THE EFFECTS OF FLOORING MATERIAL ON THERMAL COMFORT IN A COMPARATIVE MANNER.

Ceramic tile and wood flooring

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ABSTRACT

The buildings sector, being a leading energy consumer, would need to lead in conservation efforts as well. There is a growing consensus that variability in indoor conditions can be acceptable to occupants, improve comfort perception, and lower building energy consumption. This work aim to examine and summaries the effects of flooring material on human thermal and comfort perception to such variations in the indoor environment: spatial transients, non-uniformities, and temperature drifts. We also briefly discuss personalized comfort systems since they work on an occupant's micro-climate and create non-uniformities in the indoors. The inspection of works done on effect of flooring material on thermal comfort points to the need for synchronizing the overall indoor environment's quality – in terms of décor, air quality, lighting etc. – to improve occupant thermal comfort. Essence of the overall discussions come out to be that indoor thermal environment can varies depending on the type of flooring material being used in the space.

A comparison between **ceramic tile** and **wood flooring** will be done in this work to see how each material affects the room thermal comfort and how each material work i.e. similarities, advantages/disadvantages and characteristics. A questionnaire will be distributed to the users of ceramic tile and that of wood flooring to begin with, asking their level of satisfaction on the material.

Keywords

Thermal comfort, floor material, temperature, comparison, recommendation,

1. INTRODUCTION

There are various types of flooring materials used in building construction and their selection depends on applications, aesthetics and choice of user. A floor in building construction is a leveled surface which can support the objects, occupants etc. Different flooring types are there based on different factors. The flooring material is chosen as per requirement of the user and based on applications which provides the most satisfying results for objective, either it may be economically or durability wise but in this work, we are going to be analyzing and comparing the two most common types of flooring materials (ceramic tiles and wood flooring).

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Ceramic tile flooring and laminated wood flooring are the most common types of flooring material used at homes and other spaces. They very different in looks, in style and also how they work. Both are made from natural resources but they do not work in the same manner.

Some flooring materials are especially good at holding in heat and others are specifically good at cooling off quickly when exposed to heat. Understanding how a floor holds in or gives off heat can help you make a better choice in which type of flooring material to installed when improving your property or space to an energy saving and comfortable space.

RESEARCH OBJECTIVES are as follows

To investigate how flooring material affects thermal comfort,   to identify the problem that lead to low thermal comfort of a space, To recommend which type of flooring material is better for the space.

2. LITERATURE REVIEW

thermal comfort means that a person feels neither too cold nor too warm. Thermal comfort is important for health and well-being as well as productivity. A lack of thermal comfort causes stress among building occupants. When they are too warm, people can feel tired; when too cold, they will be restless and distracted. As you may guess, thermal comfort has to do with more than the temperature. It can be achieved only when the air temperature, humidity and the movement of the air are in proper balance with each other. Adding to the complication, it is obvious that one person's thermal comfort zone is not the same as another's. Temperature preferences vary greatly among individuals, and it may not be possible to satisfy everyone in a group. Thermal comfort can also be a matter of perception.

Let's start with temperature. There is no one ideal temperature for all times any more than there is one for all people. Generally, it is recommended that indoor temperatures be kept between 69 and 73 degrees F. The outdoor weather is a factor, however, when outdoor temperatures are hotter, it may be advisable to keep air-conditioned spaces warmer to minimize the temperature difference between indoors and outdoors. So-called radiant heat is also an important consideration. One will certainly feel warmer sitting in direct sun than sitting in the shade at the same air temperature. Building occupants near sun-exposed windows will feel warmer in the same space than others further away.

"It's not the heat, it's the humidity!" This oft-repeated refrain can be quite true. Humidity is an important element of thermal comfort, and humidity control is a major (and energy-intensive) function of building HVAC systems. Excessive humidity makes occupants feel warmer, and the air seem "stuffy". It is also unhealthful because it can lead to the development of bacterial and fungal growth. Too little humidity causes discomfort by drying out people's throats and sinuses, and contributing to skin rashes. Dry conditions also lead to the familiar electrostatic discharge when people touch each other or different surfaces. Depending on regional climate and building design, HVAC systems may be capable of either humidifying the air supplied to the building interior, dehumidifying it, or both.

