ANALYSIS ON THE THERMAL TRANSMITTANCE/ CONDUCTANCE OF BUILDING ELEMENTS (ROOF, WALL AND FLOOR) BASED ON THE DIFFERENT BUILDING MATERIALS USED IN FAMAGUSTA

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Abstract: **Buildings are generally made of different elements, and to create a shelter or complete building, the three basic elements that make up the shelter space or building. They are the roof element, the wall element and the floor element. These different elements directly affect the thermal comfort of the space which they form and as such the materials used in creating these elements play a main role in the thermal comfort of this space. Therefore this study will be dealing with the calculation of the thermal resistance and conductance of the elements based on the type of materials used.**

Keywords: **Thermal Conductance- U. Value, thermal Resistance – R value, Building Element, Roof Element, Wall Element, Floor element.**

1. INTRODUCTION

Thermal comfort is a very important factor in terms of the general well-being of humans and were they live and although most times the environment cannot be controlled as it comes from mother nature, there spaces in which we live in and create as shelter can help provide thermal comfort relatively shielding humans from the sometimes harsh conditions given by the environment.

Although, with the further advancement of technology especially in building technology, thermal comfort can be reached through the use of mechanical and electrical means like the use of Air conditioners, Radiators, Fans and so on. These all help in regulating the temperature to the appropriate value that we might need at that particular time and space.

But these can also go as far as to regulate the temperature for a particular time period and its left for the controlled space to be able to conduct or resist these temperature to be able to retain the thermal comfort and this is done by the elements that constitute the space which are the walls, roof and floor elements and furthermore, the materials that make them up.

Thermal resistance of existing building envelopes is an important factor in defining the total energy consumption of heating and cooling systems and achieving optimal thermal comfort for occupants. The R-value is a measure of how well an envelope resists the heat-flow. With higher R-values, the insulating effectiveness is greater. The R-value or conductance depends on the material type, thickness, and density of each layer. The heat transfer by conduction, radiation

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and convection can be reduced through appropriate construction techniques and choice of materials. In some conditions, the real R-value of building envelope components does not always agree for various reasons with the value declared by manufactures or estimated in the design phase. It is important to measure and analyze the building envelope R-value in situ.

This study aims to study the thermal resistance and transmittance of the elements that constitute a typical building in Famagusta and thereby create a table and value for the construction materials that are generally used in the various elements of the particular building. And this will give an idea of the thermal capacity of the given building. Or elements as it is needed. Thermal transmittance and resistance are what constitute the overall thermal conductance of the elements and therefore the building in general.

Nomenclatures that will be encountered during the research and literature review include;

R_n test wall thermal resistance calculated after n measurements [m2 K/W]

t_{sw} surface temperature on the test wall warm side [◦C, K]

t_{sc} surface temperature on the test wall cold side [◦C, K]

q   heat-flow rate through the test wall [W/m2]

R_{10} R-value calculated with a tair ≈10 ◦C [m2 K/W]

R_7 R-value calculated with a tair ≈7 ◦C [m2 K/W]

 s   thickness of a layer of the test wall [m]

 S   area of the wall [m2]

R_D R-value calculated through the destructive method [m2 K/W]

Q   transmission heat loss through a wall [W]

q   Transmission heat loss through a wall per unit area and per unit difference of temperature [W/m2 K]

h_i internal surface heat transfer coefficient [W/m2 K]

h_e external surface heat transfer coefficient [W/m2 K]

t_{int} internal set point temperature [◦C, K]

t_{ext} external temperature [◦C, K]

2.   LITERATURE REVIEW

Many existing structures in Cyprus have poor thermal execution.

Florides et al.[4] reenacted a normal house with different development designs that speak to present day Cypriot houses, and found that without warming or cooling indoor temperatures gone from 10 to 20C in winter and up to 30– 50C in summer.

