A STUDY ON IMPACT OF DIFFERENT FLOORING TYPES TO THERMAL COMFORT IN BUILDINGS

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS

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**A thesis submitted
in fulfillment of the requirements for the degree of
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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

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DEDICATION

This thesis is dedicated to my parents, who always been supportive, encouraging, and wise. I am also extremely grateful to my thesis supervisor, for essential advice, ongoing support, and patience during my journey. Their vast experience have inspired me in my academic research. Their dedication to academic excellence and willingness to share their knowledge have sparked my aspirations for greatness. I deeply appreciate their mentorship, which has played a vital role in my intellectual growth. My sincere friends deserve special recognition for their unwavering support, understanding, and encouragement, which have helped me through all the highs and lows of this academic journey. Lastly, I dedicate this work to the countless individuals who have paved the way for knowledge and progress.

ABSTRACT

An effective flooring system not only improves the building's structural integrity and visual appeal, but it also significantly affects the occupants' thermal comfort. In order to address this issue, this study will examine three different flooring materials, such as ceramic, marble, and stone-plastic composite. The main objective of the research is to conduct a thorough investigation of how different types of flooring affect a building's thermal comfort. In order to shed light on the unique qualities of each flooring material, the study will examine the inherent thermal characteristics of those materials. In addition, the study intends to assess the thermal efficiency of different flooring materials under various environmental and building configurations. The study seeks to improve awareness of the complex interaction between flooring choices and thermal comfort. The main takeaway from the discussion as a whole is that stone-plastic composite flooring is better suited for thermal comfort. The findings will help architects, designers, and building owners choose flooring materials that optimize thermal conditions while boosting occupant comfort. This research contributes to the advancement of sustainable building design and indoor well-being.

ABSTRAK

Sistem lantai yang berkesan bukan sahaja meningkatkan integriti struktur bangunan dan daya tarikan visual, tetapi ia juga memberi kesan ketara kepada keselesaan terma penghuni. Bagi menangani isu ini, tesis ini berfokus untuk mengkaji tiga bahan lantai yang berbeza, seperti seramik, marmar, dan komposit plastik batu. Objektif utama tesis adalah untuk menjalankan penyiasatan menyeluruh tentang bagaimana pelbagai jenis lantai mempengaruhi keselesaan terma bangunan. Kajian ini meliputi ciri terma yang wujud bagi bahan tersebut untuk memberi penerangan tentang kualiti unik setiap bahan lantai. Tambahan pula, kajian ini bertujuan untuk menilai kecekapan terma pelbagai bahan lantai dalam pelbagai konfigurasi bangunan dan keadaan persekitaran. Di samping itu, kajian ini akan meningkatkan kesedaran tentang interaksi kompleks antara pilihan lantai dan keselesaan terma. Pendapat utama daripada perbincangan secara keseluruhan ialah lantai komposit plastik batu lebih sesuai untuk keselesaan terma. Hasil kajian ini akan membantu arkitek, pereka bentuk dan pemilik bangunan memilih bahan lantai yang mengoptimumkan keadaan terma sambil meningkatkan keselesaan penghuni. Penyelidikan ini akan menyumbang kepada kemajuan reka bentuk bangunan.

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	-	Degree Celsius
HVAC	-	Heating, Ventilation and Air Conditioning
MBIE	-	New Zealand Ministry of Business, Innovation and Employment
DPC	-	Damp Proof Course
%	-	Percentage
PVC	-	Polyvinyl chloride
DIY	-	Do-it-yourself
etc	-	et cetera
°F	-	Fahrenheit
mm	-	Millimeter
LEED	-	Leadership in Energy and Environmental Design
UTeM	-	Technical University of Malaysia, Malacca
am	-	Ante meridiem, before midday
pm	-	Post meridiem, after midday
W/m·K	-	Watts per meter-kelvin
SPC	-	Stone Plastic Composite

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The study focuses on exploring how different flooring types affect thermal comfort in buildings. Thermal comfort refers to how individuals perceive and experience the temperature of their environment. It is an important factor that affects occupant satisfaction, productivity, and well-being (Di Noto, 2023).

The choice of flooring materials can have a significant impact on thermal comfort due to their varying thermal properties (Dantata & Alibaba, 2019). For example, carpet and hardwood have different insulation abilities compared to ceramic tiles or vinyl. Additionally, the climate and type of building also influence how different flooring materials perform thermally.

The study aims to provide practical recommendations based on the findings, benefiting building designers, architects, and occupants. These recommendations will assist in making informed decisions about selecting appropriate flooring types to enhance thermal comfort and improve energy efficiency. Ultimately, the study aims to create more comfortable living and working environments by optimizing thermal comfort in buildings.

1.2 Problem Statement

Thermal comfort is an important consideration in building design, especially in hot climates like Malaysia. The choice of flooring materials can have a significant impact on a room's cooling or heating requirements, making it an important consideration for engineers and designers (Nazhatulzalkiset al., 2014).

The temperature inside a room can be affected by different types of flooring, regardless of whether the space is air-conditioned or relies on natural ventilation (Atkinson, 2009). The thermal properties of flooring materials influence how heat moves between the floor and the indoor environment. Some flooring materials, such as tiles or concrete, have higher thermal conductivity, which means they can conduct heat more easily. This can result in a cooler floor surface, which is beneficial in hot climates because it provides occupants with a sense of comfort (MBIE, 2020).

Certain flooring materials, such as carpets or wooden floors, have lower thermal conductivity, which means they are less effective at conducting heat. This can lead to a warmer floor surface, which may be preferable during colder climates or during the winter months (Wood Vs Tile for Thermal Conductivity, 2023).

Students and engineers can make informed design decisions if they understand the impact of flooring on thermal comfort. They can choose flooring materials that are appropriate for the climate and conditions of the building site, ensuring optimal thermal comfort for the occupants.

Furthermore, the choice of flooring materials can have a significant impact on energy consumption (Dantata & Alibaba, 2019). In hot climates, for example, choosing flooring materials with higher thermal conductivity can help keep the indoor space cooler, reducing reliance on mechanical cooling systems such as air conditioners. As a result, energy consumption and associated costs are reduced (Sanusi et al., 2013).

Students and engineers can improve their knowledge and develop a more responsible attitude towards sustainable building practices by considering the importance of flooring in building design. They can strive to create welcoming living and working environments while reducing energy consumption and environmental impact.

In a nutshell, engineers and designers must understand the relationship between flooring materials and thermal comfort. They can improve the comfort of building interiors, reduce energy consumption, and contribute to sustainable building practices by selecting the appropriate flooring type.

1.3 Research Objectives

- To investigate and assess the impact of different types of flooring on thermal comfort in buildings.
- To analyze the thermal characteristics of various flooring materials.
- To assess the thermal performance of different flooring types in building types and climates.

1.4 Scopes of Research

In order to achieve the objective above, the following scopes of study have been drawn:

- The study will look at various types of flooring that are commonly used in homes and buildings. Specific flooring materials will be chosen based on how frequently they are used in residential and commercial buildings.
- Consider different climatic regions to understand how different flooring types affect thermal comfort in various environmental conditions.
- Offer recommendations and guidelines for building designers, architects, and occupants on selecting the most suitable flooring types to enhance both thermal comfort and energy efficiency in buildings.
- Better understanding of how flooring choices impact thermal comfort, informed decisions regarding building design, renovation, and energy efficiency.

1.5 Limitations of Research

- Inaccuracies in the results can be caused by measurement errors or limitations in the data collection tools.

- There could be time, money, or asset constraints. These constraints may affect the scope of the experiment, the number of variables that can be studied, and the length of data collection, all of which may affect the overall quality and thoroughness of research.

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CHAPTER 2

LITERATURE REVIEW

2.1 Malaysian Climate

Summer, winter, spring, and autumn are the four seasons in total. Malaysia has a tropical climate due to its location on the line of equator. The average annual temperature in Malaysia is 25.4°C (World Bank Climate Change Knowledge Portal, 2021). The monsoon seasons in Malaysia can be classified as either the Northeast or Southeast monsoon. The Southeast monsoon is more prone to sunny days than rainy days, whereas the Northeast monsoon is contrary. The Southeast monsoon has a mean temperature of 29 °C, whereas the Northeast monsoon has a temperature of 28 °C (Energy Commission Malaysia, 2017). During both monsoon seasons, the exterior temperature is measured to be 27 °C to 28 °C, and the attic temperature can reach 32 °C to 36 °C (Ahmed et. al, 2005). Solar Reflectance and Thermal Emittance are the two important variables that influence attic temperature (Figure 2.1). During the day, the trapped hot air in the attic becomes the primary source of heat. The hot air will be transferred into the building's interior via the heat transfer mechanism (Abdul Rahman et al., 2004).

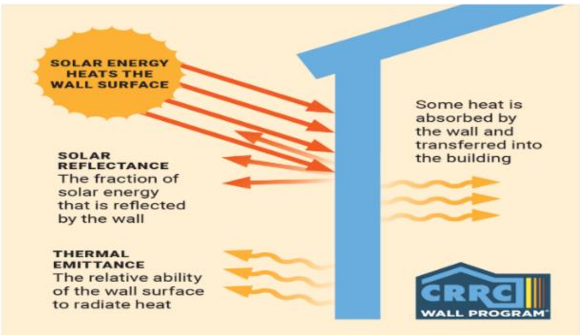

Figure 2.1 Diagram of a solar energy system

2.2 Types of Buildings

The purpose of buildings is to offer living or working space, shelter, or fulfill other requirements, and they are made by combining materials like concrete, steel, wood, and glass. They can vary in size from tiny, single-room constructions to vast, multi-level buildings, and they have a significant effect on the environment, energy usage, and quality of life of those who utilize them while also playing a crucial role in shaping urban and rural landscapes. Each building type is designed to meet specific needs and typically includes distinctive features and amenities. There are several types of buildings to take into count (Mishra, 2018).

2.2.1 Residential Buildings

Residential units are buildings that provide housing or accommodation. Other buildings may be designated as non-residential. Single-family homes, multi-family housing, townhouses, condominiums, and other similar structures are examples of these types of structures. They include kitchens, bathrooms, bedrooms, living and outdoor areas, among other things. Social design and architecture can vary greatly based on factors such as location, climate, culture, and availability of resources (Team.D, 2022).

Figure 2.2 Illustration of residential buildings

2.2.2 Commercial Buildings

The term "commercial buildings" means any building used for business, or any specific portion of a building intended for business such as retail or recordkeeping, security, sanitation, and HVAC in a commercial building. In addition, proper elevator and ground maintenance is required to ensure proper maintenance of the building. Commercial buildings include office buildings, shopping centers, hotels, healthcare facilities, restaurants, etc. (Craighead, 2012).

Figure 2.3 Illustration of commercial buildings

2.2.3 Industrial Buildings

Industrial buildings are immediately used in manufacturing or technologically productive businesses. Apart from workers, industrial buildings are not usually or typically easily available. The category of industrial buildings comprises of structures that are utilized in various aspects of manufacturing, such as generating power, extracting raw materials, producing goods, and storing different types of materials, including chemicals, plastics, textiles, petroleum products, wood and paper products, and metals (General Multilingual Environmental Thesaurus, 2021).

Figure 2.4 Illustration of industrial buildings

2.3 Components of Buildings

The fundamental elements of a building's structure include the foundation, roof, walls, columns, beams, lintels, parapet, plinth, plinth beam, damp proof course, floor, and stairs. These elements have various functions, such as providing support, enclosing, and safeguarding the building structure (Neenu S, 2019).

2.3.1 Foundation

A building's foundation is a crucial part of its structure, responsible for distributing the weight of the superstructure evenly onto the soil beneath. It is typically the first component to be built during construction, and a properly designed and constructed foundation is critical to prevent any settling or sinking of the building (K.N.S, 2017).

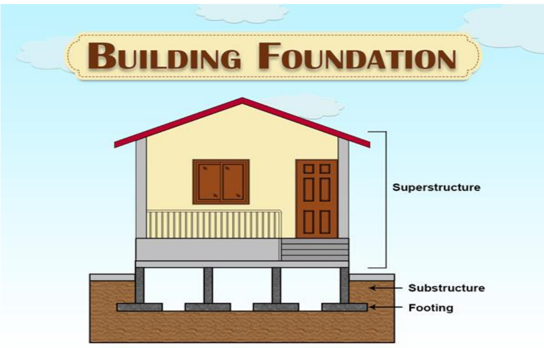

Figure 2.5 Foundation of building

2.3.2 Roof

The highest part of a building structure is known as the roof, and it provides coverage to the top surface of the building. Depending on the location and climate of the surrounding area, a roof's design may be sloping or flat (The Editors of Encyclopaedia Britannica, 1998).

Figure 2.6 Roof of building

2.3.3 Walls

Walls are upright structures that offer support for the roof and can be constructed from materials like stones, bricks, or concrete blocks. They function as a barrier against the natural elements, such as wind, sunlight, and rain. Openings in the walls allow for ventilation and entry to the building (Cladding Choices, 2023).

Figure 2.7 Walls of building

2.3.4 Columns

Architectural and structural columns are two types of columns that are vertical pieces that are raised above the ground. While structural columns safely sustain the weight from the slab above and convey it to the foundation, architectural columns are designed to improve the building's beauty (Hamakareem, 2018).

Figure 2.8 Columns of building

2.3.5 Beams

Horizontal elements in a building structure include beams and slabs. The top slab serves as the roof of a one-story building, but the beams of a multi-story building shift the weight from the floor above the slab to the columns. These elements are typically made of reinforced concrete (K.N.S, 2019).

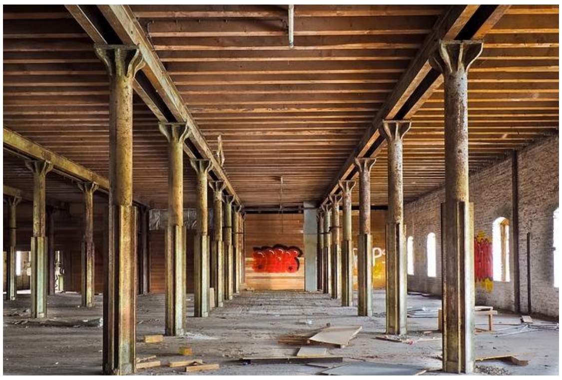

Figure 2.9 Beams of building

2.3.6 Lintels

Lintels are structural elements that are placed above openings in walls, such as doors and windows, to support the weight of the wall above them. They are typically made of reinforced cement concrete, although in some residential buildings they may be constructed from bricks (Habib, 2017).

Figure 2.10 Lintels of building

2.3.7 Parapets

Low walls known as parapets are typically placed on flat roofs and protrude over the roof slab, serving as a safety barrier for anyone utilizing the roof (Prasad, 2020).

Figure 2.11 Parapet of building

2.3.8 Plinth

The plinth is a structural unit constructed above the ground level, which serves as a connection between the building's substructure and superstructure. It is typically made of a layer of cement-mortar (K.N.S, 2019).

Figure 2.12 Plinth of building

2.3.9 Plinth Beam

A horizontal reinforced concrete beam placed at or above ground level to sustain the weight of the walls above it is called a plinth beam (K.N.S, 2019).

Figure 2.13 Plinth beam of building

2.3.10 Damp Proof Course (DPC)

DPC, or damp-proof course, is a layer of waterproof material that is installed at the base of a building's walls to prevent moisture from rising into the walls. It is typically placed at or just above ground level, and the walls are constructed on top of it (Mishra, 2020).