Green buildings may be designed to be responsive to regional climate, and use less active strategies to help provide an acceptable range of thermal comfort through the seasons. Passive solar heating will maximize the warming benefit of the sun in heating season. Passive cooling will use proper shading and natural ventilation to reduce indoor temperatures, and provide air movement to increase comfort. The timing of ventilation is important as well. Passively cooled buildings will be set up to maximize outdoor air intake at night, when it is cool. The "stack effect" set up by rising warm air, vented near the top of a space, will serve to draw in cooler air down low.

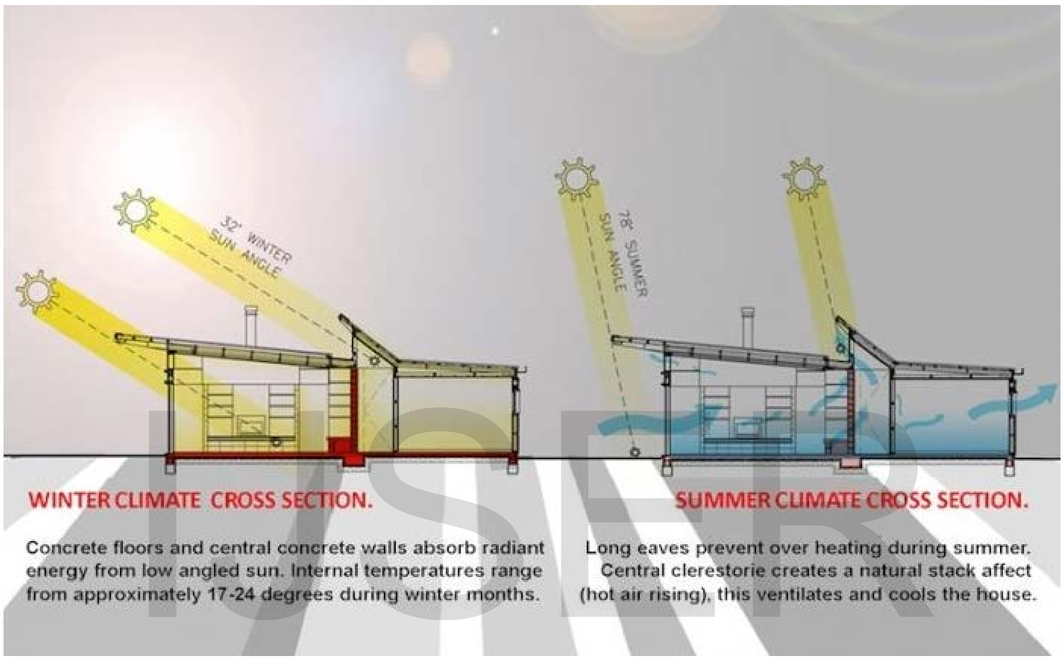
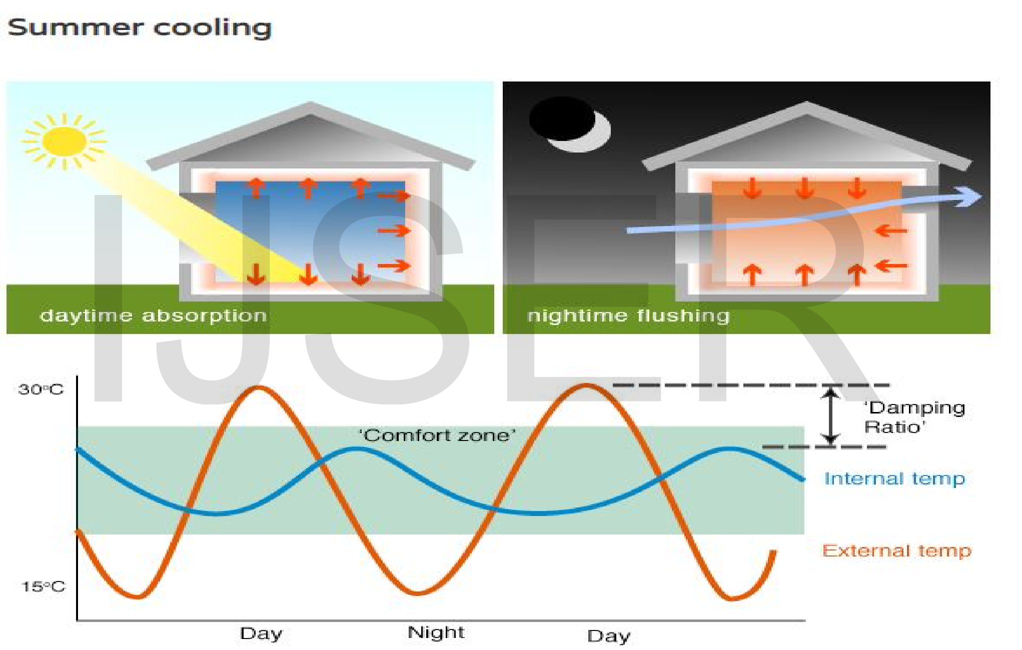
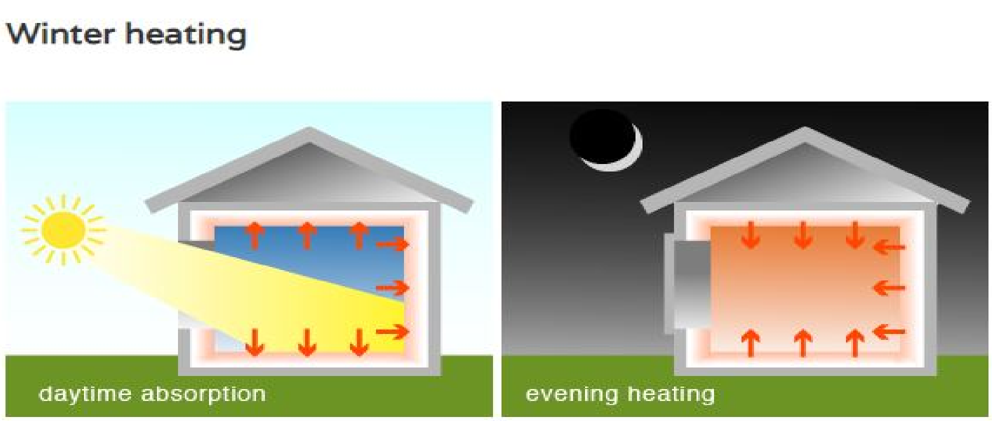


