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Thermal Behavior of Old and Recent Façades

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Abstract. Losing heat additionally results in greater energy expenses and waste of resources. In any construction building, the façades ensure the heat transfer between the exterior and the interior surfaces of the structure. The thermal transfer of a façade is dominated by conduction. This exchange makes them responsible for guaranteeing thermal comfort to the occupants. Uninsulated outside walls can cause substantial heat loss, particularly during the winter. The heat is able to pass via such façade, leaving it hard to keep the appropriate temperature inside the construction. Furthermore, there is traditional outside insulation that uses isolative boards, which come in a variety of materials. They require a coat of render on top to provide additional protection from the outdoors as well as a beautiful finish. Impermeability and additional costs are the main disadvantages of such systems. In recent façades (rainscreens), the use of ventilated or unventilated cavities influences the thermal resistance. The rainscreen tends to have lower thermal transmittance than the stone façade. The thermal transmittance of the curtain wall depends on the thermal transmittance of the glazing and that of the mullions/transoms including the spacer of the double-glazing, calculated from a 2D analysis, so the total thermal transmittance will be a weighted average value. Surface or interstitial condensation occurs when humid air touches a surface T less than the dew point temperature; it is less likely to occur in a recent façade than in an old one. The aim of this topic is to achieve an energy comparison between two identical resident structures. The first one was provided with an old façade; however, the other house had a recent façade. The obtained results show an important saving of energy of the recent façade (refund in electricity bills), ensures thermal comfort, reduces embodied carbon, and protects the planet, the atmosphere, and the environment.

Keywords. Thermal transfer, old façade, recent façade, rainscreen.

1. Introduction

Thermal comfort is a subjectively assessed state of mind that reflects happiness regarding the thermal climate. Thermal comfort is further defined as an individual's perception of the thermal environment, as well as an individual's neutral mood with

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regard to certain thermal surroundings, without being sweaty. Human thermal discomfort is a key concern in tropical regions where temperature and humidity tensions are still considerable. Thermal convenience criteria are influenced by a person's position along with the weather both inside and outside the structure [1].

The ambient temperature, wall temperature, heating method, construction method, and construction materials influence this thermal comfort. Nowadays this thermal comfort in buildings are getting closer to guaranteeing in order to improve the quality of life of occupants and limit energy consumption for heating and cooling to protect the planet [2].

Façades are considered as heat transfer surfaces between the internal environment and the external environment of the structure; this makes them largely responsible for the thermal operation and energy performance of buildings. Thermal transmissions become more sophisticated due to the numerous façades types that have been incorporated as well as new materials, standards, software, and methods of calculation and analysis that have been integrated into the field of façades and the world of engineering in general [3].

The recent specifications that affect all buildings have resulted in improving the thermal performance of structure envelopes to reduce energy consumption and therefore protect the planet [4]. For this, several research have been part of an approach aimed at optimizing the thermal behavior of façades. The type, materials, affects thermal behavior and method of construction and this has a positive or negative impact on energy consumption and CO_2 emissions [5, 6, 7].

The thermal behavior or energy performance of a façade or walls is about the thermal transmittance U (in W/m^2K) and surface and interstitial condensation. The lower the element's U-value, the more effective its thermal insulation. It is a measurement of a structure's capacity for transferring heat within constant circumstances. Furthermore, Warm, wet air may also permeate via construction elements, eventually reaching cooler, lower-pressure circumstances outside. Condensation throughout the structural element is conceivable if the construction elements have a relatively low water vapor resistance. This will happen on that initial cold surface, which is below the point of dew temperature that the moisture vapor reaches as it passes through the structure [8]. To evaluate these two physical phenomena, manual and digital calculations are determined by using 2D, such as THERM program, which can be used to evaluate the heat transfer properties of construction parts and connections, or even 3D software.

Recent façades such as panel walls or curtain walls, whose energy performance adopt a method of calculating or evaluating energy behavior different from that of an old stone façade [9]. This is due to the difference in the construction method of each type; therefore, the heat path differs as well as the thermal bridges that are characterized as regions of the building envelope, which have extremely low thermal resistance because of penetration through the building insulation layers [10]. This research deals with the types of calculation of thermal transmission and the hygrometry of old and recent façade as well as the physical phenomena that arise; in addition, analyzes the energy influence on the structure and human comfort.