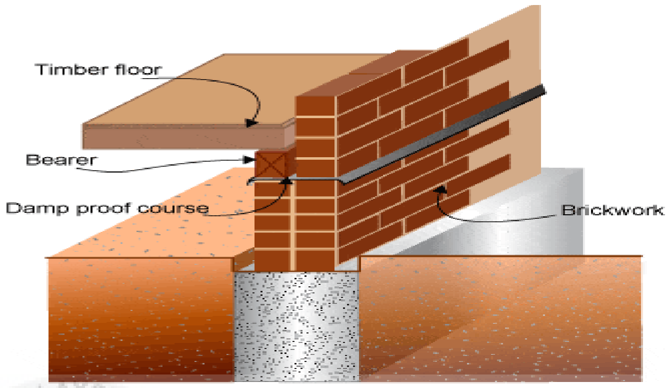

Figure 2.14 DPC of building

2.3.11 Floor

The floor is the level surface that is situated on the plinth level. There are different materials that can be used for flooring such as tiles, granite, marble, and concrete. Before installing flooring, the ground must be appropriately compacted and leveled (Anupoju, 2021).

Figure 2.15 Floor of building

2.3.12 Stairs

A stair is a set of steps that links different levels of a building structure. The area taken up by the stair is known as the stairway. Stairs come in a variety of styles, including wooden stairs, reinforced cement concrete stairs, and many others (Anupoju, 2021).

Figure 2.16 Stairs of building

2.4 Types of Flooring

2.4.1 Cement or Lime Concrete

The primary flooring material that is widely used is concrete, which can be applied to any type of construction project and is cost-effective and long-lasting. A mixture of 1:3:6 to 1:5:10 cement concrete or lime concrete with a 40 % 1:2 lime sand mortar and 60 % coarse aggregate is utilized as the base course. Once the base course hardens, a 1:2:4 cement concrete mixture with a 40-millimeter-thick layer is placed as the topping. In industrial buildings, a granolithic finish is utilized to obtain a tough, long-wearing surface. A rich concrete mixture with a sturdy coarse aggregate is used to achieve the granolithic finish (Anupoju, 2021).

Figure 2.17 Concrete flooring

2.4.2 Bricks

Although bricks can be utilized for flooring, they are not recommended for use in residential or public buildings. Brick flooring is typically employed in less significant spaces, such as warehouses. To achieve the desired outcome, well-fired bricks that are uniform in size and color should be employed (Anupoju, 2021).

Figure 2.18 Brick flooring

2.4.3 Flagstones

Sedimentary rocks like flagstone are produced by splitting along the bed planes. It is made up of iron oxide, calcite, and silica. The stone is utilized to create tiles of various sizes and shapes (Brick & Bolt, 2020).

Figure 2.19 Flagstone flooring

2.4.4 Marble

Marble is commonly used for flooring in commercial buildings, kitchens, bathrooms, and other areas. Due to their stain-resistant and easy-to-clean properties, they are preferred in spaces where extra cleanliness is required, particularly in bathrooms. Moreover, they come in a variety of colors and designs (Anupoju, 2021).

Figure 2.20 Marble flooring

2.4.5 Glass

Glass is utilized as a flooring material for special purposes such as transmitting light from upper to lower floors. Glass tiles are available and are fixed within closely spaced frames. Although expensive, glass provides a stunning appearance (Anupoju, 2021).

Figure 2.21 Glass flooring

2.4.6 Ceramic

Ceramic floor tiles are a popular choice. Ceramic is an inorganic material that possesses strong compression resistance, brittleness, and hardness (Anupoju, 2021).

Figure 2.22 Ceramic flooring

2.4.7 Stone Plastic Composite (SPC)

Stone Plastic Composite (SPC) flooring is a type of rigid core vinyl flooring known for its durability, water resistance, and easy maintenance. It mimics the look of natural materials like stone and wood and typically consists of a wear layer, decorative layer, rigid core with limestone powder and PVC, and an underlayment. (SPC) flooring is water-resistant, easy to install, and suitable for high-traffic areas. It is durable, low-maintenance, and comes in various styles (Sharma, 2023).

Figure 2.23 Stone Plastic Composite flooring

2.4.8 Mud and Murram

Mud has been utilized as a flooring material for many years and is essentially damp earth. It possesses effective thermal insulation characteristics and chopped straw is often added to prevent cracking. Additionally, cow dung may also be mixed in at times. Similarly, murram is a natural substance resulting from rock disintegration and shares many of the same qualities as mud, making it a viable option for flooring material (Poudel, 2023).

Figure 2.24 Mud and murram flooring

2.4.9 Wood

Wood or timber flooring is one of the most popular choices. It works best in places with cheap lumber, like hills. Flooring is made of wooden blocks or bards. Wooden floors are ideal for dance floors, auditoriums, and similar spaces. Wooden floorboards require the installation of a damp-proof course (Anupoju, 2021).

Figure 2.25 Wood flooring

2.4.10 Cork

Cork is derived from the bark of the cork oak tree and is frequently used as a carpet flooring material. These carpets are known for their ability to absorb sound, making them a popular choice for public places such as libraries and theaters. In addition to carpet, cork tiles made from high quality cork bars that have been compressed into molds are also readily available (Formisano, 2022).

Figure 2.26 Cork flooring

2.4.11 Linoleum

Linoleum is a type of product produced by oxidizing linseed oil together with gum, resins, pigments, cork dust, and other materials. It is commonly sold in sheet form and is typically utilized as a covering for concrete or wooden floors. These sheets can either be plain or adorned with a printed design (S. Sharma, 2017).

Figure 2.27 Linoleum flooring

2.4.12 Asphalt

Asphalt is a thick liquid derived from petroleum that is commonly used as a flooring material. It can be utilized in a variety of ways for this purpose. For instance, a mixture of asphalt and sand in a 1:2 ratio creates asphalt mastic, which is then poured over a concrete base to create a flooring cover. Additionally, asphalt mosaic is created by substituting sand with marble chips. Asphalt tiles composed from asphalt fibres, inert ingredients, and mineral pigments are also available as a flooring alternative (Civil Engineering Tutor, 2017).

Figure 2.28 Asphalt flooring

2.4.13 Rubber

There are also rubber tiles and sheets available as a flooring option. These are made of pure rubber, which has been blended with cotton fibers and asbestos fibers. The rubber tiles are then affixed to a concrete or wooden base utilizing suitable adhesives. Rubber flooring is well-known for its quietness and is commonly used in public places such as libraries and offices (Anupoju, 2021).

Figure 2.29 Rubber flooring

2.5 Factors Affecting Selection of Flooring Material

The initial cost, longevity, hardness, smoothness, cleanliness, slipperiness, attractiveness, sound insulation, thermal insulation, damp proof, fire resistance, and maintenance are all taken into consideration while choosing flooring materials (Anupoju, 2021).

2.5.1 Initial Cost

Flooring materials come with different price ranges. The quality and durability of the material may often increase in proportion to its cost. However, several considerations, including the type of building, the planned usage of the floor, and the total cost estimate of the construction, go into choosing the flooring material. Therefore, these parameters should be used to establish the starting cost (Anupoju, 2021).

2.5.2 Durability

The chosen flooring material ought to possess ample strength and resilience to withstand various forms of weathering, loads, and decay, among other factors. The longevity of the flooring material should be roughly equivalent to that of the other components of the structure. Marble, concrete, and mosaic floors are the most durable among other materials (Anupoju, 2021).

2.5.3 Hardness

The flooring material must be sufficiently durable to withstand damage caused by loads such as furniture, machines, and it must also prevent the production of dents when such loads are moved on it (Anupoju, 2021).

2.5.4 Smoothness

It is important for the top surface of the flooring material to be smooth and level. A rough surface not only detracts from the overall appearance, but it can also cause damage to the equipment that is placed on the floor (Anupoju, 2021).

2.5.5 Cleanliness

The chosen flooring should be simple to clean and maintain. It should not absorb solutions such as oils and greases. It should also be resistant to the accumulation of stains (Anupoju, 2021).

2.5.6 Slipperiness

It is not anticipated that the smoothness of the top surface of the flooring material will result in slipperiness, particularly when the flooring is wet. An unfavourable slippery surface can result from excessive polishing. Bathroom floor tiles, for example, should be coated with an anti-slippery solution to avoid slipperiness (Anupoju, 2021).

2.5.7 Appearance

It is important that the flooring also looks visually appealing. There is a wide variety of flooring products available on the market, created from a variety of materials. These products come in a wide range of colours, forms, designs, and sizes, making it easier to obtain the desired look. Materials such as marble, tiles, and terrazzo tend to provide a pleasing appearance (Anupoju, 2021).

2.5.8 Sound Insulation

The flooring material should have good sound insulation properties to avoid producing noise when people walk on it. Materials such as timber, cork, and rubber are good at sound insulation (Anupoju, 2021).

2.5.9 Thermal Insulation

The chosen floor material should be thermally resistant, meaning it should have the ability to resist or insulate against temperature changes. PVC, asphalt, cork, and rubber are examples of materials that are good thermal insulators (Anupoju, 2021).

2.5.10 Damp Proof

The flooring material must be moisture resistant, particularly in humid places such as kitchens and bathrooms. Otherwise, it may deteriorate or become slippery, leading to potential hazards on the floor (Anupoju, 2021).

2.5.11 Fire Resistance

It is important that the floor has a high level of fire resistance, especially on the upper stories. Despite the fact that materials such as concrete, marble, and terrazzo have excellent fire resistance capabilities, materials such as rubber, cork, and timber are less resistant to fire. In such cases, it is important to provide a fire-resistant base layer when selecting these materials (Anupoju, 2021).

2.5.12 Maintenance

The flooring materials selected should require minimal maintenance and should not allow dust to settle on them. Requirements for maintenance ought to be readily remediable and reasonably priced. Stone, marble, and concrete often require less upkeep than other materials such as wood or brick (Anupoju, 2021).

2.6 Importance of Selecting Correct Type of Flooring in Modern Buildings

Choosing the appropriate type of flooring is critical for modern buildings for various reasons. Firstly, flooring has a significant impact on the overall appearance of the building (Coblonal, 2019). The right flooring can enhance the visual appeal of a space and contribute to its design and ambiance. Secondly, flooring is essential for maintaining indoor air quality and promoting good hygiene. Certain types of flooring, such as carpeting, can accumulate dust and allergens, which can negatively affect air quality and aggravate respiratory problems. In contrast, hard surface flooring, like tile or hardwood, can be easier to clean and maintain, promoting better hygiene in the building. The choice of flooring also depends on the function of the space. For instance, high-traffic areas, such as lobbies or corridors, require durable and slip-resistant flooring to prevent accidents and wear and tear (Ojdavey, 2021). In conclusion, selecting the appropriate type of flooring is vital to ensure the safety, hygiene, and overall aesthetic appeal of modern buildings.

2.7 Air Condition (Centrally Conditioned Buildings)

A building that relies on a central air conditioning system to regulate temperature throughout the entire structure is known as a centrally conditioned building. This approach involves cooling or heating air in one central area and then circulating it throughout the building via ducts and vents, as opposed to using separate air conditioning units to regulate individual spaces (McKenzie, 2015). This type of system is frequently seen in large-scale residential and commercial structures.

2.8 Natural Ventilation (Naturally Ventilated Buildings)

Natural ventilation is a technique that utilizes natural forces such as wind and thermal buoyancy to facilitate the circulation of air inside a building (Ventive, 2020). This involves positioning openings such as windows and vents strategically to facilitate the intake and outflow of air. This approach can enhance indoor air quality and reduce the demand for mechanical ventilation, thereby resulting in energy savings. It is widely adopted in residential buildings, and it is especially suitable for regions with mild climates (Ganesh et al., 2021). However, natural ventilation may not be adequate in locations with severe temperature variations or high levels of air pollution.

2.9 Energy Consumption

Energy utilization alludes to how much energy consumed by an individual, family, association, or local area. This energy could be produced from power, flammable gas, oil, or different sources. Due to its frequently linked among other things, to emissions of greenhouse gases and a variety of pollutants, the amount of energy used is an important factor in determining the impact that a particular activity or program has on the environment (Martin, 2023).

2.10 Thermal Mass of Material

Materials that possess high thermal mass have the capability to absorb and retain heat energy, without undergoing considerable changes in temperature. Consequently, they are valuable in managing indoor temperatures, as they can stabilize temperature changes by gradually absorbing and releasing heat over a period (Shafigh et al., 2018). Building materials like concrete, brick, stone, and adobe are examples of materials with high thermal mass, and they are frequently utilized in constructing buildings located in regions with significant temperature swings, such as desert areas (Sharaf, 2020). This is because they can aid in maintaining comfortable indoor temperatures, by keeping the interior of the building cool during the day and warm at night. The thermal mass of a material is determined by its density and specific heat capacity. Materials with a greater density and specific heat capacity typically have higher thermal mass (Guo & Shi, 2011). The thermal mass of a building or structure is influenced by the thickness and type of materials used in its construction, as well as its overall design.

2.11 Thermal Resistance

Thermal resistance refers to a material's capacity to prevent heat from transferring through it via conduction, convection, and radiation (Williams, 2014). It measures the quantity of thermal energy needed to traverse a unit area of a material for a given temperature difference across it. Insulators are materials with high thermal resistance, as they hinder the flow of heat. The thickness, density, and thermal conductivity of a material, along with the temperature difference across it, are some of the factors that determine its thermal resistance. This parameter is essential to consider in designing building envelopes and insulation systems to regulate heat loss or gain and enhance energy efficiency (Wikipedia contributors, 2023).

2.12 Thermal Comfort

Thermal comfort is a person's satisfaction with the surrounding temperature both physically and psychologically (Shooshtarian & Ridley, 2017). Factors that can affect thermal comfort include air temperature, radiant temperature, humidity, wind movement, and personal clothing. Since thermal comfort is subjective, it may vary from person to person depending on various individual factors such as age, sex, metabolic rate, level of activity (Yang et al., 2021). Air temperatures are 30 between 20-27°C (68- 81°F) for most people to realize that 60 % is the ideal humidity, called the "comfort zone" (Sykes, 2021). Maintaining thermal comfort is essential to increase efficiency and quality indoors, making it an important consideration in design, heating, ventilation, and air conditioning systems for working in buildings (Bueno et al., 2021).

2.13 Temperature Collection Data of Malacca City

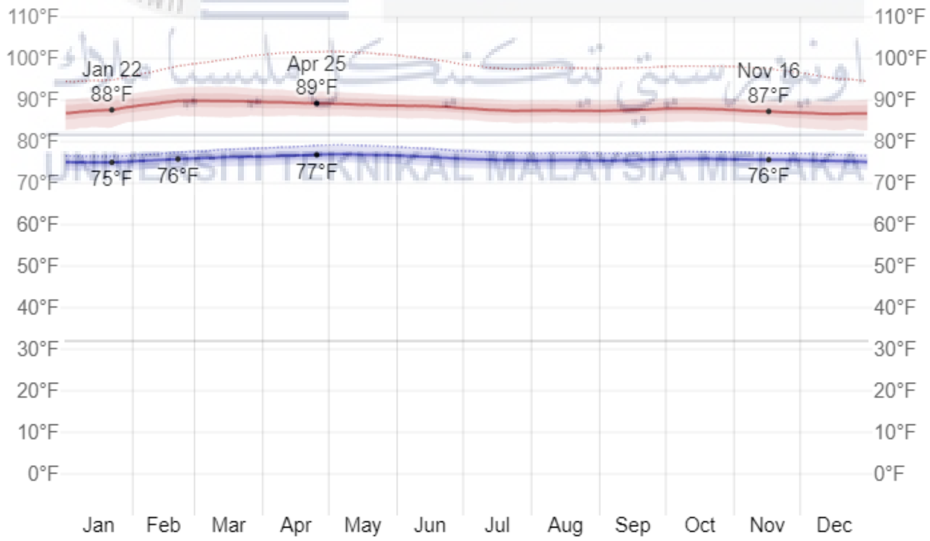

Figure 2.30 Temperature Collection Data of Malacca City

Source: https://weatherspark.com/Average-Weather-in-Malacca-Malaysia-Year-Round

Figure 2.30 indicates April is the hottest month of the year. The average temperature for April is 31.7 °C while January is the coldest month of the year with 23.9 °C.

