

Preliminary Study to Show the Effect of Building Envelope Materials on Thermal Comfort of Buildings Located in Hot Humid Climate

Roa'a Mohammed Omar, Shifana Fatima Kaafil Rehumaan

Department of Architecture, Hekma School of Design and Architecture, Dar Al-Hekma University, Jeddah, Saudi Arabia

Email: rmomar@dah.edu.sa, skaafil@dah.edu.sa

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Abstract

The main aim of this paper is to study the effect of building envelope constructed with different materials on thermal comfort of buildings located in Jeddah, Saudi Arabia. Four different buildings constructed with brick, glass, stone, and gypsum are taken into account to study the difference in temperature of the indoor and outdoor environments. Also, this paper explores the heat conducted by walls of different materials with different thicknesses. In addition, survey is conducted among the residents of Jeddah to know their perspective about thermal comfort of buildings. From the study, it is found that building envelope constructed with glass is more effective compared to envelope constructed with other materials of with least thickness of wall. Also, it is found that the envelope constructed with brick is more effective in absorbing the heat provided the thickness of the walls remains the same.

Keywords

Thermal Comfort, Building Envelope, Conduction of Heat, Brick, Glass

1. Introduction

The environment is the human responsibility. People are responsible for affecting the health of the environment, as buildings greatly influence the environment. Nowadays, they use materials in buildings which has a negative environmental impact. The comfort of building residents is affected by the thermal environment. And the thermal environment's main influence on building occu-

pants is its impact on comfort. The most important consideration is the increase in the occur by increasing the temperature of the building that affects the thermal comfort. These cases force people to use HVAC system, harming the environment by acting as the ozone shield and energy consumption. Lan *et al.* [1] pointed out that using air conditioning systems significantly increases energy consumption, thus, lowering the temperature of the building. It is well-known that air conditioners and similar equipment that keep us warm or cold have increased energy expenses worldwide.

Building control research reduces energy demand through optimal operation while studying the human satisfaction in buildings in the thermal comfort community. Thus, balancing the two is essential for a sustainable and comfortable building stock wall which affects thermal comfort. Thermal comfort helps reduce energy consumption. This research focuses on building envelope materials and sizes of walls that help to achieve thermal comfort in the building. The different building envelope materials considered in this study are glass, brick, stone and gypsum without insulation and air cavity. The purpose of this research is to show the effect of building envelope materials on thermal comfort of buildings located in hot humid climate.

1.1. Thermal Comfort

Thermal comfort is a general term known as the most critical factor in improving occupant comfortability with their interior environment. But the American Society of Heating, Refrigeration, and Air-Conditioning Engineers ASHRAE [2] defines that as the mental condition in which one feels comfortable is with the thermal environment. It can be impossible to reach a thermal environment that satisfies all the building occupants because of individual preferences. So, thermal comfort is a relatively broad subject of study. But Park & Nagy [3] found that building control focuses mainly on energy savings rather than incorporating findings from thermal comfort based on occupant satisfaction. Al-Yasiri *et al.* [4] mentioned that PCMs are used to reduce cooling and heating loads across the building envelope, allowing for sufficient thermal comfort to be maintained.

1.2. Effect on Thermal Comfort

The thermal indoor environment is affected by both internal and external sources. Alwetaishi [5] and Kuchen [6] found that thermal comfort effect by personal and environmental factors. Physical factors such as climate, humidity, air currents, and radiation directly impact indoor thermal comfort. Leo Samuel *et al.* [7] specifies the temperature of the indoor air and the temperature of the interior surfaces have a more significant impact on thermal comfort. In addition, it mentions that thermal comfort was achieved by designing the building to suit the local climatic conditions. Also, Leo Samuel *et al.* [7] indicate that using thick walls with high thermal mass to moderate the incoming or outgoing energy demands. But Saleem *et al.* [8] pointed out that the primary heat source is solar

gain from exterior windows of the building associated with people and lighting. While the ceiling and internal walls only account for a small portion of the building's total heat gain. The study results on buildings designed based on natural ventilation (infiltration) and air movement positively affect thermal comfort conditions and energy consumption by ceiling fans. Homod *et al.* [9] define that the building energy-saving potential is significantly affected by the thermal mass and insulation of the building. High thermal inertia is provided by the heavy perimeter walls, and this structure can result in significant energy saving. The total thermal stability of the indoor is affected by the size of the thermal mass. Thus, the high storage capacity of the building envelope reduces overheating.