2. Materials and Methods

Despite numerous research efforts on heat transport through façades, several elements remain unexplored. The conduction phenomenon occurs as heat transmission in-built walls; it happens without altering the molecules' positions; the energy travels by collision between the molecules.

The U-value is based on the resistance to thermal change, which includes surface resistance; because it has a temperature degree varied from the environment, heat transfer will occur; this phenomenon contributes to the heat passage through the material layer with (e) thickness in the direction of heat transfer. The inner surface resistance is denoted "R_{si}", whereas the outside surface resistance is designated as "R_{se}".

The higher the thermal conductivity λ, the more the heat transfer in conduction increases, for this the resistance of a solid is given by:

$$R = e/\lambda \tag{1}$$

However, the thermal transmittance is calculated as follows:

$$U = \lambda/e \tag{2}$$

The temperatures at the interfaces of the good material are extremely near to the temperatures at the exterior and interior façades; it is more difficult for heat to flow through via conduction a material with a relatively low thermal conductivity, which is a favorable sign of the insulation utilized.

Thermal insulation is usually applied within the ventilation cavity in the façades, producing a sort of capillary breakthrough preventing water seepage across the façade and increasing the structure's drying capabilities by permitting airflow beyond the cladding. In non-airtight façades, the cavity is additionally used as a drainage plane, and the cladding operates as the pressure-balancing layer, reducing the pressure difference within it. However, if the cavity is not exposed to an external environment, then it will not be removed from the thermal modeling and will not remove any layer of the construction; then it will be considered a hot cavity.

The presence of a cavity in the wall increases thermal transmission compared to an insulating material used instead. In addition, on the other hand, the succession of layers increases the risk of interstitial condensation and the accumulation of water, so all the physical phenomena of the façade should be checked carefully. In case an interior cavity became a ventilated cavity, this would remove the layers that would follow, eliminating the main layer of insulation and ending up with too high thermal transmission results [11].

3. Results and Discussion

An energy comparison was achieved between two houses types. The first one was providing with old stone façade (figure 1), while the other has a recent curtain wall and panel façade (figure 2). The area of each house was 75 m^2, and the main façade was oriented towards the west. All the necessary data was collected and submitted it in the Design Builder software, such as region and annual climatic conditions, construction orientation, residential category, the function of rooms or areas of the house, construction materials with their properties, thickness of layers (exterior walls, partition, roof, slab...), glazing configuration, and type of window frame.

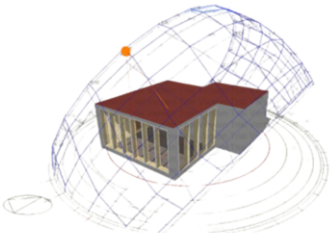

Figure 1. House with Stone Façade.

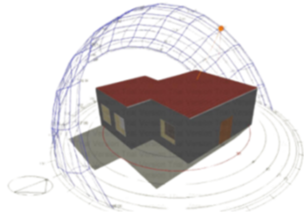

Figure 2. House with Panel Façade.

After modeling these two types of houses, the software will simulate them to have the results of annual energy consumption, for maintaining thermal comfort (heating and cooling), maintaining visual comfort (Natural and artificial lighting, which is affected by the façade choice), total annual energy consumption, quantity of carbon incorporated according to the choice of materials.

The obtained results for each of the two houses were compared and interpreted. Such comparison achieved to conclude the advantages and disadvantages of adopting old and recent façade, as well as the impact of each on the planet and the environment. The thickness of the used materials for the panel walls are summarized in the following table (table 1) as mentioned in figure 3.

Table 1. Thickness of used material in the panel walls.

Type	Thickness (mm)
Aluminum panels	3.0
Vented cavity	40.0
The mineral wool insulation layer	200.0
Interior wooden cladding panel	12.0
The mineral wool insulation layer	150.0

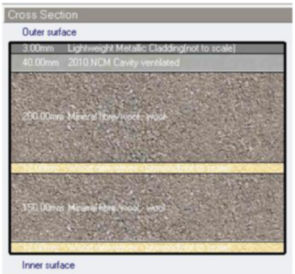

Figure 3. Section in the panel walls.