2.14 Climate Collection Data of Malacca City

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	26 °C (78.7) °F	26.6 °C (79.8) °F	26.9 °C (80.5) °F	27.1 °C (80.7) °F	27.3 °C (81.2) °F	27.3 °C (81.1) °F	27 °C (80.6) °F	26.8 °C (80.3) °F	26.7 °C (80.1) °F	26.6 °C (80) °F	26.2 °C (79.2) °F	26.1 °C (78.9) °F
Min. Temperature °C (°F)	24.1 °C (75.3) °F	24.2 °C (75.6) °F	24.8 °C (76.6) °F	25.1 °C (77.2) °F	25.4 °C (77.8) °F	25.4 °C (77.8) °F	25.1 °C (77.2) °F	25 °C (76.9) °F	24.8 °C (76.7) °F	24.8 °C (76.7) °F	24.6 °C (76.3) °F	24.4 °C (76) °F
Max. Temperature °C (°F)	28.6 °C (83.5) °F	29.6 °C (85.3) °F	29.7 °C (85.5) °F	29.4 °C (85) °F	29.3 °C (84.8) °F	29.1 °C (84.4) °F	28.8 °C (83.8) °F	28.6 °C (83.5) °F	28.7 °C (83.6) °F	28.7 °C (83.6) °F	28.5 °C (83.3) °F	28.4 °C (83.1) °F
Precipitation / Rainfall mm (in)	122 (4)	83 (3)	159 (6)	217 (8)	226 (8)	188 (7)	193 (7)	203 (7)	198 (7)	234 (9)	276 (10)	227 (8)
Humidity(%)	80%	77%	80%	83%	83%	82%	82%	82%	83%	83%	85%	83%
Rainy days (d)	13	10	17	19	20	18	19	19	18	19	20	18
avg. Sun hours (hours)	8.6	8.9	8.9	8.8	8.8	9.1	9.0	8.9	9.0	9.0	8.4	8.5

Figure 2.31 Climate Collection Data of Malacca City

Source: https://en.climate-data.org/asia/malaysia/malacca/malacca-city-3939/

Figure 2.31 reveals there is a 193 mm difference of rainfall between the driest and wet month. The difference of the temperature within a year is around 1.0°C.

2.15 Flooring Fundamental

The basic principles and considerations involved in selecting, installing, and maintaining flooring materials in buildings are referred to as flooring fundamentals. Understanding these fundamentals is critical for making informed flooring decisions and ensuring the longevity, safety, and aesthetic appeal of flooring in different spaces. Individuals can make informed decisions about flooring materials that meet their needs, budget, aesthetics, and sustainability goals by understanding and applying these flooring fundamentals. Consulting with flooring professionals or experts can provide helpful advice and ensure the best possible outcome for any flooring project (Joseph Lewitin, 2022).

2.15.1 Function and Purpose

When choosing flooring materials, keep the space's purpose and function in mind. Different parts of a building may have different needs, such as durability, slip resistance, noise reduction, or ease of maintenance. High-traffic areas, such as corridors or entrance halls, may require more durable flooring than residential spaces (Hamakareem, 2021).

2.15.2 Installation Considerations

Maintain the integrity and functionality of flooring materials by ensuring proper installation. Preparing the subfloor, following manufacturer guidelines, and using appropriate installation methods may all be required. Professional installation or expert guidance is frequently recommended to avoid mistakes and ensure a successful outcome (Wheelis, 2022).

2.15.3 Acoustics

Examine the effect of flooring on sound transmission in a room. Some flooring materials absorb or dampen sound, making the environment quieter, whereas others reflect or amplify noise. Acoustic considerations are especially important in environments where noise control is critical, such as offices, classrooms, and music studios (Alan S. Bigger, 2019).

2.15.4 Material Selection

Examine the various flooring materials' properties, performance, and suitability. Hardwood, overlay, cover, vinyl, ceramic tiles, regular stone, and cement are well known decisions. Considerations include aesthetics, environmental impact, durability, cost, maintenance requirements, and sustainability (Anupoju, 2021).

2.15.5 Sustainability

Consider the environmental impact of flooring materials and choose sustainable alternatives whenever possible. Consider using renewable resources, recycled content, low VOC emissions, and recyclability at the end of the flooring's life cycle. Environmentally friendly options can be identified using certifications such as LEED or FloorScore (Annex B, 2021).

2.15.6 Maintenance and Cleaning

Create a maintenance plan to keep the flooring looking good and performing well. This may include regular cleaning, refinishing, or resealing on a regular basis, and addressing issues such as stains, scratches, or wear and tear. In order to prevent damage or voiding warranties, follow the manufacturer's recommendations for cleaning products, techniques, and frequency (Alan S. Bigger, 2019).

2.15.7 Safety and Compliance

In cases where selecting flooring materials, keep safety in mind. Slip resistance, fire resistance, and compliance with building codes and regulations are all factors to consider. Infection control, hygiene, and chemical resistance may be required in certain environments, such as healthcare facilities or commercial kitchens (Wheelis, 2022).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methods and processes used throughout the project. The procedure began with a target location for the experiment was selected. Then, an examination of the various types of flooring material. This chapter also goes over the flooring materials and equipment that have been used. The chapter then describes how the experiment was monitored as well as the testing that has been performed to obtain sample data. This study is to gain insights into the relationship between flooring types and thermal comfort. The data will be used to analyze how different flooring types influence occupants' perceptions of temperature, their preferences, and their overall satisfaction.

3.2 Flowchart of The Project

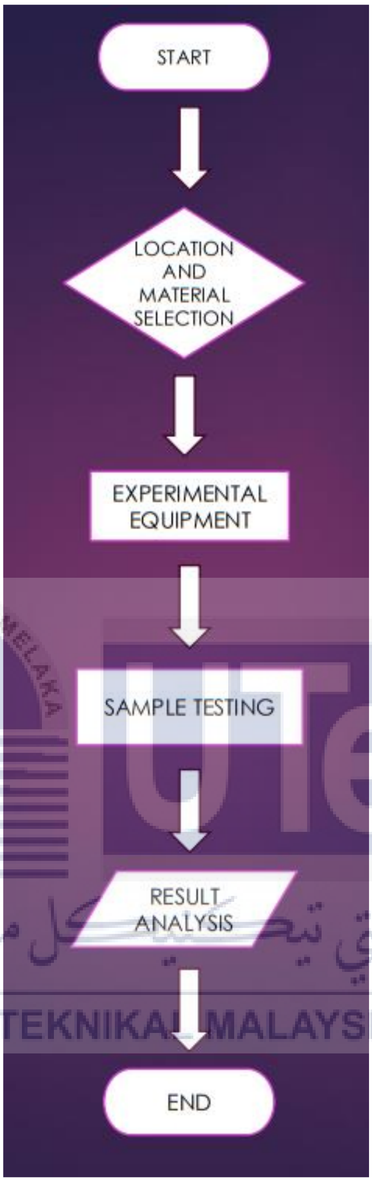

Figure 3.1 Flowchart of the project

3.3 Experiment Description

Pangsapuri Bukit Beruang Bestari, Ayer Keroh, Malacca, was chosen as the experiment's location, and the experiment was carried out around the perimeter. The selected location's address is 6-16, Pangsapuri Bukit Beruang Bestari, Jalan Bukit Beruang, Taman Bukit Beruang Bestari, 75450, Ayer Keroh, Malacca. Figure 3.2 depicts the area of study, indicating the location of the experiment. This was chosen as the targeted location where the samples were exposed. The project flow begins with the selection of location along the housing perimeter, followed by three prepared samples. The samples of flooring materials were labelled and exposed to the environment. This experiment uses:

- Ceramic
- Marble
- Stone Plastic Composite (SPC)

This experiment also includes gathering in Ayer Keroh, Malacca weather forecast data from Met Malaysia as a reference for obtaining temperature and humidity data around the desired location. Temperature and relative humidity data are collected in three periods; morning, afternoon, and evening. At the same time, temperature and relative humidity data are being collected at the location site thrice a day for three selected days per week. These data also include morning, afternoon, and evening conditions.

The exposure lasts about four weeks. The first exposure began on November 6th and ended on December 8th, 2023. Following this period, these samples were taken out for testing. The data are then analyzed accordingly.

3.3.1 Location Selection

Locations was chosen based on early observations of exposed samples around the housing area.

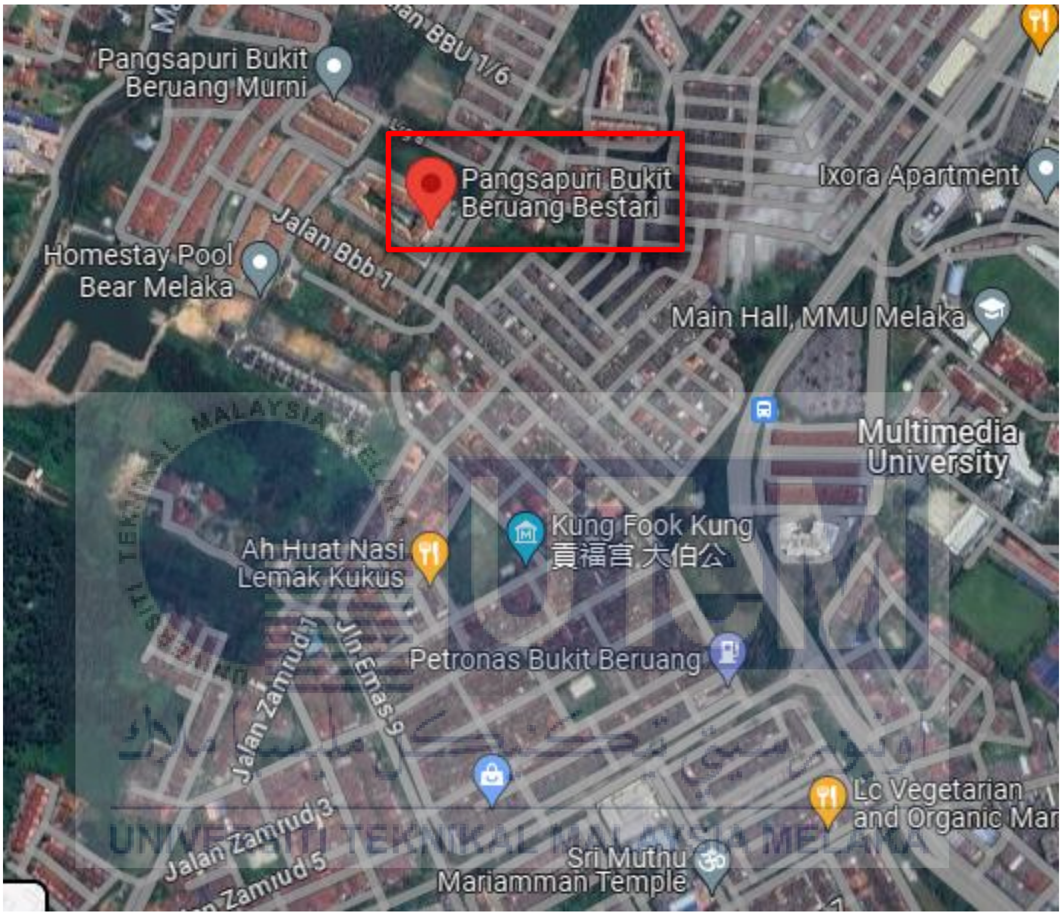

Figure 3.2 Maps of case study

(Sources: maps.google.com)

3.4 Sample Selection

Three samples were chosen from the targeted perimeter. The entire chosen area was exposed to the elements. All the samples can be found at Pangsapuri Bukit Beruang Bestari. Ceramic is the flooring material used in this area. The second sample is also at Pangsapuri Bukit Beruang Bestari. The flooring used in the space is marble flooring. The third sample can also be found at the same perimeter. Stone plastic composite (SPC) flooring is used in this setup.

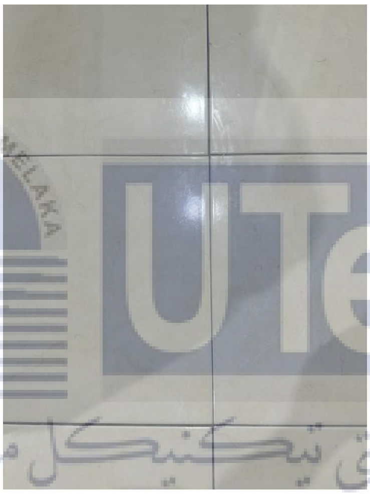

Figure 3.3 Ceramic flooring as Sample 1

Figure 3.4 Marble flooring as Sample 2

Figure 3.5 SPC flooring as Sample 3

3.4.1 Comparison between Selected Materials

Table 3.1 Comparison of flooring materials

Aspect	Ceramic	Marble	Stone plastic composite
Material	Clay and other natural materials	Natural marble	Limestone, PVC, and stabiizers
Appearance	Wide variety of colours, patterns, and textures	Elegant and luxurious	Wide variety of colours, patterns, and textures
Durability	Very durable, resistant to scratches and stains	Durable, but prone to scratching and staining	Highly durable, resistant to scratches, stains, and water damage
Maintenance	Relatively low maintenance, easy to clean	Requires regular sealing and maintenance	Low maintenance, easy to clean
Water Resistance	Generally water-resistant	Porous and prone to water damage	Highly water-resistant
Installation	Requires professional installation	Requires professional installation	Can be installed as a DIY project
Cost	Moderate to high, depending on the type	High cost	Moderate cost

3.5 Experimental Equipment

3.5.1 Digital Hygrometer

A digital hygrometer is a device used to monitor the temperature and humidity levels in the air. It is commonly used in various settings, including homes, offices, laboratories, and industrial environments. The primary purpose of a digital hygrometer is to provide accurate and real-time humidity readings (Thomas Scientific, 2023).

Figure 3.6 Xiaomi Digital Hygrometer

(Sources: shopeemalaysia.com.my)

3.6 Experiment Monitoring

This experiment was carried out at 6-16, Pangsapuri Bukit Beruang Bestari, Jalan Bukit Beruang, Taman Bukit Beruang Bestari, 75450, Ayer Keroh, Malacca.

3.6.1 Temperature and Humidity Monitoring

In this location, the temperature and humidity were measured with a digital hygrometer. This information was gathered thrice daily, in the morning, afternoon and at evening for three days out in a week; Monday, Wednesday, and Friday for about 4 weeks. This information was relatively different with Malacca's temperature and relative moistness gauge. The location data were also collected on the same day, sometimes even at the same time as these forecast data.

Table 3.2 Time Interval for data collection

Monday, Wednesday & Friday	**Time Interval**
Morning	7:30 am to 8:00 am
Afternoon	1:00 pm to 1:30 pm
Evening	4:30 pm to 5:00 pm

3.7 Results and Analysis

All the data collected during the experiment was tabulated and analyzed. The data set includes the sample appearance image, as well as temperature and humidity readings.