An overview by Lapithis et al.[5] found that most tenants of present day houses in Cyprus complained of lacking comfort; 80% of members feeling chilly in winter and 87% inclination hot in summer. Thermal construction of structures in Cyprus can be enhanced by changes to building geometry also, developments. Rabah[6] expressed in North Cyprus, modelers and architects have not considered the neighborhood atmosphere amid the arranging stage and this causes poor thermal solace. In light of Mahoney investigation, he prescribed that structures ought to have a minimized yard plan with long hub arranged east– west, little opening sizes (up to 20% of divider surface), and overwhelming dividers, rooftops and floors with a period slack of 8 hours. Ozdeniz and Hancer[7] tried 14 distinctive rooftop developments on a test room in Cyprus. They discovered that the best performing rooftops for the summer period were a slanted timber rooftop which remained on a solid chunk with ventilated upper room, and a level rooftop which had thermal protection towards the inward layer. Kalogirou et al.[8] reenacted a four-zone Cyprus working with a thermal mass (thick concrete divider) in the south veneer. The ideal thickness of the thermal mass was observed to be 25 cm, which gave a 47% decrease in warming stack and a 4.5% expansion in cooling load when contrasted and a similar building having no included thermal mass. As of not long ago, there was no enactment with respect to vitality productivity of structures in any piece of Cyprus, and there is still

none in North Cyprus. Individuals are not commonly mindful of vitality preservation in structures, thusly this isn't a need for them. In this manner, there is an incredible requirement for low-vitality building examines in Cyprus.

A lot of calculations and experiments have already been carried out in various places in the world concerning thermal properties of different materials and not just with buildings but also with other elements.

Thermal Resistance; The flow of heat going in and out of a structure is highly dependent on the temperature difference going on the opposite sides, the rate of conductivity of the materials used in line with the width of the given material. Definitely, the differences in temperature is also a factor to be considered externally. This width and conductivity are characteristics of the given materials. A bigger width translates into less thickness means less heat flow and so does a lower conductivity. Together these parameters form the thermal resistance of the construction. The thermal resistance is proportional to the thickness of a layer of the construction and inversely proportional to its conductivity. A construction layer with a high thermal resistance (e.g. rock wool), is a good insulator; one with a low thermal resistance (e.g. concrete) is a bad insulator.

k = represents the conductivity of the material (W/mK)

For a composite building component made up of various layers of various materials, its aggregate resistance is given as:

$R_t = R_{so} + \sum R_n + R_{si}$

where the resistance of the nth layer is:

$R_n = l_n/k_n$

R_t = the aggregate by and large resistance of the component (m²K/W),

R_n = the resistance of the nth material inside a composite component (m²K/W),

R_{so} and R_{si} are the outside and inside surface resistances individually (m²K/W)

l_n = the thickness of the nth material in a composite component (m), and

k_n = is the conductivity in of the nth material in a composite component (W/mK).

Luckily, enough is thought about different materials to empower the figuring of a general thermal character for most normal settled measurement building frameworks with the goal that a general resistance (or conductance) can be determined. Figures can be determined for single coated and twofold coated windows, solid piece floors, suspended wooden floors, dividers, etc. These qualities are normally composed as either a R-Value (for protections) or a U-Value for different components.

The R-Value

Resistance is generally given as a "R" esteem which is the resistance of one square meter of the material subject to a one degree temperature distinction. Hence a R estimation of a regular fiber glass bat might be given as R = 2.4, with the suggestion that it has the units m²K/Watt. This implies on the off chance that one takes the region of protection in square meters duplicated by the temperature distinction in degrees Kelvin and isolated by 2.4, one gets the warmth stream in Watts.

For instance, 100 square meters of R = 2.4 protection, presented to a 20 degree K contrast, will go around 833 Watts.

Indeed, the warmth misfortune would be required to be somewhat from this in light of the fact that there is an extra resistance in getting the vitality from within air to the divider surface, and from the outside divider surface to the outside air. Additionally, the warmth exchange outwardly surface may differ with wind speed.

Transmittance or U-Value; In actuality, situations in all the building segments, warm exchange happens through all the three modes. For instance, in the outline beneath, the divider gets warm through convection from the encompassing air, through conduction the warmth gets transmitted up to the inward surface where again through convective warmth exchange due to inside room air, and warmth goes into the building. Using the idea of warm opposition, the general warmth exchange can be found using:

$Q_c = (T_{outside} - T_{inside})/\{(1/h_o A) + (l/kA) + (1/h_i A)\}$

The above equation can be written in an improved frame as:

Qc = U * A * (T outside – T inside)

Where,

U = 1/{(1/ho) + (l/k) + (1/hi)}

The term 'U' speaks to by and large warm conductance from the outside to inside covering all methods of warmth exchange. From the above equation, 'U-value' can be characterized as the rate of warmth stream over unit region of any building segment through unit generally speaking temperature contrast between the two sides of the segment.