Figure P.1 https://www.lpattenandsons.ca/collingwood-custom-home-blog/2018/2/23/what-is-a-passive-house

Air movement is also important. A simple fan can provide a cooling breeze in warm weather; but the same breeze in a colder situation would be an uncomfortable and unhealthful "draft". A small amount of air movement is always necessary, if only to ventilate a space – introducing fresh air and removing stale air. In fact, the power to drive the fans that move air around a building can be the largest job – energy-wise – of the HVAC system. Fully climate-controlled buildings have energy-consuming equipment that will heat and cool the interior spaces as well as add or remove moisture from the air, as appropriate. Fans will move air for various purposes. Automatic shading systems can regulate solar radiant heat to maintain comfort, as well as Other buildings may be much simpler. Consider a house with radiators to provide heat, and that is all. A radiator heats the air that is already in the room, and natural air currents are set in motion as warm air rises, Hot-air heating systems blow heated air into a space. Other than that, we may have windows and doors that open, shades to admit or exclude the sun's rays, fans – built-in or portable -- and no "air conditioning". In older homes and buildings without central heating systems, fireplaces and stoves were the sole source of warmth. Buildings in tropical climates may have no heating at all.

HOW THERMAL MASS WORKS by alternately storing and releasing heat, high thermal mass 'smooths out' the extremes in daytime temperatures. In warm /hot climates where there is significant temperature variation between day and night ('diurnal' variation), heat is absorbed during the day and then released in the evening when the excess can be either 'flushed out' through natural ventilation or it can be used to heat the space as the outside temperature drops. The entire process can then be repeated the next day.