3.8 Gantt Chart

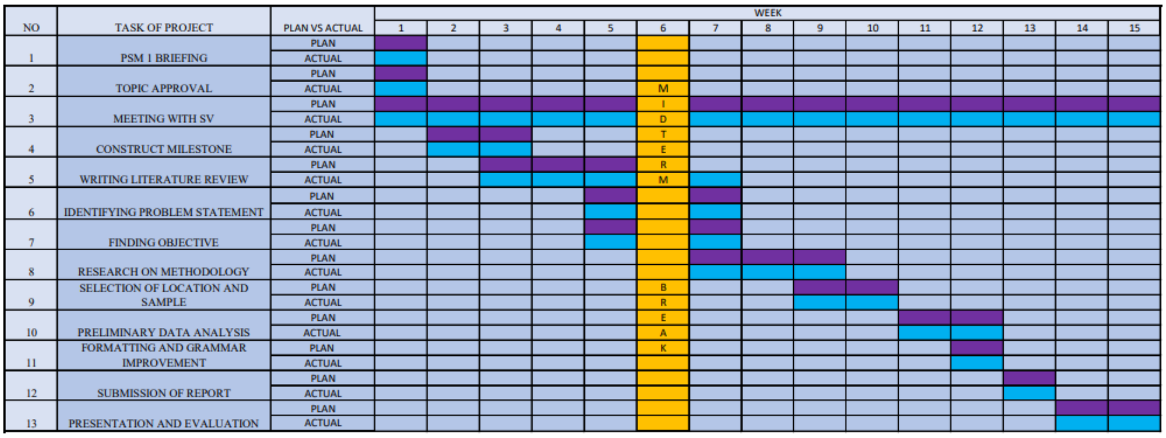

Figure 3.7 Gantt Chart of Project 1

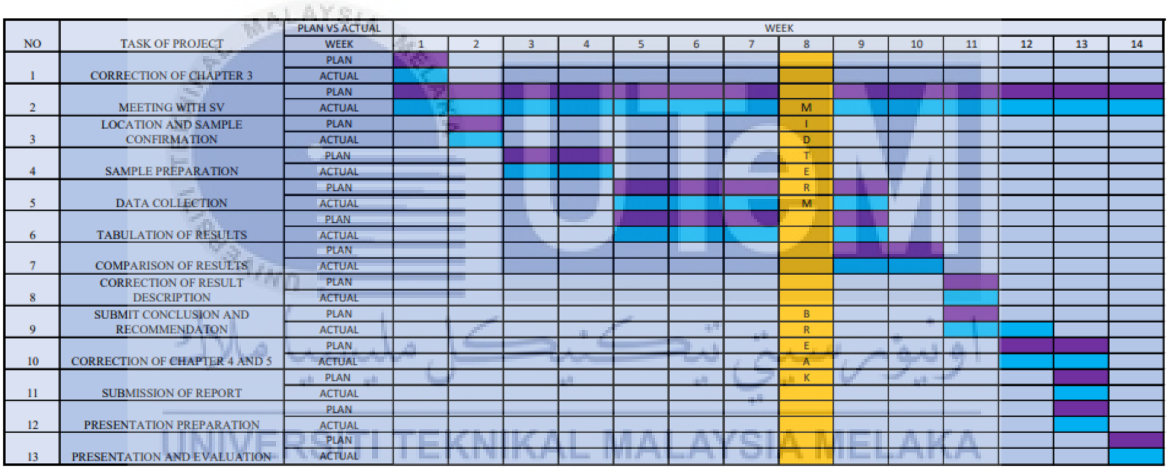

Figure 3.8 Gantt Chart of Project 2

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Experiment Description

The aim of this study was to investigate the effect of different flooring types on thermal comfort in buildings. This section presents the findings of the study, along with a discussion of the implications for understanding the relationship between floor properties and thermal comfort. The study focused on three flooring types such as ceramic, marble, and stone plastic composite (SPC). These observations provide insight into the relationship between floor types and thermal comfort in buildings. The data can help architects, designers, and building owners make informed decisions about the selection and use of flooring materials to improve both thermal comfort and occupant well-being.

4.2 Thermal Conductivity

Ceramic materials generally exhibit low to moderate thermal conductivity, with variations depending on the specific type of ceramic. Marble, being a natural stone, possesses a moderate thermal conductivity influenced by factors like mineral composition and density. Stone plastic composite (SPC), a composite material comprising limestone and polyvinyl chloride, typically displays lower thermal conductivity compared to metals. The specific thermal conductivity values for these materials can vary based on formulation, manufacturing processes, and external conditions. It is recommended to refer to manufacturer specifications for precise information, and advancements in materials science may introduce variations in the thermal properties of newer formulations within these material categories.

4.3 Influence on Surface Temperature

The surface temperature of ceramic, marble, and stone plastic composite (SPC) is influenced by several factors. Ceramics, known for their low thermal conductivity, tend to have cooler surface temperatures. Marble, a natural stone with moderate thermal conductivity, can absorb and retain heat. The thermal properties of (SPC), a composite material, depend on its specific composition and can be engineered for different purposes. The color of these materials also plays a role, with dark colors absorbing more heat than light colors. Density is another factor, where higher-density materials may take longer to heat up but retain heat for a longer period. Environmental conditions, such as exposure to sunlight and climate, further impact surface temperatures. It is crucial to consider the specific characteristics of each material and their intended use when evaluating their thermal performance.

4.4 Occupant Perception and Comfort

Occupant perception and comfort associated with ceramic, marble, and stone plastic composite (SPC) flooring materials involve a combination of tactile, visual, and thermal factors. Ceramic and marble, characterized by their hardness, may provide a visually appealing but potentially less tactilely comfortable surface. Their lower thermal conductivity might make them feel cooler to the touch. In contrast, SPC, being a composite material, can offer a softer and more comfortable surface, mimicking the appearance of natural materials. The choice between these materials hinges on individual preferences, with some favoring the classic and luxurious feel of ceramic and marble, while others prioritize the comfort and practicality offered by engineered options like SPC. Additionally, considerations of maintenance, aesthetics, and regional climate should guide the selection to ensure overall occupant satisfaction.

4.5 Experimental Results

4.5.1 Week 1

Table 4.1 Results of Week 1

Time	Types of Flooring	Monday (6/11/2023)	Wednesday (8/11/2023)	Friday (10/11/2023)
Morning	Ceramic	29.6°C, 81%	29.0°C, 80%	28.7°C, 78%
	Marble	29.7°C, 83%	29.1°C, 86%	28.3°C, 81%
	SPC	29.5°C, 74%	29.1°C, 78%	28.1°C, 79%
Afternoon	Ceramic	29.5°C, 75%	29.8°C, 75%	28.9°C, 76%
	Marble	29.3°C, 77%	29.7°C, 76%	29.0°C, 77%
	SPC	29.2°C, 75%	29.6°C, 74%	28.9°C, 75%
Evening	Ceramic	29.1°C, 75%	28.9°C, 74%	29.0°C, 75%
	Marble	29.1°C, 76%	28.9°C, 78%	29.1°C, 77%
	SPC	28.6°C, 76%	28.9°C, 75%	28.9°C, 76%

Represents rainy condition

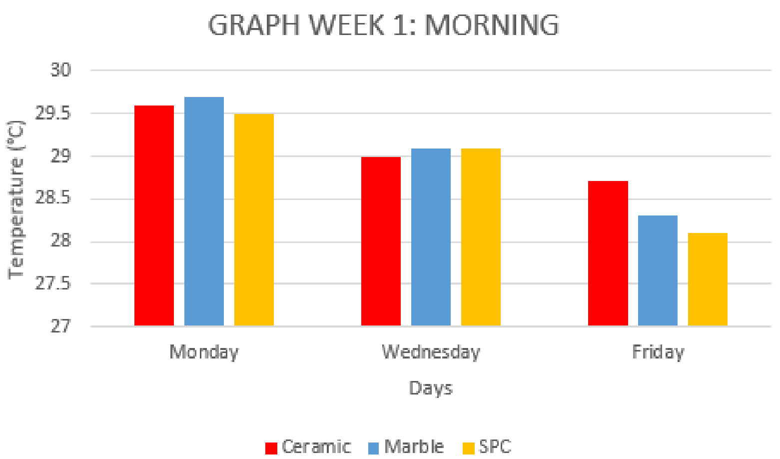

Figure 4.1 Temperature of Week 1: Morning

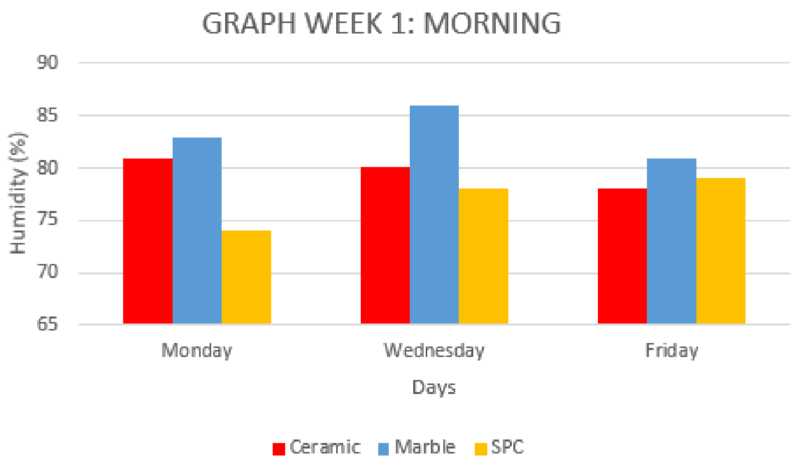

Figure 4.2 Humidity of Week 1: Morning

Ceramic flooring generally has slightly lower temperatures compared to marble and (SPC). Due to variations in thermal conductivity and heat retention, ceramic flooring usually feels colder to the touch than marble and (SPC). Ceramic tiles have less prosperous thermal conductivity and disperse heat faster, giving the impression of being cooler. Marble feels warmer because of its increased thermal conductivity and better heat retention. The perceived temperature is also affected by the installation substrate, ambient conditions, and surface polish. According to the previous research on the relationship between thermal insulation thickness and summer overheating risk, the results states that summertime bedroom overheating is made worse by more insulation when there is no natural airflow (Rui Bo et al., 2022). Room insulation and heating systems can have an impact on the whole experience, and individual tastes may differ. When analyzing thermal characteristics, it is critical to examine the exact kind and quality of each material. Marble flooring, with its porous nature, tends to exhibit higher humidity levels, particularly noticeable on Wednesdays. In contrast, (SPC) flooring, designed for durability and moisture resistance, maintains lower humidity and temperature levels. The difference in humidity is attributed to the inherent material properties of marble and the synthetic composition of (SPC), influencing their reactions to environmental conditions.

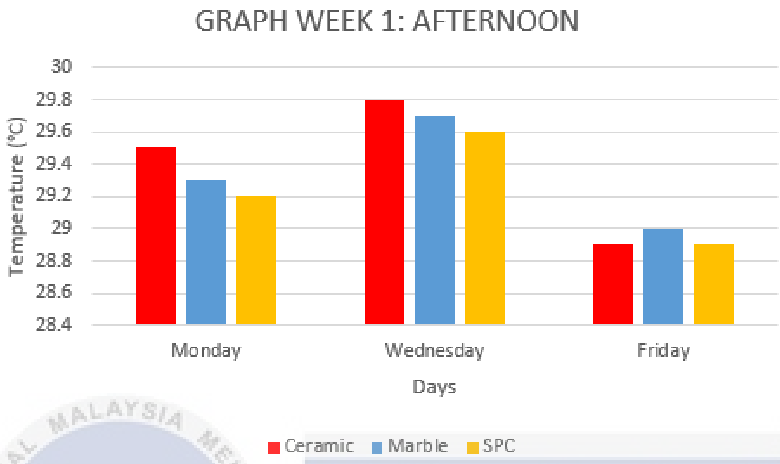

Figure 4.3 Temperature of Week 1: Afternoon

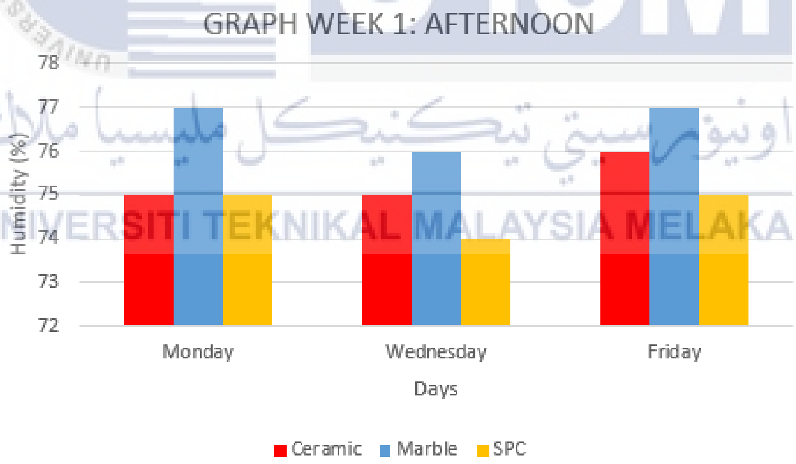

Figure 4.4 Humidity of Week 1: Afternoon

During the afternoon, both ceramic and marble exhibit temperature fluctuations, but ceramic tends to have slightly lower overall temperatures compared to marble. Essentially, temperature differences between the two materials, ceramic tends to be a bit cooler during the afternoon. Since marble flooring is inherently porous, it has greater humidity levels in the afternoon owing to moisture absorption. (SPC) flooring, on the other hand, is non-porous and synthetic, so it continuously maintains lower humidity levels, making it a better choice for areas where moisture management is critical.

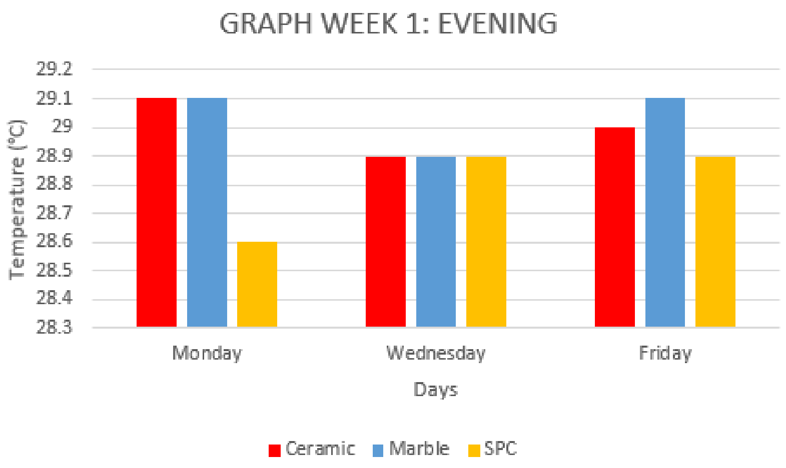

Figure 4.5 Temperature of Week 1: Evening

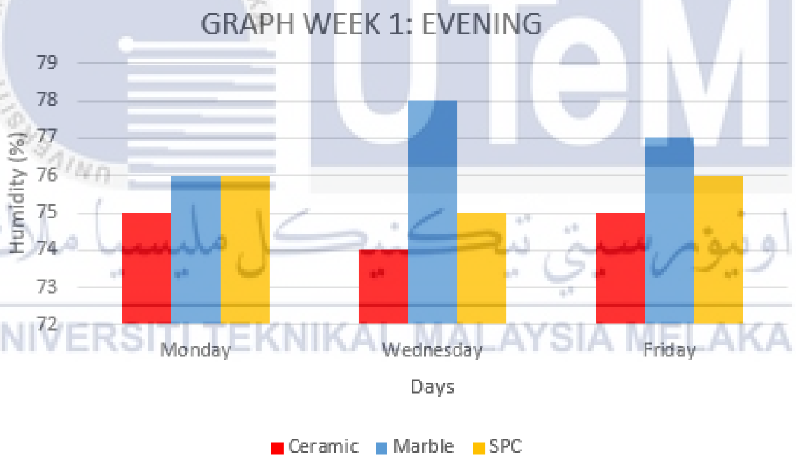

Figure 4.6 Humidity of Week 1: Evening

Evening temperatures are comparable across various flooring kinds. Marble flooring has somewhat greater humidity levels in the evening, presumably due to its moisture-absorbing characteristics. (SPC) flooring, on the other hand, maintains stable humidity levels but may undergo temperature swings, which are presumably caused by external conditions. Overall, the findings emphasize the differences between marble and (SPC) flooring in terms of temperature and humidity behavior.