Assuming that the mineral wool layer with 200 mm thickness is crossed by 3.0 mm thick aluminum L-shaped corners centered every 600 mm vertically and horizontally to support the panels. However, the mineral wool layer with 150 mm is crossed by vertical steel profiles 2.0 mm thick centered every 600 mm vertically. In addition, the fix convective heat transfer coefficient for both outside and inside is taken as 7.69 W/m^{2}K.

By checking the obtained results, it can be seen that the calculated U-value for the façade with bridging (BS EN ISO 6946) was equal to 0.181 W/m^{2}K. In addition, there is no risk of surface condensation, the interstitial condensation occurs in the ventilated layer, and the condensed water is predicted to evaporate in the spring and summer months: May and September as shown in the Glaser Diagram (figure 4).

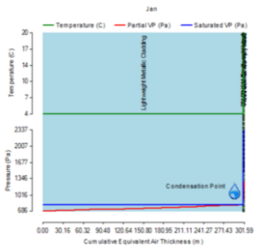

Figure 4. Glaser Diagram.

The curtain walls of vertical aluminum beams have section 200.0 mm + insulation (breaking heat flow), and centered every 1m. In addition, the glaze were clear double with low emissivity, with glass ply type 1 and type 2 with 6.0 mm thickness for each type, and 13.0 mm thickness for the cavity with Argon type provided with Vapor Control Layer (VCL).

The clay tiles roof thickness was 20.0 mm, the concrete slab thickness was 200.0 mm, the thickness mineral wool insulation layer was 150.0 mm, the unvented cavity thickness equal to 40.0 mm, and the false wooden ceiling was 12.0 mm. Furthermore, the slab ground floor with wood layer thickness was 30.0 mm, screed thickness was 70.0 mm, concrete thickness was 100.0 mm, and the insulation thickness was 100.0 mm.

The obtained results were sketched as monitored values (figure 5), colored contour lines (figure 6), or stacked lines (figure 7). The calculated U-value for the glazing data (ISO 15099/ NFRC) was equal to 1.493 W/m^{2}K. Furthermore, the calculated U-value for the roof with bridging (BS EN ISO 6946) was equal to 0.371 W/m^{2}K. In addition, the calculated U-value for the ground floor with bridging (BS EN ISO 6946) was equal to 0.314 W/m^{2}K. By checking the heat loss through the envelope and ventilation, the results were captured below.

Figure 5. Heat Loss through the Envelope and Ventilation.

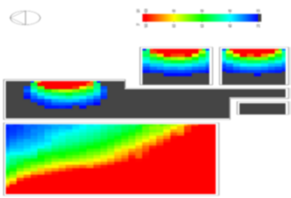

Figure 6. Lighting Results.

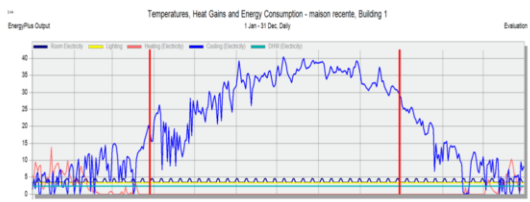

Figure 7. Annual Energy Consumption.

It was noticed that the house with a recent façade consumes a little energy between January and April for heating and maintaining thermal comfort for occupants due to the use of insulating layers in the walls and double-glazing instead of single glazing. In addition, it consumes a lot of energy between April and October for cooling and maintaining thermal comfort for occupants, due to the use of large proportions of glass façades.

All the results that can obtained of the old stone façade, the recent house constructed with curtain wall, and panel façade are presented and compared in the following table 2.

Table 2. Comparison of the obtained results.