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Locating thermal mass can be done by the following procedures

Thermal mass should be exposed ('coupled') to the heated internal space.

Thermal mass needs to be isolated from the influence of external air temperatures. This is achieved through locating the mass within the insulated building envelope.

Any heavyweight material will serve as thermal mass. It can form any part of the internal fabric, be it floor, walls or ceiling.

Though often desirable, thermal mass does not need to be exposed to direct sunlight for heat to be absorbed. Heat can be conveyed through convection and radiation between other surfaces.

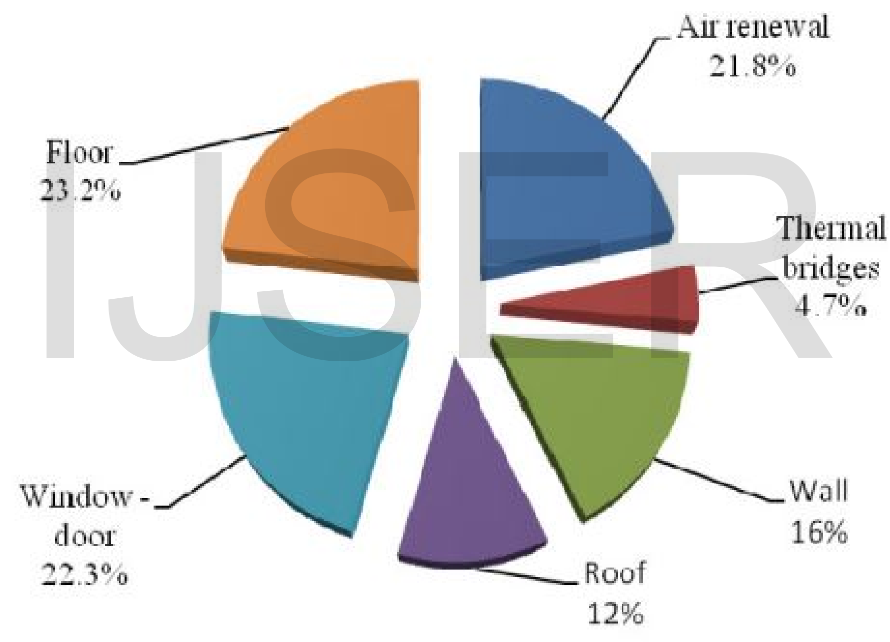

Fig. 3. Distribution of losses on the various house components

https://www.sciencedirect.com/science/article/pii/S187661021400839X

FACTORS THAT DETERMINE THERMAL MASS are as follows

Specific heat capacity
Specific heat capacity refers to a material's capacity to store heat for every kilogram of mass. A material of 'high' thermal mass has a high specific heat capacity. Specific heat capacity is measured in J/kg.K

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Density

The density refers to the mass (or 'weight') per unit volume of a material and is measured in kg/m^3. A high density material maximizes the overall weight and is an aspect of 'high' thermal mass.

Thermal conductivity

Thermal conductivity measures the ease with which heat can travel through a material. For 'high' thermal mass, thermal conductivity usually needs to be moderate so that the absorption and release of heat synchronizes with the building's heating and cooling cycle. Thermal conductivity is measured in units of W/m.K.

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CHARACTERISTICS OF THE COMPARED MATERIALS

Wood flooring

- Recyclable
- Low embodied energy at factory gates
- Renewable resource
- Biodegradable - material doesn't persist in landfill
- Non toxic
- Durable
- Thermal mass (minor) and insulation properties

- High embodied energy
- Some flooring includes formaldehyde
- Sealants, if used, can produce harmful VOCs

Ceramic tiles

- Recyclable
- Abundant natural resource
- Non-toxic
- Easy maintenance
- Extremely durable
- Usable in wet areas