4.5.2 Week 2

Table 4.2 Results of Week 2

Time	Types of Flooring	Monday (20/11/2023)	Wednesday (22/11/2023)	Friday (24/11/2023)
Morning	Ceramic	29.2°C, 78%	28.7°C, 80%	26.6°C, 87%
	Marble	29.3°C, 83%	28.8°C, 85%	26.5°C, 89%
	SPC	29.2°C, 78%	28.8°C, 81%	26.3°C, 84%
Afternoon	Ceramic	28.8°C, 83%	31.2°C, 69%	27.7°C, 81%
	Marble	28.7°C, 82%	30.9°C, 71%	27.7°C, 84%
	SPC	28.5°C, 83%	30.7°C, 71%	27.6°C, 81%
Evening	Ceramic	29.6°C, 77%	29.0°C, 76%	29.3°C, 73%
	Marble	29.6°C, 81%	29.0°C, 81%	29.3°C, 75%
	SPC	29.5°C, 77%	28.9°C, 77%	29.4°C, 74%

Represents rainy condition

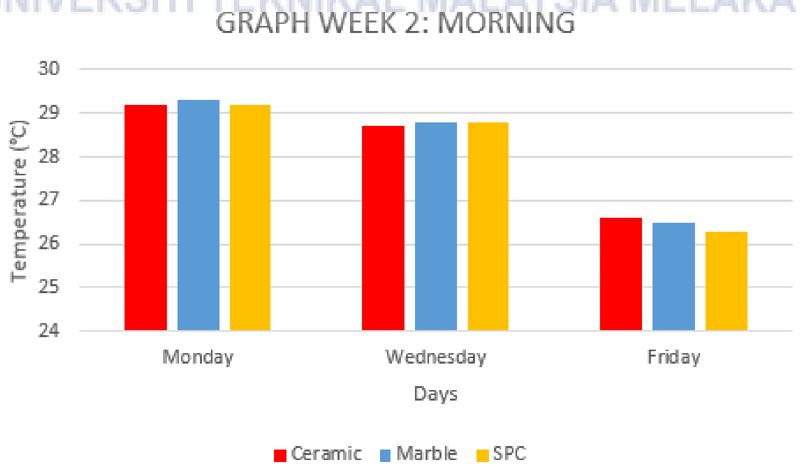

Figure 4.7 Temperature of Week 2: Morning

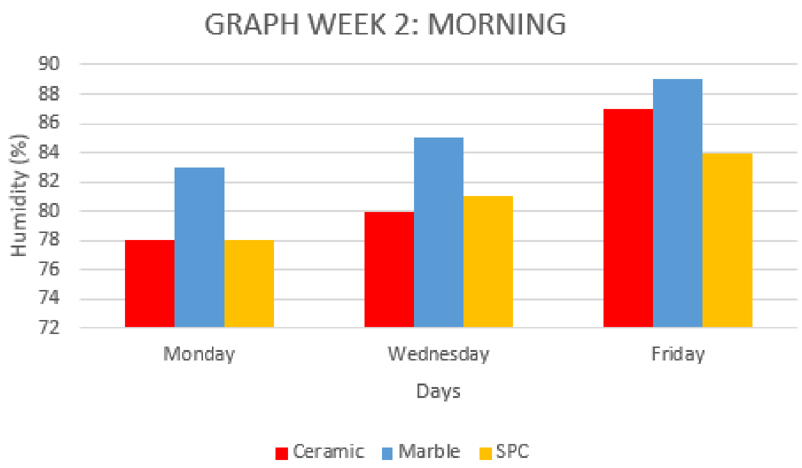

Figure 4.8 Humidity of Week 2: Morning

Ceramic and (SPC) flooring are identified as having lower humidity levels compared to marble, due to their moisture-resistant properties. Morning readings on Friday reveal a general decrease in temperature and an increase in humidity across all flooring types, potentially influenced by external factors like indoor environment changes.

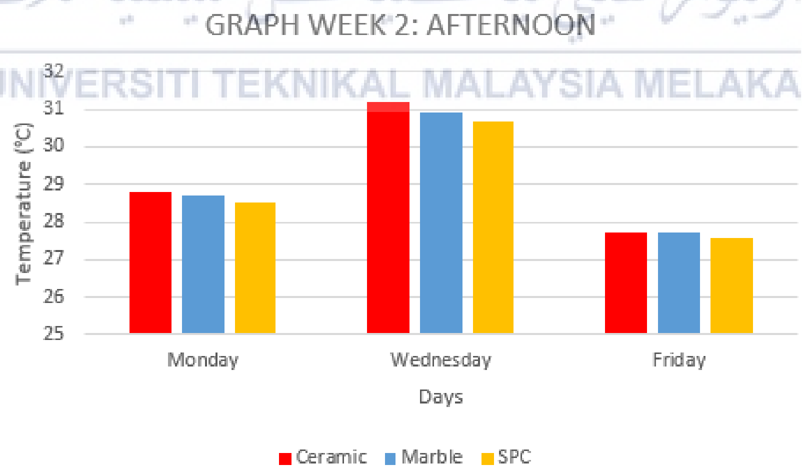

Figure 4.9 Temperature of Week 2: Afternoon

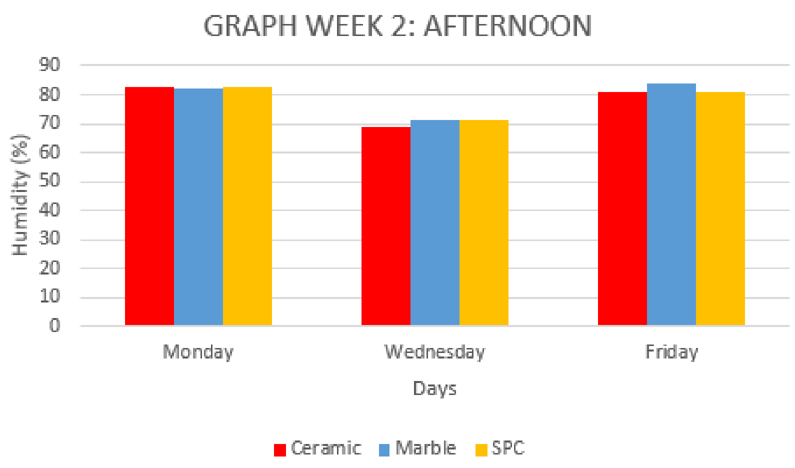

Figure 4.10 Humidity of Week 2: Afternoon

On Wednesday afternoon, a general increase in temperature is observed across various flooring types, with ceramic flooring exhibiting a particularly noticeable rise, indicating its sensitivity to temperature changes. In the case of marble flooring, higher humidity levels persist compared to Ceramic and SPC, suggesting that marble retain more moisture or be more prone to humidity, possibly influenced by environmental conditions or specific characteristics of marble.

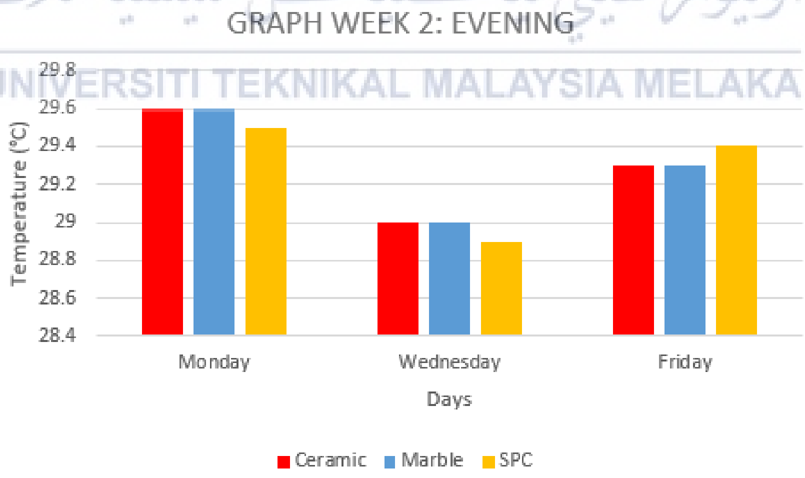

Figure 4.11 Temperature of Week 2: Evening

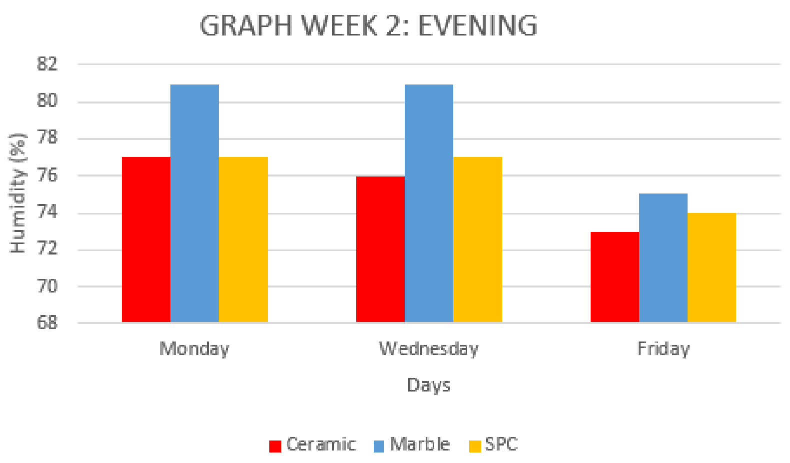

Figure 4.12 Humidity of Week 2: Evening

Ceramic retains temperatures within the range of 29.0°C to 29.6°C, accompanied by humidity levels varying between 73% and 77%. In contrast, marble exhibits a somewhat higher humidity span of 75% to 81%, whereas (SPC) displays a temperature range of 28.9°C to 29.5°C and humidity fluctuating from 74% to 77%. These variances linked to inherent characteristics of the materials, such as thermal conductivity or moisture retention, as well as external factors that might impact the surrounding environment.

4.5.3 Week 3

Table 4.3 Results of Week 3

Time	Types of Flooring	Monday (27/11/2023)	Wednesday (29/11/2023)	Friday (1/12/2023)
Morning	Ceramic	27.7°C, 76%	27.7°C, 82%	27.1°C, 82%
	Marble	27.7°C, 81%	27.9°C, 86%	27.1°C, 87%
	SPC	29.6°C, 76%	27.0°C, 88%	27.0°C, 81%
Afternoon	Ceramic	29.7°C, 73%	31.2°C, 69%	29.8°C, 76%
	Marble	29.6°C, 74%	30.9°C, 71%	29.7°C, 77%
	SPC	29.6°C, 73%	30.7°C, 71%	29.6°C, 75%
Evening	Ceramic	29.6°C, 74%	30.0°C, 72%	29.0°C, 77%
	Marble	29.6°C, 75%	30.9°C, 71%	29.0°C, 80%
	SPC	29.6°C, 76%	29.9°C, 72%	28.9°C, 76%

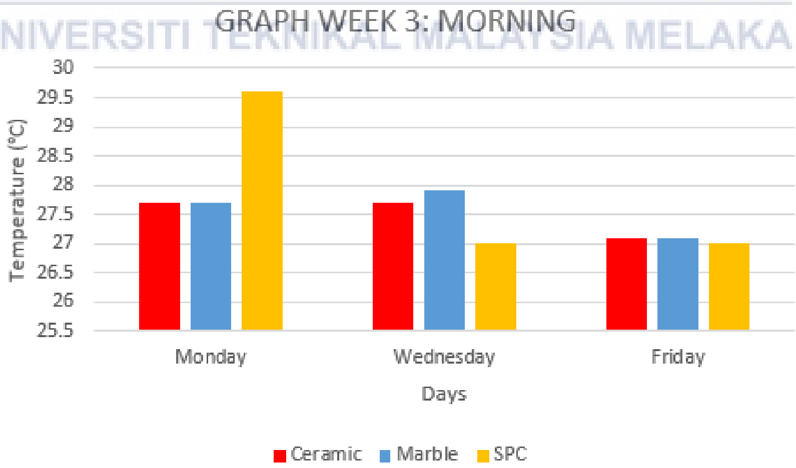

Figure 4.13 Temperature of Week 3: Morning

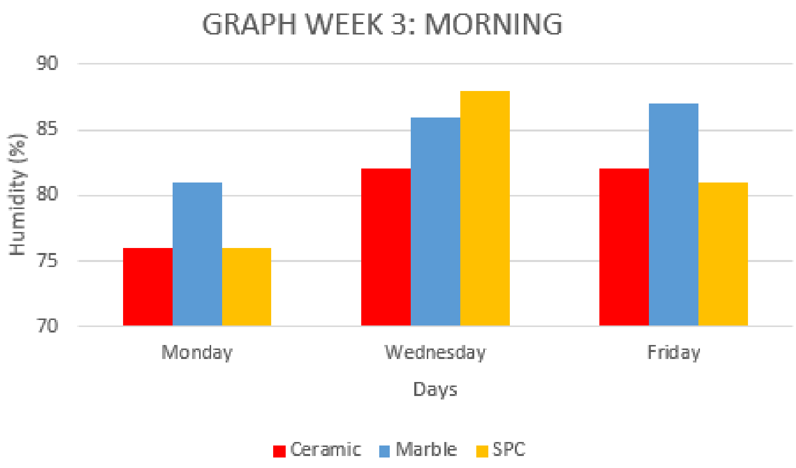

Figure 4.14 Humidity of Week 3: Morning

In the morning period, the temperature on the ceramic surface remained consistently at 27.7°C with varying humidity levels (76%, 82%, and 82%). Marble exhibited slight temperature fluctuations, ranging from 27.7°C to 27.9°C, accompanied by changes in humidity (81% to 87%). (SPC) showed a notable temperature increase from 27.0°C to 29.6°C, with varying humidity levels (76%, 88%, and 81%). The distinct thermal properties of each material, influenced by factors like thermal conductivity and insulation capabilities, contribute to temperature fluctuations. External elements such as sunlight exposure, ambient temperature, and humidity levels play a role in determining surface temperatures.