The U-Value is an imperative idea in building structure. It speaks to the aerial transmittance of a component. This alludes to how well a component conducts warm from one side to the next, which makes it the equal of its warm obstruction. Thus, on the off chance that we calculate the warm obstruction of a component, we can essentially reverse it to acquire the U-Value

U = 1/Rt

U = 1/(Rso + ∑Rn + Rsi)

The U-Value is a property of a material. Thus, its units are Watts per meter squared Kelvin (W/m² K). This implies, if a divider material had a U-Value of 1 W/m² K, for each level of temperature distinction between within and outside surface, 1 Watt of warmth vitality would course through each meter squared of its surface.

Calculation of U – value

Calculate the U-value for the 220 m block wll with 16 mm mortar within face. Assume ordinary exposure.

For brick, k=0.84W m-1K-1; for mortar k= 0.5 W m-1K-1

Inward obstruction, Rsi = 0.123 m2 K W - 1

Mortar opposition = l/k = 0.016/0.5 = 0.032 m2 K W - 1

Block opposition, Rso=0.055m2K W-1

Subsequently,

Add up to opposition = 0.123 + 0.032 + 0.262.+ 0.055 = 0.472 m2K W-1

Thusly,

U = 1/∑R = 2.12 W m - 2K-1

Thermal conductivity is a material property. It won't contrast with the elements of a material, however it is reliant on the temperature, the thickness and the dampness substance of the material. The thermal conductivity of a material relies upon its temperature, thickness and dampness content. The thermal conductivity regularly found in tables is the esteem substantial for ordinary room temperature. This esteem won't vary much somewhere in the range of 273 and 343 K (0 — 70° C). At the point when high temperatures are included, in broilers for example, the impact of temperature must be considered. By and large light materials are preferable protectors over substantial materials, since light materials regularly contain air walled in areas. Dry still air has a low conductivity. A layer of air won't generally be a decent separator however, on the grounds that warm is effortlessly exchanged by radiation and convection.

At the point when a material, for example protecting material, winds up wet, the air fenced in areas load up with water and, in light of the fact that water is a superior conductor than air, the conductivity of the material increments. That is the reason it is essential to introduce protection materials when they are dry and take care that they stay dry.

Conductivity (k) is a material property and means its capacity to lead warm through its inward structure. Conductance then again is a protest property and relies upon the two its material and thickness. Conductance breaks even with conductivity increased by thickness, in units of W/m²K. As conductivity is the complementary of resistivity, the aggregate opposition of a material can consequently be given as its thickness separated by aggregate conductivity.

Table showing the thermal conductivity of different building materials according to the specific mass. (Clear, n.d.)