	Old stone façade		Recent curtain wall and panel façade		Recent versus Old %reduction	% increase
Stone Walls / Panel Walls	Thickness(mm)	600	417		30.5%	
	U (W/m^{2}K)	1.95	0.18		90.69 %	
	Heat loss (kW)	2.89	0.22		92.38 %	
glazed window / Curtain Walls	Thickness (mm)	6	25			76 %
	U (W/m^{2}K)	5.77	1.49		74.16 %	
	Heat loss (kW)	0.43	0.63			31.74 %
Roof	Thickness(mm)	200	422			52.60 %
	U (W/m^{2}K)	2.42	0.375		84.50 %	
	Heat loss (kW)	2.57	0.21		91.83 %	
Heating needed to maintain comfort (kW)	8.07		2.18		73 %	
Cooling needed to maintain comfort.	14.09		19.09			26.20 %
Lighting Zone 5 (lux)	zone 1001(lux)	10 %	50 %			80 %
	zone 200 (lux)	90%	zone 800 – 300	50 %		
Embedded carbon ($KgCO_2/m^2$)	Stone walls	616	Panel walls	94	84.74 %	
	Window	17.9	Curtain Walls	36.68		51.2 %
	Entire house	232	67.8		70.77 %	
Total annual energy consumed (kWh)	18134		15958		12 %	

Even though that the house with recent curtain wall and panel façade versus the house with old façade has 76% as an increase in the glass thickness, and 52.60% in the roof thickness, which is mean an increase of the cost during the construction phase, however, this cost will be paid once time. By contrary that the house with old façade consumes a lot of energy for heating and a little less energy for cooling. However, the house with recent curtain wall and panel façade does not consume a lot of energy for heating, but a lot of energy for cooling.

We notice that in Lebanon, a country with moderate climate and not severe enough like other countries, in the northern of Asia or Europe, a house with a recent façade saves energy as heating in winter, while a house with an old façade requires 73 % more heating energy than a recent house.

In addition, a house with an old façade saves energy as cooling in summer, while a house with a recent façade requires 26.20 % more cooling energy than an old house.

Furthermore, the total energy consumption of an old house is 12 % higher than a recent house, and there is 70.77 % a reduction in the embedded carbon for the entire house, which have always a positive impact on the planet and the environment.

4. Conclusions

It was concluded that to calculate the thermal transmission of a (recent) panel wall façade, and by using a 2D numerical evaluation for the effects of thermal bridges due to point or continuous metal fixings crossing the insulating layers.

For the curtain wall façade (recent), a 2D modeling was used to derive the thermal transmission of the beams, which includes the edge effect of the panels (windows or opaque), and evaluate the thermal transmission U of the panels provided by the supplier.

For the (old) stone façade, the R_{si} and R_{se} were used. This method based on checking the difference in thermal conductivity between the materials is not significant enough. Therefore, by analyzing the façade using the numerical method can be more accurate with excellent results. Moreover, after analyzing the thermal transmission of the used façades, it was appeared that the recent façade is more insulating than the old façade.

As condensation, the absence of VCL in the old façade placed the construction at risk of interstitial condensation, while its use in the recent façades blocks assured a path for water vapor through the layers and protected the construction of interstitial condensation; the significant thermal inertia of the recent façade also protects it from surface condensation. The presence of cavities in the layers ensures ventilation and evaporation of condensed water if present.

As an energy comparison, for the same house adopting an old façade once and a recent one once, the impact that each leaves on the house and the environment is as follows: to maintain thermal comfort, an old house requires much more heating energy than a newer house, but it requires less cooling energy than an older house. Speaking of natural lighting, a recent house provides much more natural lighting due to the presence of bay windows in large proportion compared to the old house with opaque stonewalls and small windows.

In total, an old house consumes less energy and embedded carbon but costs more. However, this will be reimbursed to the occupant in a few years through energy savings (electricity bills), and ensuring thermal and visual comfort. Therefore, a healthy environment and a better quality of life will be guarantee without harming the environment.

The innovation is taking place in the world of construction materials, especially those incorporated in façades such as insulators, waterproofing membranes, and double-glazing. They required more sophisticated thermal performance calculation methods to obtain exact values. Taking into consideration that a design with high thermal inertia will end up with a low thermal transmission, mitigating the risk of condensation, saving in energy consumption and finally a reduction in embodied carbon. Therefore, the total carbon footprint of the construction throughout the lifespan of the construction will have an important additional value in the protection of our planet.

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