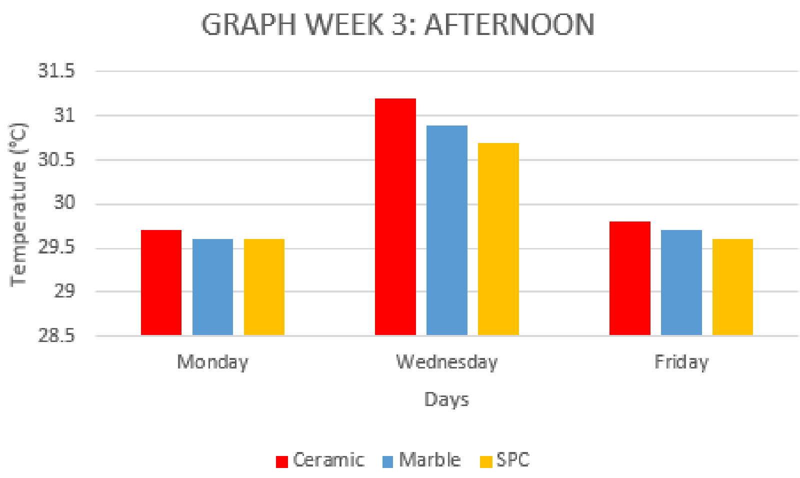

Figure 4.15 Temperature of Week 3: Afternoon

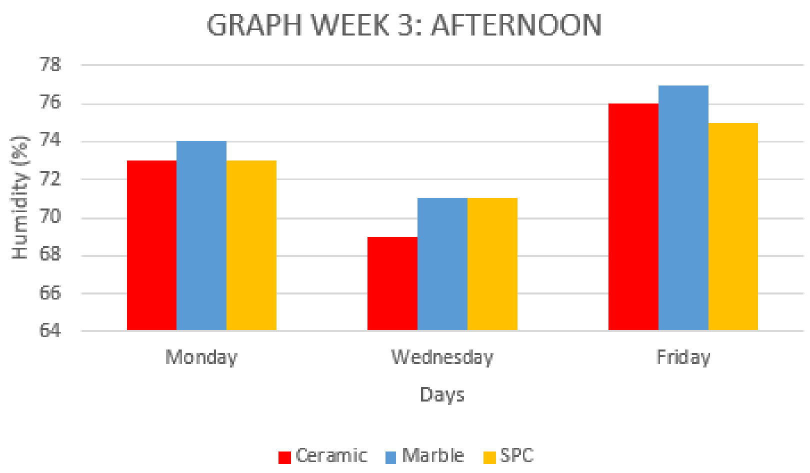

Figure 4.16 Humidity of Week 3: Afternoon

In the afternoon, the temperature and humidity readings for ceramic, marble, and stone plastic composite (SPC) surfaces display further variations. Ceramic surfaces showed an increase in temperature from 29.7°C to 31.2°C, accompanied by changes in humidity from 73% to 69% and then back to 76%. Marble exhibited a similar trend, with temperature rising from 29.6°C to 30.9°C and fluctuations in humidity from 74% to 71%, ultimately reaching 77%. SPC maintained a relatively stable temperature range, with readings ranging from 29.6°C to 30.7°C, and minor shifts in humidity from 73% to 71% and then to 75%. The afternoon readings displayed further nuances, with ceramic and marble experiencing temperature rises and fluctuations in humidity, indicative of their response to sunlight exposure. (SPC), with its synthetic composition, displayed a more stable temperature range. These dynamics suggest that natural stones like ceramic and marble respond promptly to environmental changes, while (SPC), with its insulation properties, exhibits a more tempered response.

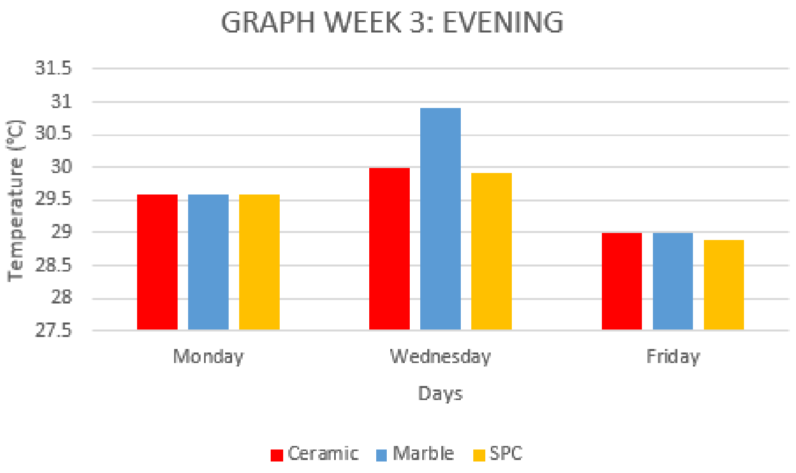

Figure 4.17 Temperature of Week 3: Evening

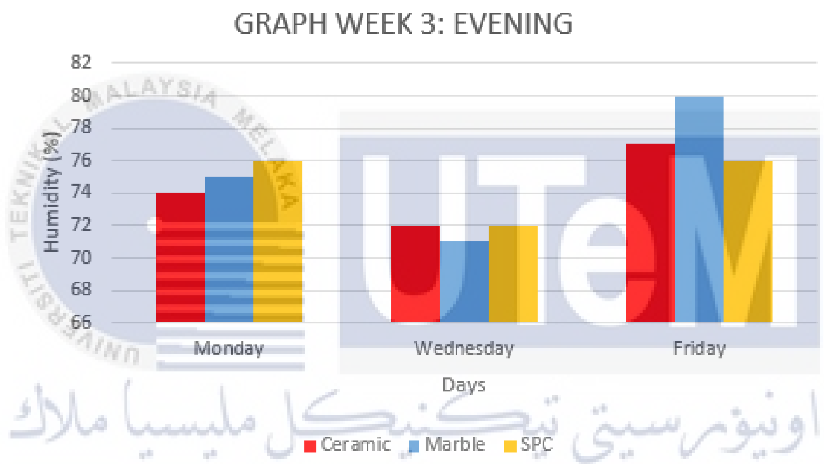

Figure 4.18 Humidity of Week 3: Evening

Evening temperatures range from 29.0°C to 30.9°C, and humidity levels fluctuate between 71% and 80%. Notably, marble exhibits the highest humidity at the second additional time. These include the time of day, environmental conditions such as weather patterns and unique properties of each material, potential microclimate differences, the accuracy of measurement instruments, and human activities in the vicinity. The variations observed highlight the sensitivity of the materials to changing environmental factors and underscore the importance of considering these dynamics in applications such as construction or manufacturing where temperature and humidity can impact material performance.

4.5.4 Week 4

Table 4.4 Results of Week 4

Time	Types of Flooring	Monday (4/12/2023)	Wednesday (6/12/2023)	Friday (8/12/2023)
Morning	Ceramic	28.6°C, 82%	29.2°C, 75%	29.1°C, 82%
	Marble	28.4°C, 84%	29.2°C, 78%	29.3°C, 88%
	SPC	28.3°C, 81%	29.1°C, 77%	27.7°C, 83%
Afternoon	Ceramic	31.3°C, 69%	29.8°C, 74%	28.0°C, 86%
	Marble	30.7°C, 73%	29.7°C, 77%	28.2°C, 89%
	SPC	30.5°C, 71%	29.6°C, 75%	28.0°C, 82%
Evening	Ceramic	29.2°C, 73%	28.3°C, 82%	28.9°C, 80%
	Marble	29.1°C, 78%	28.4°C, 81%	29.0°C, 81%
	SPC	28.8°C, 75%	28.1°C, 82%	28.9°C, 80%

Represents rainy condition

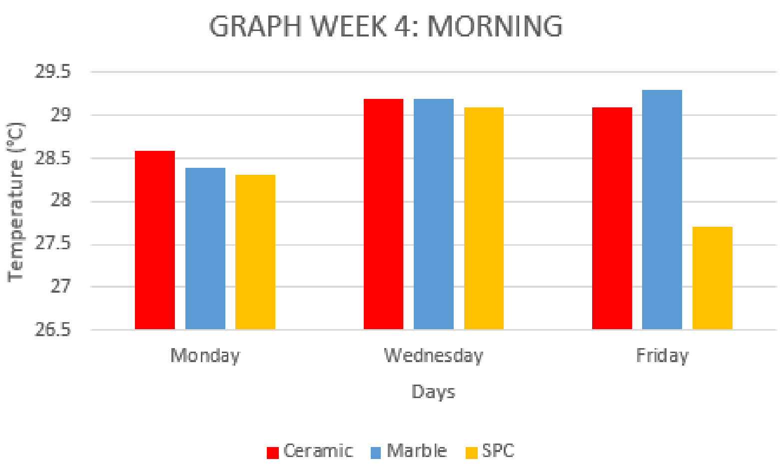

Figure 4.19 Temperature of Week 4: Morning

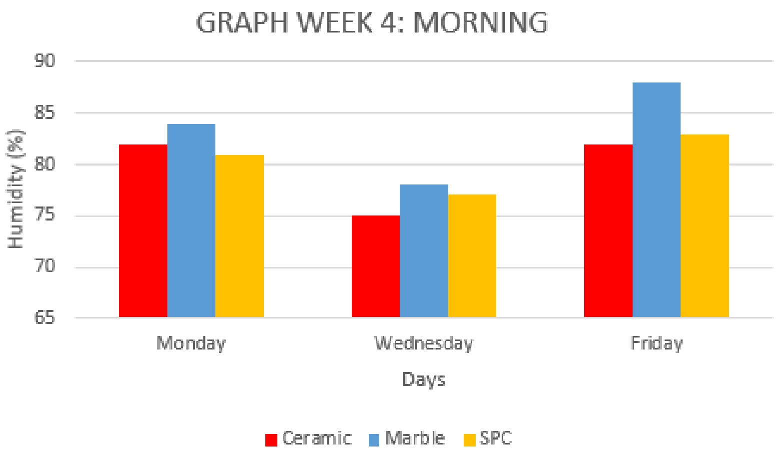

Figure 4.20 Humidity of Week 4: Morning

Each material exhibits distinct responses, with ceramic showing a decline in humidity from 82% to 75%, followed by a subsequent increase to 82%. Marble demonstrates a higher humidity range, varying from 84% to 88%, suggesting greater moisture absorption or retention compared to ceramic. (SPC) experiences a temperature drop from 28.3°C to 27.7°C and shows fluctuations in humidity. These variations are influenced by material properties, environmental conditions, and external factors such as sunlight exposure.

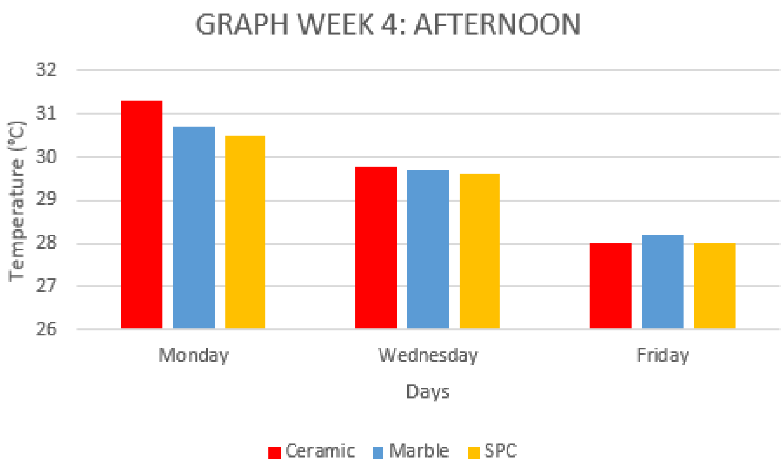

Figure 4.21 Temperature of Week 4: Afternoon

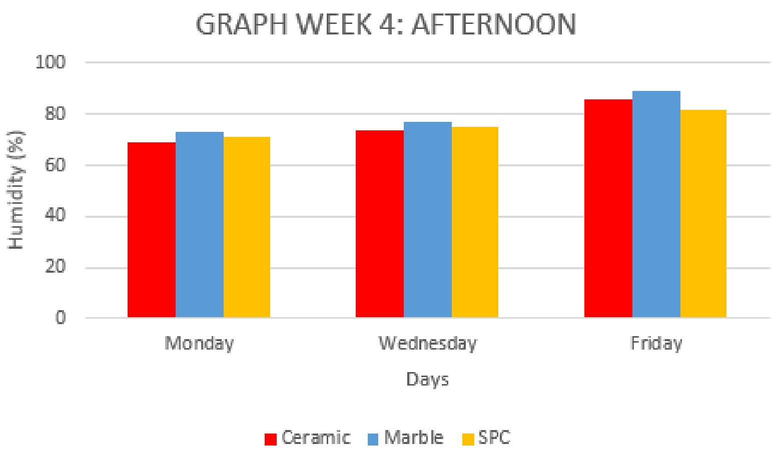

Figure 4.22 Humidity of Week 4: Afternoon

In the afternoon, ceramic exhibits the highest temperature (31.3°C) with lower humidity (69%), while marble and (SPC) also show elevated temperatures with varying humidity levels. A subsequent set of readings indicates a temperature decrease and slight humidity rise for all materials. In the evening, temperatures further decrease, and humidity levels rise, with ceramic maintaining the highest temperature (28.0°C). Accessible quantity fluctuations are complex phenomena that depend on a wide range of conditions. The temporal component, which is related to the time of day, adds dynamic fluctuations as human activity and natural cycles take place. Fundamental characteristics of the material are important because different materials react differently to external stimuli, which causes the variations that are seen. Environmental factors, which include things like atmospheric pressure and weather patterns, also influence how dynamically measured values are. Different regions experience various climatic trends and geological features that affect fluctuations according to their geographic location. Furthermore, since reading variations and device constraints can induce uncertainty, the precision of measuring instruments also adds to the complexity of observations. The difficult nature of comprehending and interpreting fluctuations in diverse scientific and environmental contexts is highlighted by the intricate interaction of time, material qualities, environment, location, and instrument precision.

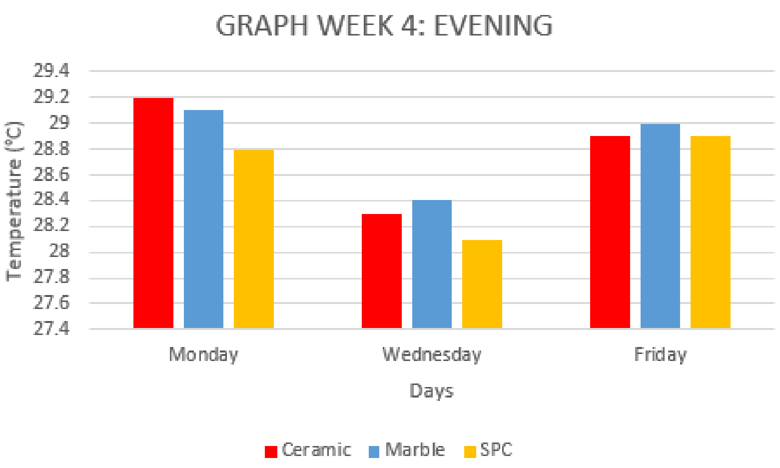

Figure 4.23 Temperature of Week 4: Evening

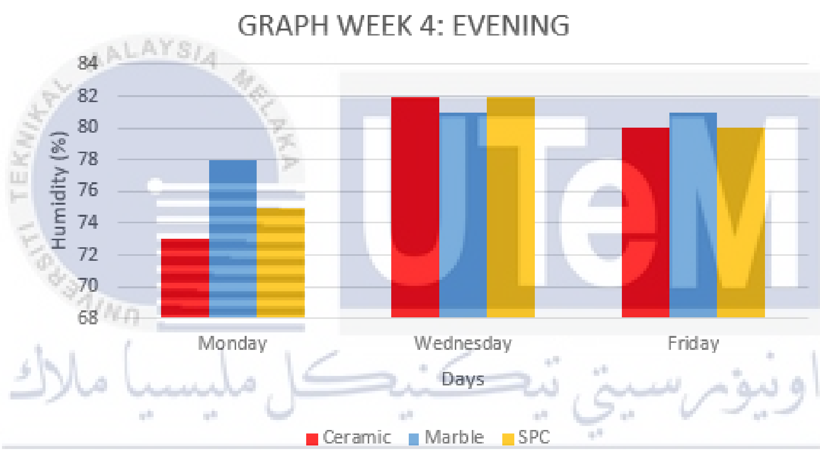

Figure 4.24 Humidity of Week 4: Evening

Ceramic recorded a temperature of 29.2°C with a humidity of 73%, while marble registered 29.1°C with a slightly higher humidity at 78%. (SPC), on the other hand, had a temperature of 28.8°C and a humidity level of 75%. Comparing these values to the preceding times, there was a marginal decrease in temperature for all materials. Ceramic showed a decrease from 28.3°C to 29.2°C, marble from 28.4°C to 29.1°C, and (SPC) from 28.1°C to 28.8°C. Diurnal fluctuations linked to the time of day, distinct thermal properties of each material, environmental conditions like weather and atmospheric pressure, ventilation levels, geographical location, indoor/outdoor settings, seasonal changes, measurement instrument accuracy, sample size and location, and human activities influenced the recorded temperature and humidity levels.

