishes that influence the interior and exterior.

2.4.1.6 Environmental Sustainability: Building materials are closely tied to the sustainability of their materials, contributing to minimizing the building's carbon footprint and conserving resources.

The relationship between building material properties and performance is crucial for determining a building's functionality and performance over time. Building materials with appropriate thermal properties like thermal conductivity, heat capacity, and insulation value determine resistance to heat transfer. Properly chosen materials can regulate indoor temperatures, reduce energy consumption, and enhance occupant comfort (Balaji, 2013).

Building materials must withstand various environmental conditions, such as moisture, temperature fluctuations, UV radiation, and chemical exposure. Durability is influenced by material composition, surface treatments, and corrosion resistance. Sound absorption and transmission are influenced by material density, porosity, and surface textures. Materials like acoustic panels, insulation, and sound-absorbing finishes can enhance indoor acoustic comfort by reducing noise levels.

Material properties like color, texture, and form significantly impact the visual appeal of a building, offering diverse design options. Building materials can have varying degrees of environmental impact, including resource depletion, energy consumption during manufacturing, and emissions of pollutants (Ameur, 2020).

2.4.2 INFLUENCE OF MATERIAL PROPERTIES ON BUILDINGS

Table 4: *Impact and analysis of material properties (Yukseg, 2015,) (Ooka, 2016)*

S.No.	PROPERTIES	IMPACT	ANALYSIS
1.	Material layer thickness	Material layer thickness influences insulation effectiveness. Thicker layers provide better resistance to heat transfer,	Analyzing thickness ensures proper insulation and helps regulate indoor temperatures, reducing energy

		improving energy efficiency and thermal comfort.	consumption and enhancing occupant comfort.
2.	Thermal conductivity	Lower thermal conductivity means less heat transfer. Materials with low thermal conductivity are essential for effective insulation, reducing heating and cooling demands.	Analyzing thermal conductivity ensures efficient insulation, preventing energy wastage and maintaining comfortable indoor conditions.
3.	Specific heat	High specific heat materials can store and release thermal energy slowly, stabilizing indoor temperatures and reducing temperature fluctuations.	Analyzing specific heat helps achieve thermal comfort by ensuring gradual temperature changes and minimizing the need for frequent heating or cooling.
4.	Density	Higher density materials are often more durable and have better thermal mass properties. They can regulate indoor temperatures by storing and releasing heat.	Analyzing density helps select materials that contribute to both structural integrity and energy-efficient thermal performance.
5.	Thermal resistance	High thermal resistance in insulation materials reduces heat flow, leading to energy savings and improved comfort.	Analyzing thermal resistance is crucial for selecting effective insulation materials that minimize heat transfer and lower energy consumption.
6.	Thermal absorptance, solar absorptance, visible absorptance	Higher absorptance values mean more energy absorption. Lower solar absorptance helps prevent heat gain in roofing materials, reducing cooling loads.	Analyzing absorptance properties ensures materials reflect or absorb solar radiation appropriately, impacting energy efficiency and thermal comfort.

Each of these properties is vital in influencing how a building performs across various dimensions, including energy efficiency, thermal comfort, durability, and environmental impact. Analysing them during material selection is crucial for several reasons:

2.4.2.1 Optimized Performance: Carefully chosen materials with the right properties contribute to enhanced energy efficiency, indoor comfort, and overall building functionality.

2.4.2.2 Cost Savings: Materials with suitable thermal properties can lead to reduced heating, cooling, and maintenance costs over the building's lifespan.

2.4.2.3 Sustainability: Analysing these properties helps identify materials with lower environmental impact, promoting sustainable construction practices.

2.4.2.4 Occupant Comfort: Materials that regulate temperature fluctuations and provide better indoor air quality contribute to occupants' well-being and satisfaction.

2.4.2.5 Longevity: Properly selected materials with adequate density and durability can extend the building's lifespan and minimize the need for frequent repairs or replacements. (Balaji, 2013)

Incorporating these analyses during material selection empowers professionals to make informed decisions that align with the project's performance objectives. By understanding how each property impacts building performance, architects, engineers, and builders can create structures that are energy-efficient, comfortable, resilient, and sustainable, thus meeting the evolving demands of modern construction.

2.5 BUILDING PERFORMANCE ANALYSIS

Building performance analysis is essential to create efficient, sustainable, and comfortable buildings. It optimizes energy use, reduces costs, and ensures compliance with codes and regulations. By assessing factors like energy efficiency, occupant comfort, and environmental impact, it guides decisions on materials, systems, and design. Additionally, it enhances resilience to climate-related risks and mitigates potential issues, leading to more durable and reliable structures.

Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 November; 6(1): 1161-1176

Building performance analysis aligns with sustainability goals, enhances client satisfaction, and contributes to a healthier, more environmentally responsible built environment. It is an integral part of modern construction practices, offering a data-driven approach to building design and operation.