1.3. Different Materials and Function Effect on Thermal Comfort

Yu *et al.* [10] found the usage of locally available resources would improve results while having a lower environmental impact. As a result, the authors study eight different types of constructions combining traditional and local materials and other modern materials like cement and concrete. In addition, they compare different types of building such as residential, institutional, and business buildings which have different effects on thermal comfort. For instance, the elements of modern office building design, such as deep layouts, glazed façades, and personal computers, have been introduced, which are responsible for the heat generated that is common in office buildings. Mirrahimi *et al.* [11] compared different elements to get the best result of thermal comfort in the building. And there are five ways in which heat and mass transfer in buildings can occur: conduction through opaque elements including external walls, ceiling, floor slabs, roofs and partitions.

1.4. Impact of Thermal Comfort

Lan *et al.* [1] studied the impact of extreme heat on human health and performance. So, the current findings of the research suggest that those who are thermally heated have adverse effects on their health and performance. It clearly shows that when the temperature increases, people's exhaustion, mental workload, and negative mood disturbance all increased, even though the subjects were generally trivial. When the temperature dictates, they feel thermally neutral.

2. Methodology

Thermal comfort is essential for the comfort of the residents, so designers need to focus on the building envelope while designing the building. Thermal comfort depends on individuals and thereby a Qualitative survey is conducted among people between the age of 20 - 45 to know their perception of thermal comfort and how to achieve the same. Also. thermal comfort of the building is determined based on the quantitative calculation of the heat transfer by building envelope constructed with different materials and thicknesses.

Hear Transfer

Heat conducted by the building envelope constructed with different materials is given by Wilson [12].

$$Q = \frac{kA(THot - Tcold)t}{d}$$

Q : Heat transferred;

k : Thermal Conductivity of material;

$THot$: Outdoor temperature;

$Tcold$: Indoor temperature;

t : Time rate of heat flow;

d : Thickness of wall;

A : Area of surface.

When the material transfers more heating, it has less thermal comfort as well the thickness of a wall. The types of building envelope materials considered in this study are glass, brick, stone and gypsum.

3. Results & Discussions

Survey results show that most people prefer to be in a room with natural ventilation to a room with an air conditioner. Passive design is better than active design to achieve thermal comfort because active strategies affect the environment too. **Figure 1** shows the preference of individual in using the air conditioner in Jed-dah which is hot humid for most of the year. It is found that most people use air conditioner for about 10 - 15 hours a day. The respondents would like to have room with natural ventilation, and they prefer to have rooms with more windows and skylight (**Figure 2**).

The survey is conducted among common people, and their response is neutral for a building without any windows as well as for an office building provided with glass wall. So, not able to come to any conclusion because their response is mostly neutral (**Figure 3**).

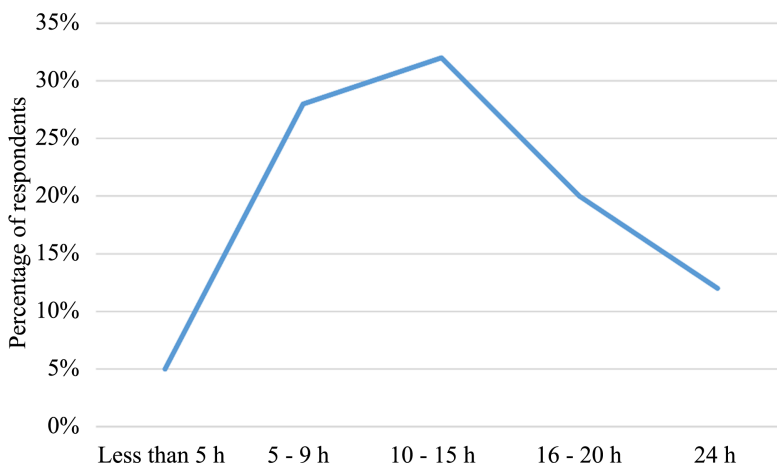


Figure 1. Duration of AC used in a day by individual.