4.5.5 Average Week 1

Table 4.5 Average Data of Week 1

Time	Types of Flooring	Temperature/Humidity
Morning	Ceramic	29.1°C, 80%
	Marble	29.0°C, 83%
	SPC	28.9°C, 77%
Afternoon	Ceramic	29.4°C, 75%
	Marble	29.3°C, 77%
	SPC	29.2°C, 75%
Evening	Ceramic	29.0°C, 75%
	Marble	29.0°C, 77%
	SPC	28.8°C, 76%

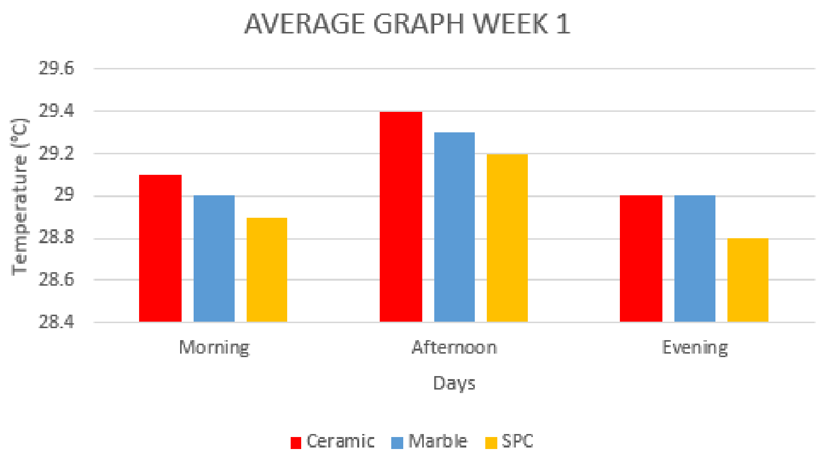

Figure 4.25 Average temperature of Week 1

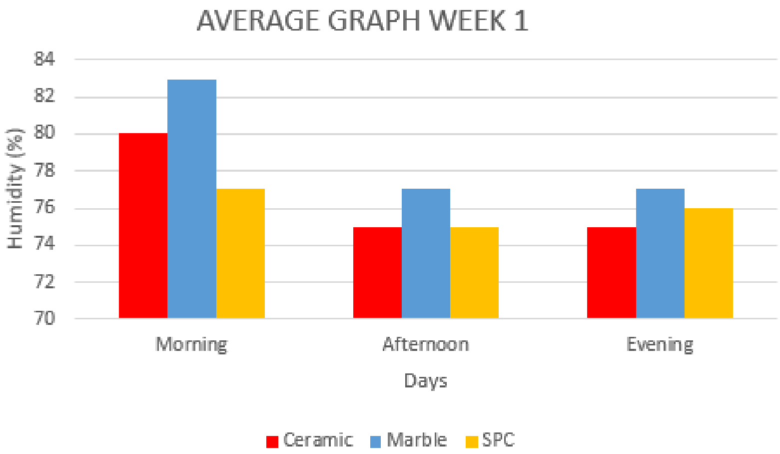

Figure 4.26 Average humidity of Week 1

The graph shows the average temperature for week 1 according to morning, afternoon and evening conditions respect to ceramic, marble and (SPC) flooring respectively. The temperature of ceramic flooring during afternoon shows the highest whereas the temperature of (SPC) flooring shows the lowest during evening. The temperature of ceramic and marble flooring is the same during evening. For interior flooring applications, Stone Plastic Composite (SPC) flooring is highly recommended due to its superior temperature resistance, which is well-known. It is less likely to expand or contract with changes in temperature because of its stiff core composition, which is normally composed of polyvinyl chloride and limestone. (SPC) flooring is especially well-liked because of its resilience to water, longevity, and ease of upkeep, which make it ideal for a variety of indoor environments, such as living rooms, bedrooms, workplaces, and retail spaces. Among other flooring options including laminate, hardwood, and conventional vinyl, (SPC) flooring stands out for its durable qualities, such as resistance to dents and scratches. Professionals and do-it-yourselfers both find it appealing because of how simple it is to install, especially with click-lock systems. It is important to evaluate wear layer quality, design possibilities, and the needs of the intended location when thinking about (SPC) flooring. All things considered, (SPC) flooring proves to be a flexible and dependable option for indoor flooring, satisfying the requirements of many settings.

4.5.6 Average Week 2

Table 4.6 Average Data of Week 2

Time	Types of Flooring	Temperature/Humidity
Morning	Ceramic	28.0°C, 82%
	Marble	28.2°C, 86%
	SPC	28.1°C, 81%
Afternoon	Ceramic	29.2°C, 78%
	Marble	29.1°C, 79%
	SPC	28.9°C, 78%
Evening	Ceramic	29.3°C, 75%
	Marble	29.3°C, 79%
	SPC	29.3°C, 76%

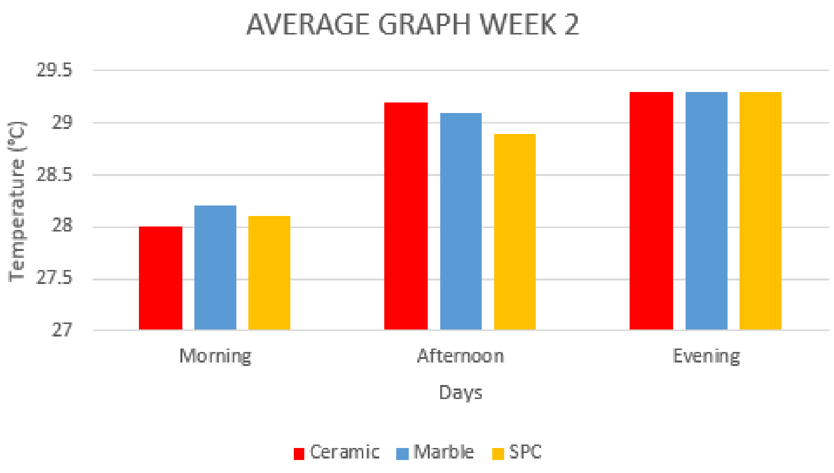

Figure 4.27 Average temperature of Week 2

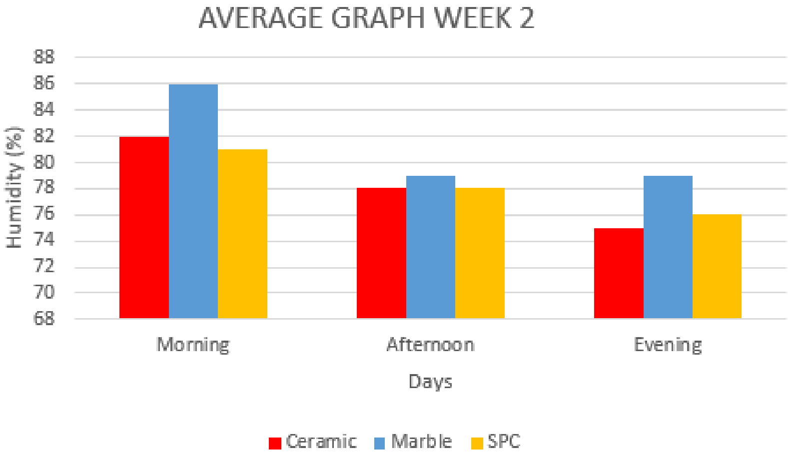

Figure 4.28 Average humidity of Week 2

The graph shows the average temperature for week 2 according to morning, afternoon and evening conditions respect to ceramic, marble and (SPC) flooring respectively. The temperature of ceramic and marble flooring during evening shows the highest whereas the temperature of ceramic and (SPC) flooring shows the lowest during evening. The temperature of ceramic and marble flooring is the same during morning. (SPC) flooring generally displays the lowest temperature, making it the ideal choice for interior flooring recommendations.

4.5.7 Average Week 3

Table 4.7 Average Data of Week 3

Time	Types of Flooring	Temperature/Humidity
Morning	Ceramic	27.5°C, 80%
	Marble	27.6°C, 85%
	SPC	28.0°C, 82%
Afternoon	Ceramic	30.2°C, 73%
	Marble	30.0°C, 74%
	SPC	30.0°C, 73%
Evening	Ceramic	29.5°C, 74%
	Marble	29.8°C, 75%
	SPC	29.5°C, 75%

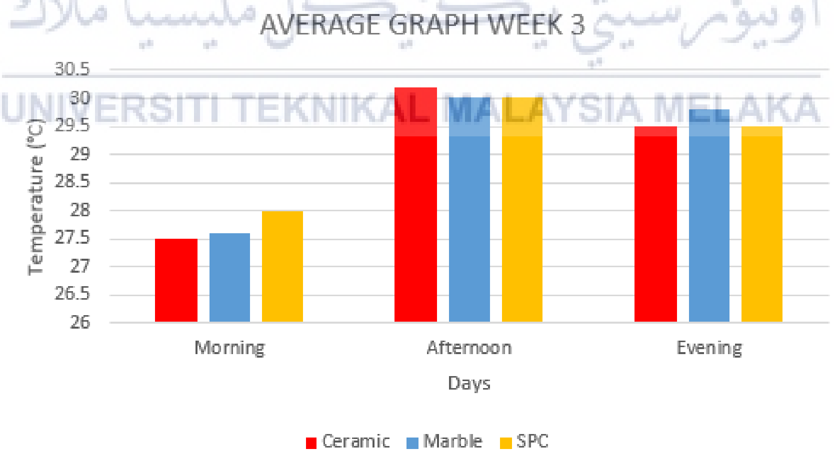

Figure 4.29 Average temperature of Week 3

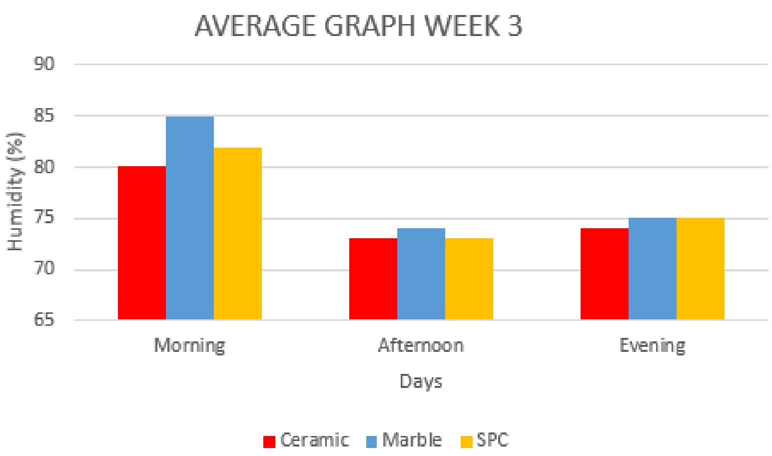

Figure 4.30 Average humidity of Week 3

The graph shows the average temperature for week 3 according to morning, afternoon and evening conditions respect to ceramic, marble and (SPC) flooring respectively. The temperature of ceramic flooring during afternoon shows the highest whereas the temperature of ceramic flooring shows the lowest during evening. The temperature of marble and (SPC) flooring is the same during afternoon. (SPC) flooring shows the highest temperature during morning but it is still reliable for afternoon and evening making it the genuine option for indoor flooring recommendations.

4.5.8 Average Week 4

Table 4.8 Average Data of Week 4

Time	Types of Flooring	Temperature/Humidity
Morning	Ceramic	29.0°C, 80%
	Marble	29.0°C, 83%
	SPC	28.3°C, 80%
Afternoon	Ceramic	29.7°C, 76%
	Marble	29.5°C, 80%
	SPC	29.4°C, 76%
Evening	Ceramic	28.8°C, 78%
	Marble	29.0°C, 80%
	SPC	28.6°C, 79%

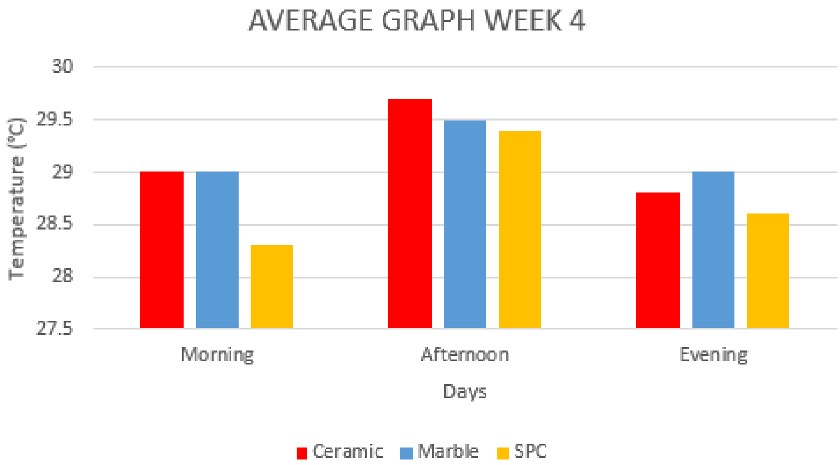

Figure 4.31 Average temperature of Week 4

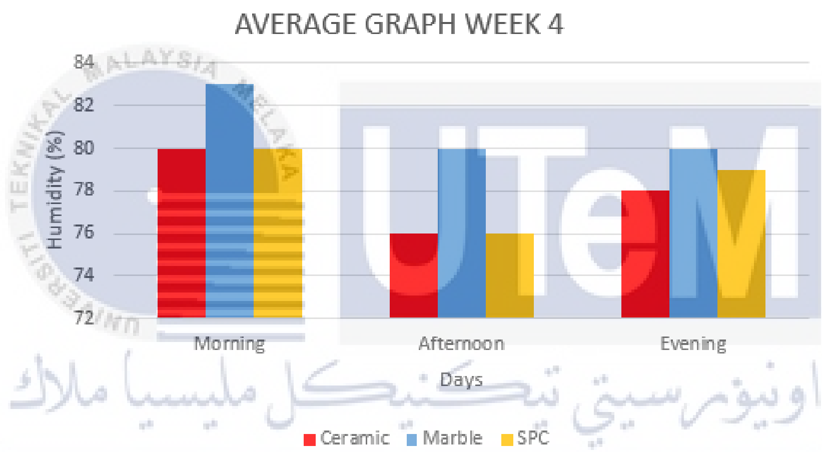

Figure 4.32 Average humidity of Week 4

In the Morning, temperatures range from 28.3°C to 29.0°C, with humidity varying from 80% to 83%. Afternoon temperatures increase slightly, ranging from 29.4°C to 29.7°C, while humidity levels decrease, ranging from 76% to 80%. Evening temperatures range from 28.6°C to 29.0°C, with humidity levels between 78% and 80%. This dataset provides a detailed snapshot of environmental conditions, allowing for potential analyses on the influence of different flooring materials on indoor temperature and humidity fluctuations throughout the day.