2.5.1 LABORATORY TESTING

Description: Lab testing involves conducting controlled experiments and measurements in a laboratory environment to gather empirical data about building materials and components. These tests assess properties such as strength, durability, thermal conductivity, fire resistance, and sound insulation. Researchers use specialized equipment and procedures to analyze the physical and chemical characteristics of construction materials.

Application: Lab testing is crucial for architects and engineers to ensure that building materials meet design specifications and regulatory standards. For example, testing concrete samples for compressive strength helps determine if the material can safely support the intended loads in a structure. Thermal conductivity tests on insulation materials provide data for optimizing a building's energy efficiency. However, this method can be time-consuming and expensive. Additionally, it may not fully capture real-world conditions and variations, being limited by available test equipment and sample sizes.

Figure 7: *Strength testing of material*

2.5.2 EMPIRICAL STUDIES

Description: Empirical studies in architecture involve collecting real-world data through observations, surveys, or field measurements. Researchers analyze this data to gain insights into how buildings perform in actual conditions. Empirical studies can focus on aspects such as indoor air quality, occupant behavior, energy consumption, and comfort levels within existing buildings.

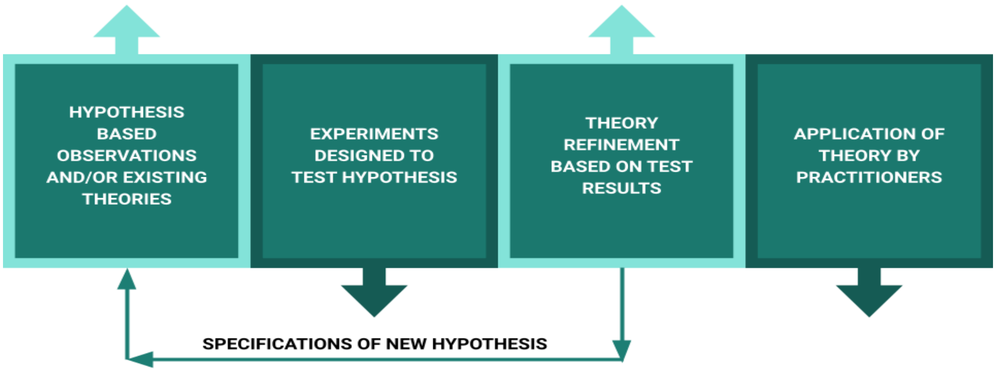

Figure 8: *Conceptual framework for research process (norjkhorloo, 2013):*

Application: Architects use empirical studies to evaluate and improve the performance of existing structures. For instance, monitoring temperature and humidity levels in a building over time can reveal patterns of thermal discomfort. Empirical data can inform retrofitting decisions and building management strategies to enhance occupant comfort and reduce energy consumption.

2.5.3 SIMULATIONS (COMPUTER MODELING)

Description: Simulation involves creating mathematical or computational models to predict how buildings will behave under different conditions. These simulations encompass various aspects, including energy performance, airflow, lighting, and thermal comfort. Simulation tools help architects and designers make informed decisions during the design phase.

Application: Building performance simulations are indispensable in architectural design. Energy 1174odelling software, for instance, predicts a building's energy usage and allows architects to optimize insulation, HVAC systems, and orientation for energy efficiency. Computational Fluid Dynamics (CFD) simulations assess indoor air quality and ventilation strategies. These simulations aid architects in creating comfortable and sustainable building designs while adhering to project constraints and goals.

SIMULATION AS THE PREFERRED METHOD

Simulations, particularly computer modelling using finite element analysis (FEA) and other advanced techniques, are often considered the best approach for analysing building material properties due to several reasons. They offer efficiency by allowing rapid testing of various scenarios, helping researchers explore a wide range of material combinations and conditions efficiently. Simulations are cost-effective compared to extensive laboratory tests or physical experiments, especially for complex or large-scale systems. They can model extreme conditions that are challenging to replicate physically, providing insights into behaviours under such scenarios. Simulations are non-destructive, allowing assessment without altering actual building components. They also support iterative design processes, enabling fine-tuning for optimal performance. While simulations have these advantages, the choice of method should be based on research goals, available resources, and required accuracy. (Ooka, 2016)