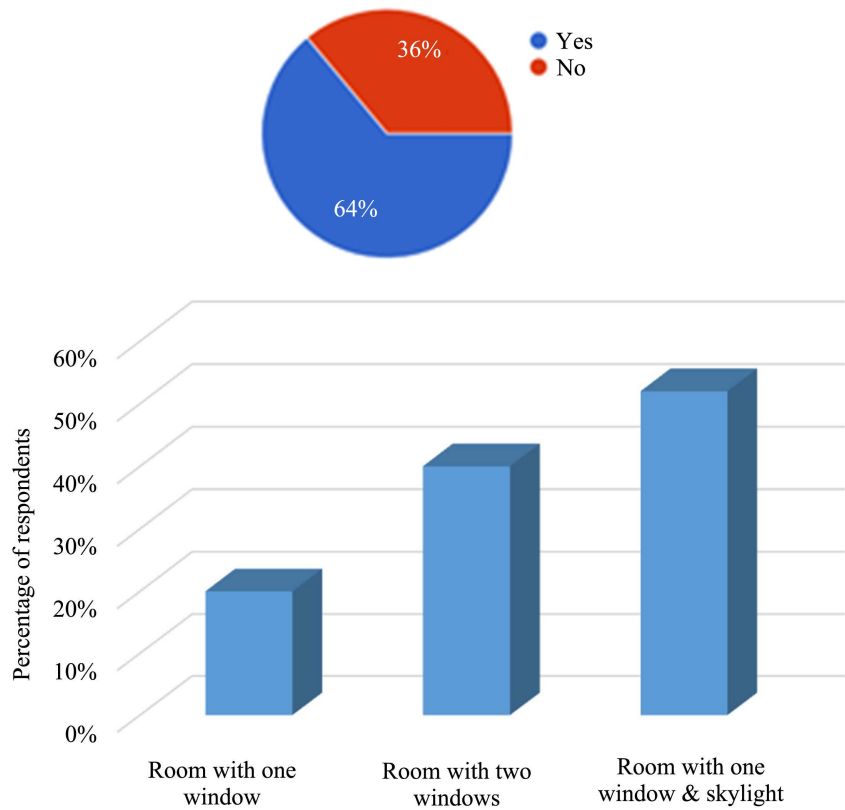


Figure 2. Preference of different types of room.

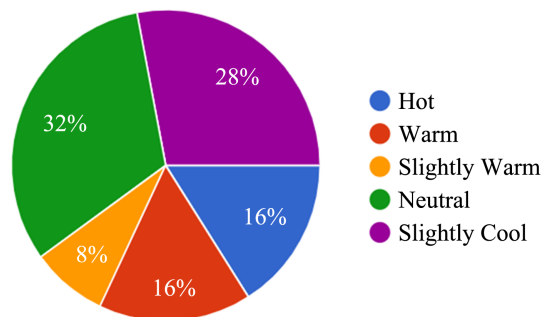


Figure 3. Thermal comfort of a room with no windows.

Table 1 and Table 2 show the thermal conductivity (k) for the materials, thickness, and surface area of the wall, indoor and outdoor temperature and heat conducted by different materials. Thermal conductivity (k) has a direct relationship with heat transferred, so if a value of (k) increase, (Q) will increase and it has inverse relationship with thickness (d). In Table 1, it is assumed the thickness of all the building envelope remains the same. In Table 2, the actual thickness of the building envelope is calculated and is included in the calculation.

Figure 4 shows the heat transfer of building envelope constructed with different material of same thickness. Brick absorbs more heat from the outdoor and thereby it transfers less heat to the indoor.