- High embodied energy
- Imported tiles add to embodied energy

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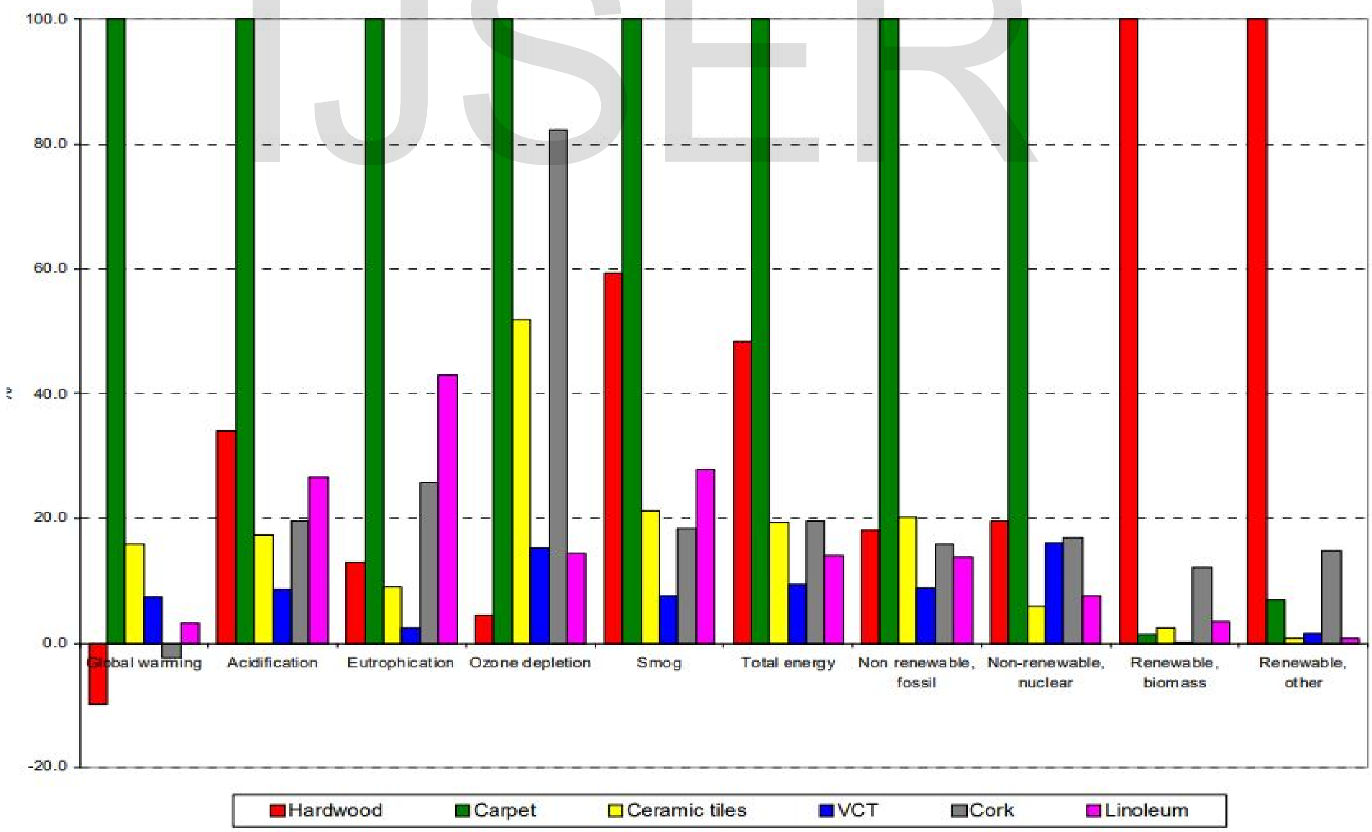

Figure p2 http://hardwoodinitiative.fpinnovations.ca/files/publications-reports/reports/project-no1-flooring-comparison-lca-final-report.pdf

Above shows a comparative life circle assessment of alternative flooring material types

Comparison survey of ceramic tile vs engineered hardwood flooring

WHICH FLOORING IS BETTER?

