Heat Transfer in a Typical Malaysian Room

Mohanad Yahya*, Mohamed H. Nassir

1School of Engineering, Taylor’s University, Selangor, Malaysia.
*m.mihrabi@gmail.com

Abstract— The lack of consistent studies of heat transfer through walls, doors, and windows of typical Malaysian constructions urges us to conduct this study for deep and accurate vision regarding this matter. To achieve this purpose a typical Malaysian room was scaled down and made of cement walls then data was collected by measuring temperature outside and inside the room for ample period of time. Windows are modified to serve as a single, double, and triple layer of glass at 10 mm gap. Initial results show significant reduction in heat transfer as the number of layers increases.

Keywords— Heat Transfer, House Architecture, Malaysian Construction, Cement Wall, Window’s Thickness

1. Introduction

The heat transfer through walls and composite layers has been a subject of significant investigations [1], [2]. Despite the availability of huge number of studies, the information in a certain and specific field is widely spread over almost unlimited various cases. Studies of heat transfer through walls and windows have considerable discrepancies due to huge number of structures, conditions of experimental work, and the widespread setting of experiments [3]. As another depth, studies in heat transfer through basic constructions in Malaysia are minimal. This project provides very essential knowledge equipped with physical data on a scaled-down Malaysian room. The room is fabricated using cement walls and roof with two windows and a door with both were scaled down similarly. The windows, as essential parts in the construction, are made of a single layer, which could be extended to a double and triple layer with 10 mm gaps. Armando Gallegos and his colleagues [4] investigated the thickness of the air layer and found that the heat transfer is significantly reduced as the number of the layers increases or the gap between layers increase. The theoretical part includes the modes of heat transfer, thermal conductivity, and the methodology of solving equations [5], [6]. The heat transfers in conduction mode \( \dot{Q} \) through a single layer of thickness \( x \) is given by Fourier’s law of heat conduction

\[
\dot{Q} = -kA \frac{dT}{dx}
\]  

(1)

where \( T \) is temperature and \( k \) is thermal conductivity. The conduction equation could be written in 2 or 3 dimensions. For more than one layer, the system will be analogous to resistors connected in series [5], [6]. There are two other modes for heat transfer, namely convection and radiation. The convection mode is explained by Newton’s Law of Cooling,

\[
\dot{Q} = hA \left( T_w - T_{\infty} \right)
\]  

(2)

where \( h \) is the connective heat transfer, and by radiation mode which is known by Stefan-Boltzman law,

\[
\dot{E} = \sigma T^4
\]  

(3)

where \( \sigma \) is Stefan-Boltzman constant.

To study the parameters of heat transfer in a typical Malaysian room under natural conditions and to map the temperature variation inside the room by examining these parameters as a function of a single, double, and triple glass window layers. Having measured these parameters, the best design will serve as better energy saving.

2. Experimental

Regarding the experimental part, the scaled-down room was fabricated as shown in Fig. 1 using CAD. The walls, roof, and the door are made of cement board because of easy to maintain, its affordability, and easy to handle. The size of the room is 1x1x1 m^3 and 20mm-wall thickness. It is placed in an open field on campus as shown in Fig 2.

The windows, which are crucial part of the study, were equipped with capability to handle a single, double, or triple glass layer. There are three types of glass layer with thickness, namely 2mm, 4mm and 6mm. The gap between the layers is 10mm. To measure temperature, four thermocouples were used and mounted outside and inside the room. The data was collected during day time and then repeated throughout night time until a constant temperature difference is achieved. Data collection was repeated for several days and results were averaged.

Fig 2 The Fabricated Room of 1x1x1 m and 2mm Wall Thickness
3. Results and Analysis

All measurements were taken simultaneously during day time measurements between 10 am and about 3 pm are shown in Fig 3. Temperature difference was measured in the vicinity of the windows (location A facing east and location B facing west) with a single and double layer (A1, B1 and A11, B11); respectively and the difference of temperature between outside and inside was reported. The single layer measurements shows very low maximum difference of 1.5 degrees compared to 3 degrees for double layer. For east-ward location A, the single layer measurements fluctuate to achieve maximum difference between the inside and outside (1.5 degrees) about noon while the double layer shows constant behavior until 1 pm where both layers have their minima of 0 degree and a half degree; respectively. For west-ward location B, the single layer shows very small difference of about 1 degree while the double layer shows 3 degrees maximum at noon time. The results for all cases show almost no difference in temperature about 3 pm except the B-double layer location of about half a degree. The data of east-ward, single-layer window shows fluctuation with two maxima one about 12 noon and another about 2.30 pm.

![Fig 3 Temperature Difference versus Time during Daytime](image)

Similarly, the same procedure of the experiment has been followed during the night time. Temperature measurement were taken from 4 pm to 9 pm are represented in Fig 4. The single layer measurements on location B shows 1.5 degrees as the maximum difference reached. However, in comparison with the double layer on location B, the maximum difference is almost 2.5 degrees. Location B results tend to have fluctuation in the measurement as shown in Fig 4. This is because location B has more sun exposure during this time since the window is located on east side of the room. On the other hand, location A shows steadiness in the measurement as they almost follow the same trend as shown in Fig 4, since they have started the cooling down phase. Moreover, using single layer window on location B shows no difference in temperature at 7 pm, whilst the double layer window shows 2 degrees difference in temperature. At 9 pm, the data for all the cases shows almost half a degree difference. Particularly, this behavior shows the rate of dissipating the heat in the double layer and maintaining a cool climate inside the room.

![Fig 4 Temperature Difference versus Time during Nighttime](image)

4. Discussion

The results signify the role of the double layer glass as the results has shown significant difference between the single and double layer. Based on research done by Daikin [private interview with Mr. Chow at Daikin conducted on 23/04/2010], one degree Celsius reduction of the atmosphere temperature leads to 3% improvement of the energy efficiency. The temperature difference ($\Delta T$) is obtained by measuring the temperature inside and outside the room. This small reduction in temperature difference has its own impact on two important issues, saving energy and greener environment. The difference of temperature at location A for double layer during the day time is about 3 degrees compared to about 1.5 degrees during night time. The trend of difference of temperature for all cases is almost same except the double layer at location B. The night time measurements, where the difference of temperature is measured between the outside and inside, show similar trend with lower maxima. Almost all measurements show a kind of fluctuation where the maximum appears more than once. This behavior may reflect very important result of temperature reduction that may lead to improve the energy efficiency; however, it is too early to confirm such a finding or the extent of it. Overall result are promising and encouraging for further studies not only about the double layer but also to include triple layer as well as to map the interior temperature distribution inside the room.

5. Conclusions

The lack of scientific and reliable studies on the heat transfer in a Malaysian typical room has supported the necessity of conducting this experiment as well as extending the investigation for further studies. Based on Daikin’s results of a single temperature reduction could result in 3% reduction of energy which reflects an important impact on the environment. The experimental results show that the reduction was about a degree and a half based on single to double layer. Despite the slightly high cost of the two layers, the gained that comes from saving energy and friendly impact on environment is, by no means, comparable. It is important to note that the double layer is 50% more efficient than it’s a single layer, which corresponds to the maximum temperature difference ($\Delta T$) using double layer. However, when the single layer window glass is used, the maximum temperature difference is 1.5 degrees as show in Fig 3, which represents the daytime results. It is also important to take the reading for few times to ensure accurate results and avoid the sudden changes effects of the Malaysian weather. The hope is that this study becomes a corner stone and bench marking to similar studies in order to have better and higher energy saving.

References