Table 1. Heat conducted by building envelope materials of the same thickness.

Material	Thermal conductivity (j/m.s. °C)	Thickness (m)	Area of surface (m ²)	Time. (s)	Outdoor temperature. T ₂ (°C)	Indoor temperature. T ₁ (°C)	Heat Transferred Q (J)
Brick	0.17	0.3	10.7	36000	27	26.5	449400
Glass	0.8	0.3	8.6	36000	25.6	23.1	206400
Stone	1.6	0.3	7.6	36000	26	25.4	87552
Gypsum	0.3	0.3	10.7	36000	24.2	23.7	19260

Table 2. Heat conducted by building envelope materials of different thicknesses.

Material	Thermal conductivity (j/m.s. °C)	Thickness (m)	Area of surface (m ²)	Time (s)	Outdoor temperature. T ₂ (°C)	Indoor temperature. T ₁ (°C)	Heat transferred Q (J)
Brick	0.17	0.2	10.7	36000	27	26.5	16371
Glass	0.8	0.01	8.6	36000	25.6	23.1	6192000
Stone	1.6	0.26	7.6	36000	26	25.4	109440
Gypsum	0.3	0.1	10.7	36000	24.2	23.7	57780

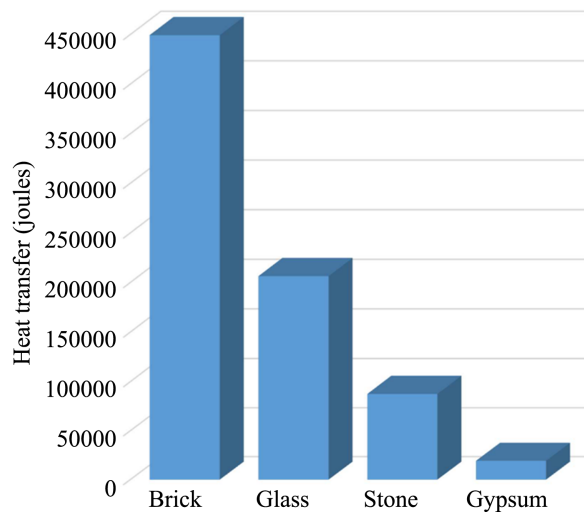
**Figure 4.** Heat transfer (in joules) of building envelope materials of the same thickness of wall.

Figure 5 shows the temperature difference between indoor and outdoor and is found that building envelope with glass performed better compared to other materials. Brick is not reflecting the heat instead it is trying to absorb the heat and transfer less heat to the indoor. So, building envelope with brick is suitable for warm places as well as in hot arid climate. Building envelope constructed with stone absorbs, stores, and radiates heat, which means that the warmth can really improve the efficiency inside a room to reach a thermal comfort in a cold place or in winter season. Building envelope with gypsum heats up well, acting more as an insulator than a heat conductor.

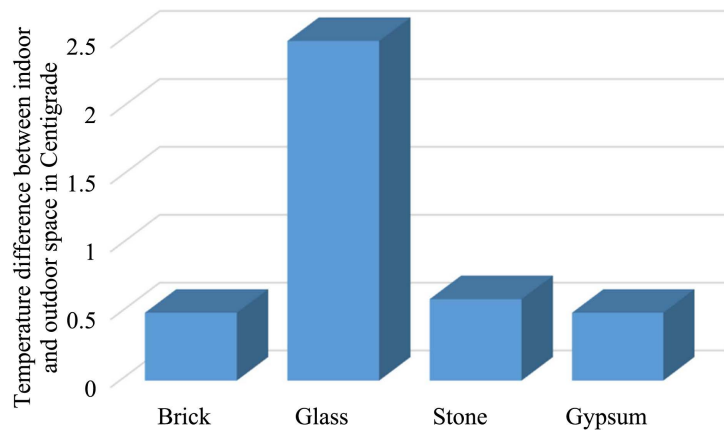


Figure 5. Temperature difference between indoor and outdoor space of different building envelope.