	CERAMIC TILE	RATING		WOOD FLOORING
Look and appearance	Available in wide range of styles from traditional to contemporary. Most popular colors: beige, brown, and grey.	4	5	Beautiful natural look of wood. Available in variety of colors and shades. Most popular species: oak, maple, and cherry.
Suitability	Can be installed in any room. Best suits for a bathroom, kitchen, hallways, and basement.	5	4	Good for most rooms in the house, but not recommended for installation in areas with potentially high moisture level such as bathrooms, powder rooms, or laundry rooms. Best choice for a living room or bedroom.
Child friendliness	Easily withstands any abuse, but feels hard under the feet.	4	3	Can be damaged by heavy abuse or constant liquids spills.
Pet friendliness	Wearing layer of glazed ceramic tile impervious to pet urine and hard enough not to be scratched by even bigger dog's claws.	5	3	Susceptible to pet urine and can be scratched by claws.
Stain resistance	Glazed ceramic tile is insusceptible to stain. Grout between tiles might lose its appearance overtime if not sealed periodically.	5	3	Even highest quality hardwood floors could be stained and discolored spots might appear on wood surface if water, juice or pet urine won't be wiped from the floor immediately.
Water resistance	A few hours standing water on the surface of quality glazed ceramic	5	2	Water or even high moisture level in the room can cause multiple problems to the wood

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	tile with low water absorption coefficient (less than 3%) won't do any damage to the tile.			floors including bucking, cupping, warping or crowning.
Fade resistance	Ceramic tile do not fade or change color under any conditions.	5	2	Direct sunlight can cause discoloring of wood floors. Some wood species might even change in color overtime under normal light intensity.
Durability and hardness	Ceramic tile with high resistance to abrasion is one of the most durable flooring materials.	4	3	Depends on species and finish quality, but wood is softer product than ceramic tile.
Longevity	Lifetime with proper installation and care.	5	4	Lifespan significantly vary. Glue or nail down installation 50+ years, floating engineered floors 25+ years.
Maintenance	Very little care required after installation.	2	4	Regular cleaning and elimination of any liquids from wood surface right away will ensure long lasting flooring performance.
Manufacturer warranty	Greatly vary.	-	-	Warranty on hardwood flooring depends on a manufacturer and product quality. Most reputable wood floors producers offer 25 – 55 years limited wear warranty on their products.
Normally sold in	Boxes 12" x 12", 16" x 16" or 24" x 24", but many other dimensions are available.	-	-	Cases 48'' - 84'' long.
Typical weight per square foot	3.5 – 4 lb/ ft^2	-	-	1.4 – 2.6 lb/ft^2

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Products view				
Typical thickness	0.3125 in. – 0.375 in.	-	-	0.375 in. – 0.75 in.
Price	Vary, but normally cheaper compare to wood flooring.	3	4	Some exotic wood hardwood floors might be quite expensive.
Installation cost (labor)	Cost of ceramic tile installation normally higher compare to laying hardwood floors.	4	2	Cheaper to install.
Installation methods	Setting tile on mortar.	-	-	Nail down, glue down, click and lock.
Installation complexity	Typically tile slightly harder to install.	4	3	Prefinished wood floors installation is not a complicated task and many homeowners are able to do it themselves.
Installation time	Depends on complexity, but in general, for an experienced tile setter tiling 11’ x 15’ kitchen using 12” x 12” or bigger tile is one day project excluding possible preparation work and grout application.	4	3	Experienced hardwood installer normally is able to complete nailing down 3 ¼ in. wide engineered hardwood flooring in 14’ x 16’ master bedroom in one day, not accounting any preparation or extra work. But complex installation might take twice longer.
Replacement time	Replacement of ceramic tile could be an extremely time consuming process. Demolishing of existing tile and preparation work	5	3	Floating wood floors very easy to remove and replace with new ones. Nail down floors are much harder to replace. Demolishing and replacing glue down

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	might actually last longer compare to installation of new tile itself.		hardwood floor might take the same time as replacing ceramic tile.
Common problems	With proper installation ceramic tile flooring shouldn't have any problems except grout lines discoloring which can be easily fixed by cleaning and (or) rerouting tile. Cracks are normally a result of poor completed project.	5 3	Hardwood floors are much more susceptible to damages, and even adequately installed quality wood flooring can be easily damaged by high moisture level in the room or simply placing heavy and sharp objects on its surface.