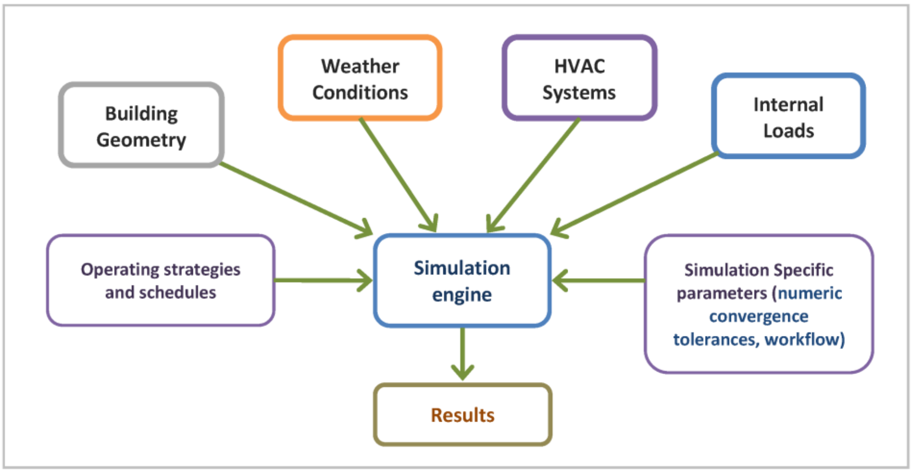

Figure 9: *General input data of thermal simulation engines*

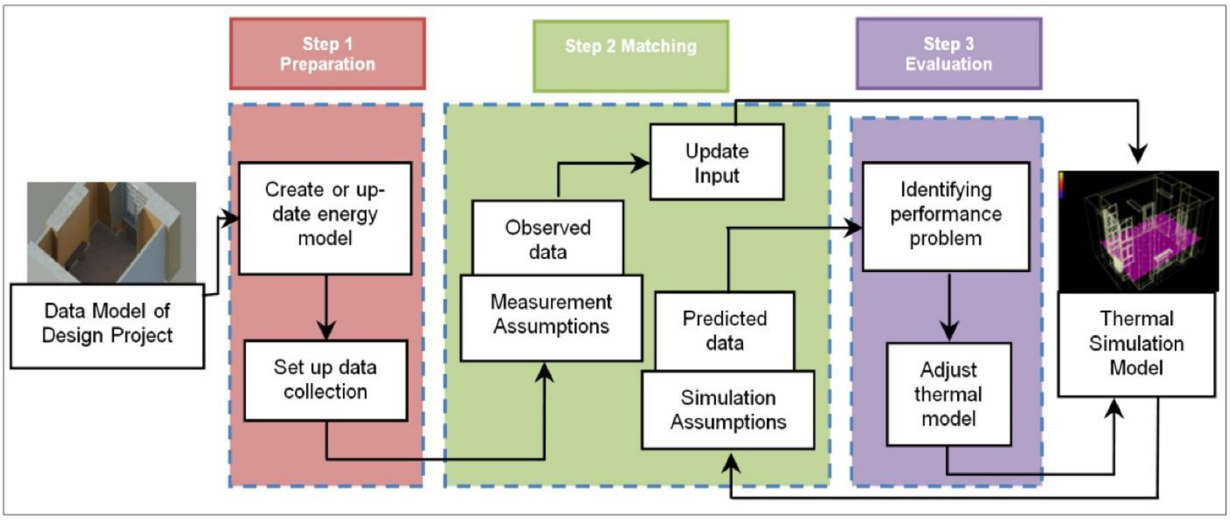

Figure 10: *Workflow to produce a Thermal Simulation Model*

CHAPTER 3: CONCLUSION

5.1 CONCLUSION

The journey of exploring the influence of building materials on the performance of the academic block concludes with several noteworthy insights. The study delved into the intricate relationship between material choices and the overall performance of the academic block, emphasizing the critical role played by the building envelope in shaping energy efficiency, thermal comfort, and long-term sustainability. This section synthesizes the diverse findings, drawing together the threads of the research to provide a cohesive and insightful conclusion.
The analysis revealed that the careful selection of building materials is pivotal for achieving high-performance standards in institutional buildings. The nuanced interplay between walls, roofs, and glazing systems has a profound impact on energy consumption, indoor comfort, and the environmental footprint of the academic block. The study underscores the importance of adopting a holistic approach to material selection, considering both immediate and long-term implications.

5.2 SUMMARY AND FINDINGS

In this section, a concise yet comprehensive summary of the research journey is presented, encapsulating the key findings that emerged from various phases of the study. The literature review laid the groundwork by exploring the significance of the building envelope, building performance metrics, and the role of materials in shaping energy-efficient and sustainable structures. The simulation and comparative analysis delved into the specifics, offering a nuanced understanding of how different materials impact the performance of the academic block.
The findings highlight the importance of considering climate-specific challenges, conducting life cycle analyses, and prioritizing materials that exhibit superior energy and thermal efficiency. The comparative analysis sheds light on the performance variations among different roofing, glazing, and wall materials, providing architects and stakeholders with valuable insights for future projects.

5.3 CONTRIBUTION TO ARCHITECTURE AND EDUCATION

This subsection delineates the tangible contributions of the dissertation to the fields of architecture and education. By unravelling the complexities of material selection criteria and their impact on building performance, the study contributes to the body of architectural knowledge. Architects and designers gain practical guidelines for creating high-performance educational facilities that prioritize sustainability, energy efficiency, and occupant well-being.
Furthermore, the dissertation's findings hold relevance for the education sector, as educational buildings are not merely physical spaces but integral components of the learning environment. The insights generated can inform future designs of academic structures, fostering environments that enhance the overall educational experience. The study thus bridges the gap between theoretical understanding and practical application, offering actionable recommendations for those involved in the planning and design of educational institutions.

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