4.5.9 Total Average for 4 Weeks

Flooring Material	Ceramic			
Time/Week	1	2	3	4
Morning	29.1°C, 80%	28.0°C, 82%	27.5°C, 80%	29.0°C, 80%
Afternoon	29.4°C, 75%	29.2°C, 78%	30.2°C, 73%	29.7°C, 76%
Evening	29.0°C, 75%	29.3°C, 75%	29.5°C, 74%	28.8°C, 78%
Average	29.1°C, 77%			

Flooring Material	Marble			
Time/Week	1	2	3	4
Morning	29.0°C, 83%	28.2°C, 86%	27.6°C, 85%	29.0°C, 83%
Afternoon	29.3°C, 77%	29.1°C, 79%	30.0°C, 74%	29.5°C, 80%
Evening	29.0°C, 77%	29.3°C, 79%	29.8°C, 75%	29.0°C, 80%
Average	29.1°C, 80%			

Flooring Material	Stone Plastic Composite			
Time/Week	1	2	3	4
Morning	28.9°C, 77%	28.1°C, 81%	28.0°C, 82%	28.3°C, 80%
Afternoon	29.2°C, 75%	28.9°C, 78%	30.0°C, 73%	29.4°C, 76%
Evening	28.8°C, 76%	29.3°C, 76%	29.5°C, 75%	28.6°C, 79%
Average	28.9°C, 77%			

Figure 4.33 Total Average for 4 Weeks

4.6 Factors That Can Affect the Readings of Hygrometer

4.6.1 Temperature

The accuracy of hygrometer readings can be affected by temperature. Temperature changes can have an impact on the moisture-holding capacity of the air. Temperature compensation is used in some hygrometers to produce more accurate readings across a wide temperature range.

Figure 4.34 Change in surrounding temperature

4.6.2 Calibration

Calibration is required on a regular basis to ensure the accuracy of hygrometer data. Hygrometers can deviate from their initial calibration over time, resulting in incorrect results. For accurate results, the hygrometer must be calibrated on a regular basis.

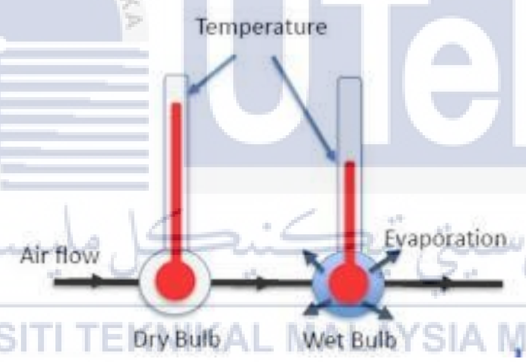

Figure 4.35 Calibration of hygrometer

4.6.3 Airflow and Ventilation

Moisture distribution inside a place is influenced by airflow and ventilation. Stagnant air can cause localized humidity changes, affecting the representativeness of the hygrometer measurement for the entire room.

Figure 4.36 Ventilation at area of testing

4.6.4 Placement of Hygrometer

The location of the hygrometer in a room is critical. It should be placed in a location that reflects the general circumstances of the room. Place it away from heat sources, vents, and direct sunshine, as they can all affect readings.

Figure 4.37 Placement of hygrometer on flooring material

4.6.5 Moisture Source

Hygrometer readings can be affected by proximity to moisture sources such as water leaks, damp surfaces, or indoor plants. It is critical for reliable thermal comfort evaluation to identify and manage such causes.

Figure 4.38 Presence of moisture on testing material

4.6.6 Humidity Source

Variations in humidity can be caused by a variety of activities within a structure. Cooking, bathing, and even the amount of people in a room can influence humidity levels. When evaluating hygrometer data, keep these things in mind.

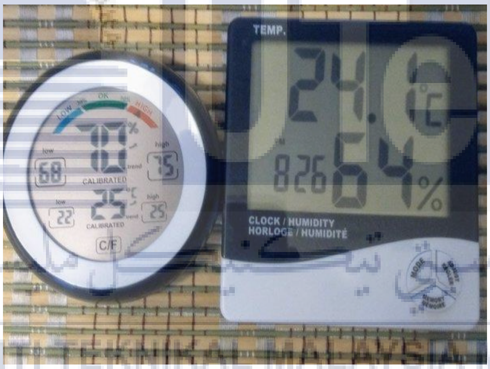

Figure 4.39 Humidity change at surrounding

4.6.7 Weather Conditions

Weather changes, such as rain or high humidity levels, can influence interior humidity. Building sealing difficulties can potentially contribute to moisture penetration during inclement weather.

DATE	WEATHER	FORECAST
08/01/2024 Monday	Isolated thunderstorms	**Morning:** No rain **Afternoon:** Isolated thunderstorms **Night:** Isolated rain **Min:** 24°C **Max:** 33°C
09/01/2024 Tuesday	Isolated thunderstorms	**Morning:** Isolated rain **Afternoon:** Isolated thunderstorms **Night:** Isolated rain **Min:** 24°C **Max:** 33°C
10/01/2024 Wednesday	Isolated thunderstorms	**Morning:** No rain **Afternoon:** Isolated thunderstorms **Night:** No rain **Min:** 24°C **Max:** 33°C
11/01/2024 Thursday	Isolated thunderstorms	**Morning:** No rain **Afternoon:** Isolated thunderstorms **Night:** Isolated rain **Min:** 24°C **Max:** 33°C

Figure 4.40 Weather condition at area of testing

(Source: https://www.met.gov.my/en/forecast/weather/state/St012/)

4.6.8 Occupancy Patterns

Humidity levels may be influenced by the number of inhabitants and their activities in a place. The occupancy and usage patterns of a building might affect hygrometer results.

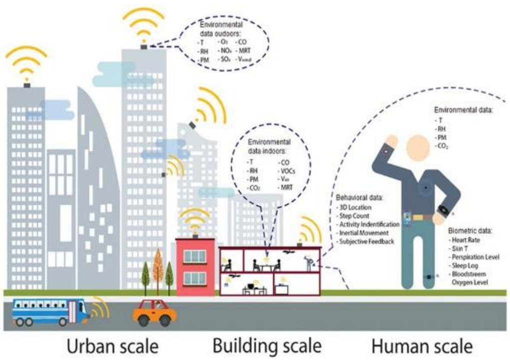

Figure 4.41 Occupancy Pattern

4.7 Impact of Different Flooring on Thermal Comfort

The effects of stone plastic composite (SPC), marble, and ceramic on interior thermal comfort depend on several important variables that together define a space's atmosphere. Ceramic tiles are distinguished by their low thermal conductivity and cool surface qualities, which contribute to a consistent and stable temperature ambiance indoors. Marble responds to temperature changes more gradually than other materials because of its increased thermal conductivity and substantial thermal mass. This causes marble to act as a slower heat absorber and releaser, which affects perceived comfort levels. (SPC) is a hybrid of ceramics and marble, with variable thermal conductivity and the potential for a compromise between stability and comfort. The selection of flooring material is only one factor to consider, though, and that is important to understand. The total thermal comfort that is felt in a particular indoor environment is greatly influenced by factors like colour, texture, and the particulars of each area (Thermal Comfort in Buildings, 2023).

4.8 Thermal Characteristics of Various Flooring Material

Ceramic, marble, and stone plastic composite (SPC) exhibit distinct thermal characteristics. Ceramics generally possess low thermal conductivity, making them suitable for applications where heat resistance is essential. Marble, renowned for its cool and smooth surface, demonstrates lower thermal conductivity, offering a cooler feel and the ability to absorb and radiate warmth. (SPC), composed of limestone and stabilizers, typically exhibits lower thermal conductivity and good insulation properties, providing a comfortable surface. While ceramics and marble are known for their heat resistance, insulation qualities of (SPC) makes it suitable for applications such as flooring, particularly in conjunction with radiant heating systems. When assessing the thermal performance of materials in diverse applications, it is imperative to consider compositions, colours, and finishes. This is because the effects of these parameters on aesthetics, conductivity, emissivity, absorption, and reflectivity are crucial. The correct decisions improve durability, safety, energy efficiency, and temperature control in a variety of settings, including industrial operations, electronics, and architecture.

4.9 Thermal Performance of Different Flooring Types

Ceramics are unique in the field of thermal performance because of their low thermal conductivity, which gives them an inherent resistance to heat. Their suitability for settings where exact temperature control is crucial is greatly enhanced by this feature. Ceramics are excellent in offering a dependable and heat-resistant solution, whether they are used in kitchen environments, where hot surfaces are frequently encountered, or in other applications needing thermal stability.

Marble, however, offers a special blend of smoothness and coldness on its surface, creating a unique tactile experience. Due to its decreased heat conductivity, the material is suitable for applications such as floors and worktops since it feels cold to the touch. Beyond aesthetics, marble's ability to absorb and release heat makes it more desirable in settings where temperature control and comfort are important factors.

In the thermal landscape, Stone Plastic Composite (SPC) becomes a flexible alternative because of its composition of stabilisers and limestone. Strong insulating qualities set (SPC) apart, and it finds use in flooring applications, particularly when combined with radiant heating systems. This combination is a sensible option for both residential and business settings since it offers effective temperature regulation in addition to a comfortable walking surface.

It is important to emphasise that a careful examination of these materials' thermal properties calls for an advanced technique. Their specified functions, surface treatments, and specific compositions all have a considerable impact on how they behave thermally. The ideal thermal characteristics needed for marble or (SPC) can vary depending on the application, as a polished ceramic surface may not be as heat-resistant as a textured one. Essentially, having an in-depth knowledge of these fundamental characteristics guarantees that choices of materials are well-informed and meet functional requirements and particular needs.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As the conclusion, the main objective of the study was achieved which is to investigate and assess the impact of different types of flooring on thermal comfort in buildings. The investigation into the effects of diverse flooring types on thermal comfort in buildings has yielded valuable understandings regarding the intricate interplay between flooring materials and indoor thermal conditions. A thorough examination of various flooring types clearly indicates that the selection of flooring can exert a substantial impact on the thermal comfort encountered by occupants.

The results underscore that specific flooring materials exhibit superior thermal insulation characteristics, thereby enhancing overall thermal comfort. Parameters such as thermal conductivity, heat retention, and surface temperature are pivotal in shaping the overall influence of flooring on indoor thermal conditions. After a thorough analysis into the thermal properties of various flooring materials, the second objective was successfully achieved. Furthermore, the research emphasizes the significance of accounting for climatic conditions, building design, and occupant preferences in the choice of flooring materials to optimize thermal comfort.

Additionally, the study emphasizes the need of a comprehensive approach to building design and construction that considers not only aesthetic and practical factors but also the thermal efficiency of flooring materials. This is especially true in the context of environmentally friendly and energy-efficient construction techniques, where the thermal qualities of flooring may have a major influence on overall energy consumption and environmental sustainability. A building's and climate's thermal performance for various flooring types is assessed by taking into account elements including occupant comfort, insulation qualities, thermal conductivity, and environmental effect. In order to adjust to temperature requirements, materials with better insulating qualities and lower heat conductivity are used, taking into account the local climate. Crucial factors include sustainability, energy efficiency, maintenance needs, and flooring system design.

Based on the insights gleaned from the study, architects, builders, and homeowners can now make more educated choices regarding flooring options, aiming to establish indoor environments that foster optimal thermal comfort. (SPC) flooring stands out for its effective insulation, boasting lower thermal conductivity than materials like ceramic tiles. This flooring type doesn't absorb or retain heat like stone or ceramic, ensuring comfort in both warm and cold conditions. With its rigid core structure, (SPC) flooring efficiently transfers heat, making it compatible with underfloor heating. Stability is a key feature, preventing expansion or contraction with temperature fluctuations, which helps maintain its structural integrity. Resisting temperature changes, it remains durable and suitable for various climates. In colder areas, it provides a warmer feel underfoot. Offering a stylish appearance with diverse colours, patterns, and textures, (SPC) flooring combines aesthetics with durability, resisting scratches, stains, and water damage. Cleaning is effortless, ensuring a polished look. Its water resistance makes it a dependable choice for wet environments. The user-friendly installation process and reasonable cost make (SPC) flooring an accessible and cost-effective option for those seeking both quality and affordability. Stone plastic composite (SPC) flooring will be the finest choice of indoor flooring in order to cater the best thermal comfort compared to ceramic or marble. As advancements in building materials persist, there is a call for additional research and innovation in flooring technology to further enhance the overall thermal performance of buildings.

In summary, the study adds significant insights to the realm of building design and construction. It establishes a groundwork for subsequent studies and real-world implementations focused on developing indoor environments that emphasize both occupant comfort and energy efficiency.

5.2 RECOMMENDATION

The study investigating how various flooring types affect thermal comfort in buildings provides essential recommendations for architects, builders, and stakeholders in building design. The primary suggestion emphasizes the importance of considering the climatic conditions of the building's location. Customizing flooring selections based on the climate ensures the choice of materials with suitable thermal properties, thereby enhancing thermal comfort in alignment with regional requirements. For example, in colder climates, prioritizing materials with superior thermal insulation is advised, whereas in warmer climates, materials with effective heat dissipation capabilities may be more appropriate.

Furthermore, there is a significant emphasis on incorporating sustainable flooring practices. Promoting the adoption of environmentally friendly materials characterized by low embodied energy and recyclable content aligns with overarching objectives of sustainable and green building practices. This suggestion highlights the crucial need to factor in not only the thermal performance but also the environmental impact of flooring materials during the decision-making process.

Within the realm of design guidelines, a key recommendation is to prioritize thermal performance. Architects and designers are advised to be attentive to the thermal properties of flooring during the design phase, incorporating guidelines that underscore the importance of flooring materials in attaining optimal thermal comfort. This approach guarantees the seamless integration of thermal considerations into the overall design, thereby contributing to the well-being of building occupants.

For efficient knowledge dissemination, stakeholders ought to invest in educational initiatives. It is essential to raise awareness among architects, builders, and homeowners regarding the influence of flooring choices on thermal comfort. Educational materials and workshops can empower stakeholders to make informed decisions that strike a balance between functional and thermal considerations. This approach fosters a deeper understanding of the role flooring plays in overall occupant well-being, promoting informed decision-making in this aspect of building design.

Another crucial recommendation is to promote cross-disciplinary collaboration. Encouraging teamwork among architects, engineers, and material scientists can spur the development of innovative flooring solutions that excel in both functionality and thermal comfort. This interdisciplinary approach plays a significant role in creating flooring materials that align with evolving design standards and meet user expectations.

Moreover, it is imperative to explore technological innovations to advance the thermal properties of flooring materials. Research and development initiatives targeting emerging technologies, such as phase-change materials or smart materials, have the potential to yield dynamic solutions. These solutions can effectively respond to changing thermal conditions, thereby enhancing indoor comfort, and promoting energy efficiency.

Active incorporation of user feedback into decision-making processes is also essential. Collecting insights from building occupants about their thermal comfort experiences with different flooring types offers valuable information. This feedback loop plays a crucial role in refining recommendations for flooring choices, ensuring alignment with user comfort expectations, and contributing positively to the overall indoor environment.

In a nutshell, regular updates to building codes and standards are imperative. Collaborating with regulatory bodies to integrate evolving knowledge about flooring materials and their impact on thermal comfort ensures that industry practices stay current with the latest research and technological advancements. This proactive approach is vital for maintaining a high standard of building design that prioritizes thermal comfort, energy efficiency, and sustainability.

Future research should include field case studies at commercial and industrial buildings with various installed flooring materials to investigate the effects of different flooring materials on thermal comfort and indoor health in the real world, rather than focusing solely on ceramic, marble, and stone plastic composites.

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APPENDICES

APPENDIX A Layout of Testing Area

APPENDIX B Turnitin Report

GEVE FYP 2

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Nama pelajar: GEVEGANESH A/L S.SHASITHARAN (B092010468)
Tajuk Tesis: A STUDY ON IMPACT OF DIFFERENT FLOORING TYPES TO THERMAL COMFORT IN BUILDINGS

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Sekian, terima kasih.

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