Ceramic tile and wood flooring are great flooring options with their own advantages and disadvantages and which one to buy depends on many factors. Type of a room, ability to take cake about floors properly and homeowner's preferences should be taken into account while choosing between tile and wood.

In other words, users tend to forget how their choice of flooring will affect their thermal comfort because each floor has its properties and each property can have an impact on the room temperature which affects health and abilities. Thermal comfort is influenced by several factors, which principally contain air temperature, air humidity, air velocity, mean radiant temperature, human Clothing, and activity levels. Several specialists in this domain trust that indoor air quality may be the most important and relatively overlooked environmental issue of our time. Indoor pollutants lead to poor indoor air quality. The indoor environmental quality impacts not only health and comfort, but also the occupants, productivity, as it strongly affects working and learning competency, with effect on production and social costs.

3. METHODOLOGY

In addition to the above survey done by" http://www.rempros.com/comparison/ceramic-tile-vs-engineered-hardwood-flooring.html" A comparison between ceramic tile and wood flooring will be done in this work to see how each material affects the room thermal comfort and how each material work i.e. similarities, advantages/disadvantages and characteristics. A questionnaire was distributed to the users of ceramic tile and that of wood flooring to begin with, asking their level of satisfaction on the material and then later will calculate their U value, R value, C value, K value of each system to see which one has more thermal capabilities.

The concepts of K-value, C-value, R-value, and U-value can be summed up in the following rules:

The better insulated a system, the lower its U-value.

The greater the performance of a piece of insulation, the greater its R-value and the lower its C-value.

The lower the K-value of a particular insulation material, the greater its insulating value for a particular thickness and given set of conditions.

These are the properties upon which users of thermal insulation depend for energy savings, process control, personnel protection, and condensation control.

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R-value is essentially a product's resistance to heat flow which means that the higher the product's R-value, the better it is at insulating the home and improving energy efficiency. Adversely, **U-value** measures the rate of heat transfer. This means that products with a lower U-value will be more energy efficient. In most applications, the primary feature of a thermal insulation material is its ability to reduce heat exchange between a surface and the environment, or between one surface and another surface. This is known as having a low value for thermal conductivity. Generally, the lower a material's thermal conductivity, the greater its ability to insulate for a given material thickness and set of conditions.

3.1 **RESULTs AND DISCUSSIONS**

In this work, I created a small model of a simple room with regular walls and slabs nut changing the flooring composition in two ways, that of the ceramic tile and that of the wood flooring in finding the U value of each flooring material in a simple application as shown below Is what I design for this research using a U value calculator software called TISOFT.

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ceramic tile

floor

U 0.612 W/(m²·K)
Thickness 0.38 m
Weight 696.48 kg/m²
Heat capacity 0.000 kJ/(m²·K)

Construction type layers (from outside to inside)							
Nr	Code	Description	Special heat [C_p] kJ/(kg·K)	Density [ρ] kg/m³	Thickness [d] m	Thermal conductivity [λ] W/(m·K)	Thermal resistivity [R=d/λ] (m²·K)/W
1	4.7.2	Ceramic floor tiles	0.84	2,000.00	0.05	1.840	0.03
1	E001-20	2cm Plasterboard	0.84	1,600.00	0.02	0.727	0.03
1	C12	50 mm Heavyweight concrete	0.84	2,243.00	0.05	1.731	0.03
1	B16	4 mm Insulation	0.84	91.00	0.00	0.043	0.09
1	6.4.6	Cotton	1.30	60.00	0.05	0.040	1.25
1	B16	4 mm Insulation	0.84	91.00	0.00	0.043	0.09
1	C10	200 mm Heavyweight concrete	0.84	2,243.00	0.20	1.731	0.12
Totals					**0.38**		**1.64**

$U = 1/\Sigma R_i = 1/1.64 = 0.612$

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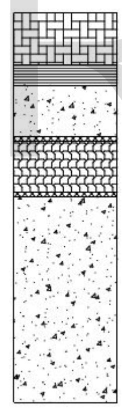