Group	Material	Specific mass (kg/m3)	Thermal conductivity (W/mK)	
			Dry	Wet
Metal	Aluminum	2800	204	204
	Copper	9000	372	372
	Lead	12250	35	35
	Steel, Iron	7800	52	52
	Zinc	7200	110	110
Natural stone	Basalt, Granite	3000	3.5	3.5
	Bluestone, Marble	2700	2.5	2.5
	Sandstone	2600	1.6	1.6
Masonry	Brick	1600-1900	0.6-0.7	0.9-1.2
	Sand-lime brick	1900	0.9	1.4
		1000-1400	0.5-0.7	
Concrete	Gravel concrete	2300-2500	2.0	2.0
	Light concrete	1600-1900	0.7-0.9	1.2-1.4
		1000-1300	0.35-0.5	0.5-0.8
		300-700	0.12-0.23	
	Pumice powder concrete	1000-1400	0.35-0.5	0.5-0.95
		700-1000	0.23-0.35	
	Isolation concrete	300-700	0.12-0.23	
	Cellular concrete	1000-1300	0.35-0.5	0.7-1.2
		400-700	0.17-0.23	
	Slag concrete	1600-1900	0.45-0.70	0.7-1.0
		1000-1300	0.23-0.30	0.35-0.5
Inorganic	Asbestos cement	1600-1900	0.35-0.7	0.9-1.2
	Gypsum board	800-1400	0.23-0.45	
	Gypsum cardboard	900	0.20	
	Glass	2500	0.8	0.8
	Foam glass	150	0.04	
	Rock wool	35-200	0.04	
	Tiles	2000	1.2	1.2
Plasters	Cement	1900	0.9	1.5
	Gypsum	1300	0.5	0.8
Organic	Cork (expanded)	100-200	0.04-0.0045	
	Linoleum	1200	0.17	
	Rubber	1200-1500	0.17-0.3	
	Fibre board	200-400	0.08-0.12	0.09-0.17
Wood	Hardwood	800	0.17	0.23
	Softwood	550	0.14	0.17
	Plywood	700	0.17	0.23
	Hard-board	1000	0.3	
	Soft-board	300	0.08	
	Chipboard	500-1000	0.1-0.3	
	Wood chipboard	350-700	0.1-0.2	
Synthetics	Polyester (GPV)	1200	0.17	
	Polyethene, Polyprotein	930	0.17	
	Polyvinyl chloride	1400	0.17	
Synthetic foam	Polystyrene foam, exp. (PS)	10-40	0.035	
	Ditto, extruded	30-40	0.03	
	Polyurethane foam (PUR)	30-150	0.025-0.035	
	Phenol acid hard foam	25-200	0.035	
	PVC-foam	20-50	0.035	
Cavity isolation	Cavity wall isolation	20-100	0.05	
Bituminous materials	Asphalt	2100	0.7	
	Bitumen	1050	0.2	
Water	Water	1000	0.58	
	Ice	900	2.2	
	Snow, fresh	80-200	0.1-0.2	
	Snow, old	200-800	0.5-1.8	

Air	Air	1.2	0.023	
Soil	Woodland soil	1450	0.8	
	Clay with sand	1780	0.9	
	Damp sandy soil	1700	2.0	
	Soil (dry)	1600	0.3	
Floor covering	Floor tiles	2000	1.5	

Table showing the thermal conductivity of different building materials according to the specific mass. (Clear, n.d.)

3. METHODOLOGY

While examining the researches and studies done by others concerning the thermal comfort of different spaces and elements in buildings, but these are just usually always an approximate value because it calculates the size of the building just generally.

The use of U-values allows for the comparison of different build ups for applications, so the insulating properties of a solid wall could be compared to that of a cavity wall for example, or allows the comparison of two different types of insulation at different thicknesses. It is the most accurate way of measuring the insulating properties of the application or material and Building Regulations/Standards specifies U-values which have to be achieved when building or refurbishing a building. For example when building in Dubai, a roof in a villa has a recommended best starting point of a U-value of 0.30W/m^2.K. Without knowing the U-value of a wall or a floor or roof, you won't know how energy efficient the whole building will be.
Before you start any building work you should calculate the U-value as part of the design process, to make sure that meets or is lower than that specified by Building Regulations/Standards.

Using the U-value calculator provided by Ti-soft, the different values of the different elements can be calculated because it gives a comprehensive section and arrangement of the materials used to make these elements. The software calculates the conductivity, resistance and transmittance and width of each material and adds them together to be able to get the total heat property of that particular building element thus helping us understand the ability of that component to be able to transfer or retain heat and furthermore understand how thermal comfort is reached in buildings in Famagusta. Each building element would have its own report sheet with the calculations and list of materials used or commonly indigenous to the city of Famagusta.

The results of the simulations and calculations are given as follows;

In the calculation for the first building element, which was the wall element, the three most common materials were used when building in a tabular form to calculate the heat capacity, the density, the thickness, the thermal conductivity and the thermal resistance of the three different layers or materials that constitute the wall element as a whole.