4. Conclusion

The effect of building envelope on thermal comfort of building is studied in four different buildings having glass, brick, stone, and gypsum as building envelope. From the survey conducted in this research, it is found that most people are using air-conditional for long hours and thereby it is polluting the environment. It is highly recommended to use sustainable strategies by designing the building with natural ventilation and rooms with window and skylight. From the study, it is found that building envelope with glass and brick are more effective in transferring less heat to the indoor. Building envelope with glass achieves more thermal comfort compared to other materials and at the same time building envelope with brick is more effective if the thickness of the envelope is more.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Lan, L., Wargocki, P., Wyon, D.P. and Lian, Z. (2011) Effects of Thermal Discomfort in an Office on Perceived Air Quality, SBS Symptoms, Physiological Responses, and Human Performance. *Indoor Air*, **21**, 376-390.
<https://doi.org/10.1111/j.1600-0668.2011.00714.x>
- [2] ASHRAE (2016) Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
http://fh.almas-hvac.ir/download/ASHRAE_Thermal_Comfort_Standard.pdf
- [3] Park, J.Y. and Nagy, Z. (2018) Data on the Interaction between Thermal Comfort and Building Control Research. *Data in Brief*, **17**, 529-532.
<https://doi.org/10.1016/j.dib.2018.01.033>
- [4] Al-Yasiri, Q. and Szabó, M. (2021) Incorporation of Phase Change Materials into Building Envelope for Thermal Comfort and Energy Saving: A Comprehensive Analysis. *Journal of Building Engineering*, **36**, Article No. 102122.
<https://doi.org/10.1016/j.job.2020.102122>

- [5] Alwetaishi, M.S. (2016) Impact of Building Function on Thermal Comfort: A Review Paper. *American Journal of Engineering and Applied Sciences*, **9**, 928-945. <https://doi.org/10.3844/ajeassp.2016.928.945>
- [6] Kuchen, E. (2016) Variable Thermal Comfort Index for Indoor Work Space in Office Buildings: A Study in Germany. *Open Journal of Civil Engineering*, **6**, 670-684. <https://doi.org/10.4236/ojce.2016.64054>
- [7] Leo Samuel, D.G., Dharmasastha, K., Shiva Nagendra, S.M. and Maiya, M.P. (2017) Thermal Comfort in Traditional Buildings Composed of Local and Modern Construction Materials. *International Journal of Sustainable Built Environment*, **6**, 463-475. <https://doi.org/10.1016/j.ijse.2017.08.001>
- [8] Saleem, A.A., Abel-Rahman, A.K., Ali, A.H. and Ookawara, S. (2016) An Analysis of Thermal Comfort and Energy Consumption within Public Primary Schools in Egypt. *IAFOR Journal of Sustainability, Energy & the Environment*, **3**, 15 p. <https://doi.org/10.22492/ijsee.3.1.03>
- [9] Homod, R.Z., Almusaed, A., Almssad, A., Jaafar, M.K., Goodarzi, M. and Sahari, K.S.M. (2021) Effect of Different Building Envelope Materials on Thermal Comfort and Air-Conditioning Energy Savings: A Case Study in Basra City, Iraq. *Journal of Energy Storage*, **34**, Article No. 101975. <https://doi.org/10.1016/j.est.2020.101975>
- [10] Yu, W., Li, B., Yao, R., Wang, D. and Li, K. (2017) A Study of Thermal Comfort in Residential Buildings on the Tibetan Plateau, China. *Building and Environment*, **119**, 71-86. <https://doi.org/10.1016/j.buildenv.2017.04.009>
- [11] Mirrahimi, S., Mohamed, M.F., Haw, L.C., Ibrahim, N.L., Yusoff, W.F. and Aflaki, A. (2016) The Effect of Building Envelope on the Thermal Comfort and Energy Saving for High-Rise Buildings in Hot-Humid Climate. *Renewable and Sustainable Energy Reviews*, **53**, 1508-1519. <https://doi.org/10.1016/j.rser.2015.09.055>
- [12] Wilson, J.D. (2015) College Physics. Addison-Wesley Professional.