As shown in the figure above, this system composition of a ceramic tile flooring has the thermal conductivity of 6.155w/(m-k) and a special heat of **6.34kj(kg.k)**

the **U value** as shown above is **0.612** W/(m²·K)

the **K value** as shown above is **6.155w/(m-k)**

to find the **R value**, R value = thickness / K value

0.38/6.155 = **0.062**

To find the **C value,** C value = K value / thickness

=6.155 / 0.38 = **16.197**

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wood flooring

floor

U 0.361 W/(m²·K)
Thickness 0.51 m
Weight 754.48 kg/m²
Heat capacity 0.000 kJ/(m²·K)

Construction type layers (from outside to inside)							
Nr	Code	Description	Special heat [C_p] kJ/(kg·K)	Density [ρ] kg/m³	Thickness [d] m	Thermal conductivity [λ] W/(m·K)	Thermal resistivity [R=d/λ] (m²·K)/W
1	2.1.4	Oak wood	1.60	800.00	0.05	0.210	0.24
1	5.1.06	Acrylics	1.50	1,050.00	0.05	0.200	0.25
1	2.2.1.C	Chipboard , ρ=900 kg/m3	1.70	900.00	0.05	0.180	0.28
1	5.1.06	Acrylics	1.50	1,050.00	0.05	0.200	0.25
1	A004	Internal air layer in floor as defined in ISO6946					0.17
1	C12	50 mm Heavyweight concrete	0.84	2,243.00	0.05	1.731	0.03
1	B16	4 mm Insulation	0.84	91.00	0.00	0.043	0.09
1	6.4.6	Cotton	1.30	60.00	0.05	0.040	1.25
1	B16	4 mm Insulation	0.84	91.00	0.00	0.043	0.09
1	C10	200 mm Heavyweight concrete	0.84	2,243.00	0.20	1.731	0.12
Totals					**0.51**		**2.77**

$U = 1/ \Sigma R_i = 1/2.77 = 0.361$

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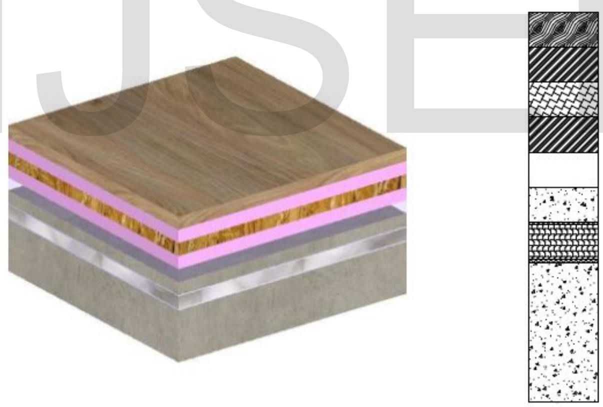

As shown in the figure above, this system composition of a wood flooring has the thermal conductivity of 4.378w/(m-k) and a special heat of **10.96kj(kg.k)**

the **U value** as shown above is **0.361** W/(m²·K)

the **K value** as shown above is **4.378w/(m-k)**

to find the **R value**, R value = thickness / K value

0.51/4.378 = **0.116**

To find the **C value,** C value = K value / thickness

=4.378 / 0.51 = **8.584**

So due to this findings, it is clear that the wooden flooring has more thermal performance than the ceramic tile.

4. CONCLUTION

During my researches and experiments, I came across several issues that Can be used in determining which flooring material is best for your house, depending on a lot of issues. These issues were identified in every alternative during study work.

It became clear that most of the people facing problems and challenges of thermal comfort in their space chose their materials based on aesthetic

So in conclusion, I found and made it clear that the use of wood flooring material is better for thermal comfort because it has lower U value (measures the rate of heat transfer), K value (is a measure of the thermal conductivity of a material, that is, how easily heat passes across it), R value (thermal resistance), C value (thermal conductance) and apart from all that is has less potential to create dampness in a high humid location.

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