WALL ELEMENT

U 4.172 W/(m²·K)
Thickness 0.24 m
Weight 259.48 kg/m²
Heat capacity 92.568 kJ/(m²·K)

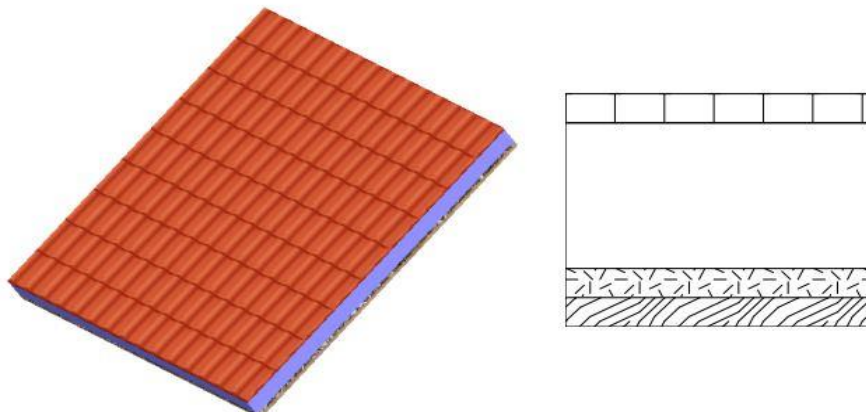|		Construction type layers (from outside to inside)					
Nr	Code	Description	Special heat [C$_p$] kJ/(kg·K)	Density [ρ] kg/m³	Thickness [d] m	Thermal conductivity [λ] W/(m·K)	Thermal resistivity [R=d/λ] (m²·K)/W
1	E1	20 mm Plaster or gypsum	0.84	1,602.00	0.02	0.727	0.03
1	C8	200 mm Heavyweight concrete block	0.84	977.00	0.20	1.083	0.18
1	E1	20 mm Plaster or gypsum	0.84	1,602.00	0.02	0.727	0.03
Totals					0.24		0.24

$U = 1/ \Sigma R_i = 1/0.24 = 4.172$
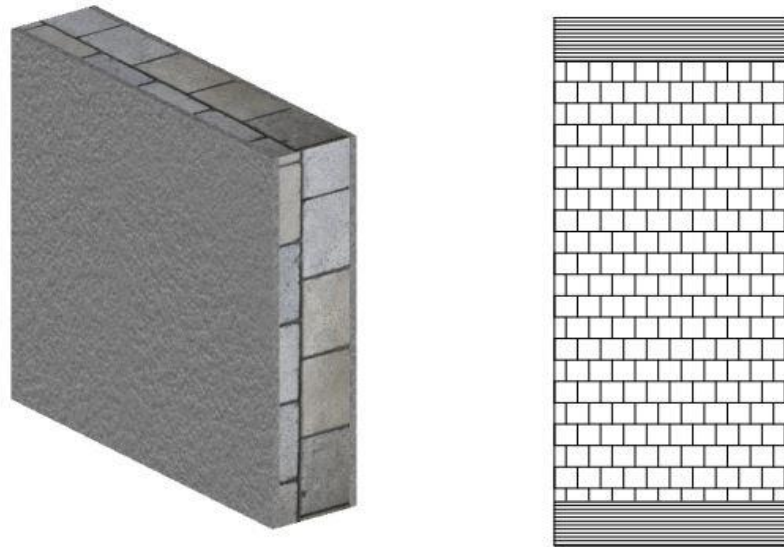
In the calculation for the second building element, which was the roof element, this calculation is also done by considering four of the most commonly used roofing materials used in Famagusta which includes the use of clay tiles, the plaster board, the water insulation sheet and the oak wood rafters or roof members. Thereby giving the total calculations of the roof elements as a whole.

ROOF

U 6.540 W/(m²·K)

Thickness 0.08 m

Weight 118.41 kg/m²

Heat capacity 132.456 kJ/(m²·K)

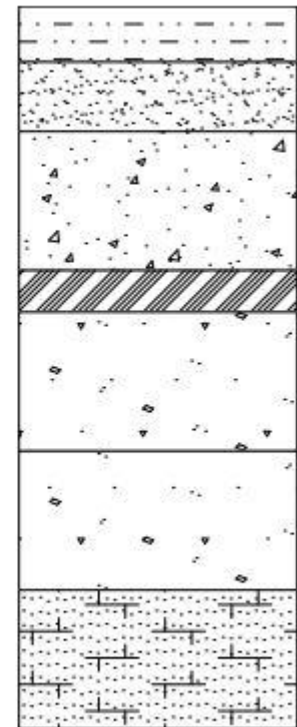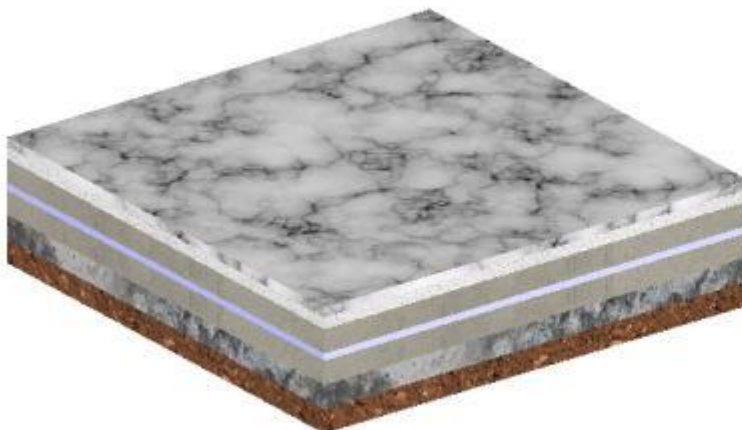|		Construction type layers (from outside to inside)					
Nr	Code	Description	Special heat [C_p] kJ/(kg·K)	Density [ρ] kg/m³	Thickness [d] m	Thermal conductivity [λ] W/(m·K)	Thermal resistivity [R=d/λ] (m²·K)/W
1	C1	100 mm Clay tile	0.84	1,121.00	0.01	0.571	0.02
1	Material 5	Plaster	1.00	1,800.00	0.05	0.870	0.06
1	5.1.02.B	Sheet Polyethylene (low density)	2.20	920.00	0.01	0.330	0.03
1	2.1.4	Oak wood	1.60	800.00	0.01	0.210	0.05
Totals					**0.08**		**0.15**

$U = 1/ \Sigma R_i = 1/0.15 = 6.540$

In the calculation for the third building element, which was the floor element, the calculation is also done by considering seven of the most commonly used floor materials used in Famagusta.

FLOOR

U 1.614 W/(m²·K)

Thickness 0.26 m

Weight 412.82 kg/m²

Heat capacity 0.000 kJ/(m²·K)

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
		Construction type layers (from outside to inside)					
1	E101	Marble slabs		3,000.00	0.02	3.480	0.01
1	A1	25mm Stucco	0.84	1,858.00	0.03	0.692	0.04
1	A302	Cement mortar		1,800.00	0.05	1.392	0.04
1	B19	15 mm Insulation	0.84	91.00	0.01	0.043	0.35
1	C134	Cellular concrete 1000 Kg/m3		1,000.00	0.05	0.557	0.09
1	1.5.04.A	Gravel concrete ρ=1500 kg/m3		1,500.00	0.05	0.640	0.08
1	1.2.01	Compact soil		1,800.00	0.05	2.000	0.03
Totals					0.26		0.62

$U = 1/ \Sigma R_i = 1/0.62 = 1.614$

4. RESULTS/ CONCLUSION

With the use of the simulation software, the density, thermal conductivity, thermal resistivity were calculated based on the density and the thickness of these materials and in turn the component as a whole which gives us a direct value of the heat transmittance or heat conductivity of each building element.

In the calculation for the first building element, which was the wall element, the three most common materials were used when building in a tabular form to calculate the heat capacity, the density, the thickness, the thermal conductivity and the thermal resistance of the three different layers or materials that constitute the wall element as a whole.

In the calculation for the second building element, which was the roof element, this calculation is also done by considering four of the most commonly used roofing materials used in Famagusta which includes the use of clay tiles, the plaster board, the water insulation sheet and the oak wood rafters or roof members. Thereby giving the total calculations of the roof elements as a whole.

In the calculation for the third building element, which was the floor element, the calculation is also done by considering seven of the most commonly used floor materials used in Famagusta.

This will greatly help in the determination of the thermal comfort of the spaces which these elements form and create and also give builders the ability to either add or remove more layers depending on the kind or range of thermal comfort needed to be achieved for the user in the city of Famagusta.

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