ROOF EFFICIENCY ASSESSMENT FOR INDOOR THERMAL ENVIRONMENT IN CONTEMPORARY HOUSES IN NAJAF CITY, IRAQ

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

May 2022

FRSB 2022 12

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Sumarni Ismail, PhD
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Summer heat can be so severe in Iraq and the ambient temperature could reach higher than 50 °C. Most of the outside surfaces, generally and roofs, specifically are affected by solar radiation beams, which would increase the usage of cooling devices and power consumption in houses. These increases have caused severe electricity shortage during the summer, in addition to the general electricity issues in Iraq. Thus, this study aimed to assess the heat flux through traditional roofs in Iraqi dwellings. The efficiency of these types of roofs in decreasing the amount of heat flux flowing through them was assessed as a second objective. This study has also examined the impact of the double-skin roof strategy (through retrofitting these roofs with a K-span roof cover) on the reduction of the total heat flux and on improving the efficiency of the whole roof as a final objective. The methodology of this study included running simulations using the Comsol Multiphysics software. Simulations were conducted for 72 hours in the summer on the 27th, 28th, and 29th of July, and results were taken within 24-hour intervals for the following parameters: exterior roof surface temperature (Tes); interior roof surface temperature (Tis); indoor room temperature (Tr); total heat flux (Q-value); and roof heat transfer coefficient (U-value). The efficiency results of roof types (RF) before being retrofitted with K-span roof cover showed that the RF3B roof was the only efficient roof with U-value that was better than the Middle East standards by 32.6%. RF3 and RF4 multi-layered roof types showed lower efficiency than the standards by 46.4% and 278%, while RF5 and RF4B single layer roofs were 733% and 603% lower than the standards, respectively. The results of retrofitting the roofs with K-span roof cover demonstrated that the average efficiency of the parameters of Tes, Tis, Tr, Q-value, and U-value that impacted the efficiency of the selected roofs were improved by 54.2% in RF3 (Room 3), 56.9% in RF3B (Room 3B), and 55.1% in RF4 (Room 4). Meanwhile, RF4B (Room 4B) and RF5 (Room 5) showed 25.8% and 30% improvement, respectively. Finally, it is important to mention that the average improvement by K-span roof cover in this study was 44%, and this value could be higher if the roof cover was treated using another insulation strategy.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN KECEKAPAN BUMBUNG UNTUK PERSEKITARAN TERMA DALAMAN DI RUMAH KONTEMPORARI DI BANDAR NAJAF, IRAQ

Oleh

AL-MOHSEN MUSTAFA ABDULMUNEM SALEH

Mei 2022

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Haba musim panas boleh menjadi sangat teruk di Iraq dan suhu sekitar boleh mencecah lebih tinggi daripada 50 °C. Kebanyakan permukaan luar, amnya dan bumbung, khususnya akan terkesan dengan pancaran sinaran suria yang akan meningkatkan penggunaan peranti-peranti penyejuk dan penggunaan kuasa elektrik di dalam rumah. Peningkatan ini telah menyebabkan kekurangan elektrik yang teruk semasa musim panas, sebagai tambahan kepada isu elektrik umum di Iraq. Oleh itu, kajian ini bertujuan untuk menilai fluks haba melalui bumbung tradisional di rumah-rumah kediaman di Iraq. Kecekapan bumbung sebegini dalam mengurangkan jumlah fluks haba yang mengalir melaluinya telah dinilai. Kajian ini turut mengkaji kesan strategi bumbung dua kulit (secara memasang semula bumbung ini dengan penutup bumbung K-span) terhadap pengurangan jumlah fluks haba dan meningkatkan kecekapan keseluruhan bumbung. Metodologi kajian ini turut menjalankan simulasi menggunakan perisian COMSOL MULTIPHYSICS. Beberapa simulasi telah dijalankan selama 72 jam pada musim panas pada 27, 28, dan 29 Julai, dan keputusan telah diambil dalam selang 24 jam untuk parameter-parameter berikut: suhu permukaan bumbung luar (Tes); suhu permukaan bumbung dalaman (Tis); suhu bilik dalaman (Tr); jumlah fluks haba (nilai Q); dan pekali pemindahan haba bumbung (nilai U). Keputusan kecekapan jenis-jenis bumbung (RF) sebelum dipasang dengan penutup bumbung K-span menunjukkan bahawa bumbung jenis RF3B merupakan satu-satunya bumbung yang cekap dengan nilai U yang lebih baik daripada piawaian Timur Tengah sebanyak 32.6%. Bumbung jenis berbilang lapisan RF3 dan RF4 menunjukkan kecekapan yang lebih rendah berbanding standard sebanyak 46.4% dan 278%, manakala bumbung satu lapisan RF5 dan RF4B masing-masing ialah 733% dan 603% lebih rendah daripada standard. Hasil pemasangan semula bumbung dengan penutup bumbung K-span menunjukkan bahawa kecekapan purata bagi semua parameter Tes, Tis, Tr, nilai Q dan nilai U yang memberi kesan kepada kecekapan bumbung terpilih telah dipertingkatkan sebanyak 54.15% dalam RF3 (Bilik 3), 56.92% dalam RF3B (Bilik 3B) dan 55.10% dalam RF4 (Bilik 4). Manakala RF4B (Bilik 4B) dan RF5 (Bilik 5) masing-masing menunjukkan peningkatan sebanyak 25.81% dan 30%. Akhir sekali, penting untuk menyatakan bahawa peningkatan purata

oleh penutup bumbung K-span dalam kajian ini ialah 44%, dan nilai ini boleh menjadi lebih tinggi jika penutup bumbung dirawat menggunakan strategi penebat yang lain.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisors, Asst. Prof. Dr. Sumarni Ismail, Ms. Ida Suriana Ismail and Dr. Shafizal Bin Maarof for their advice and support during this project. I am indebted to them for their guidance and unwavering support for my aims.

My parents, brothers, sisters, and friends, for their tolerance, motivation, direction, and assistance throughout every milestone of the journey, have provided me with enormous drive in the last weeks of my study.

Additionally, I would like to express my gratitude to Arch. Ali Kareem Jafar, M.Sc. Arch. Ali Hussein Abdulmuttaleb, and M.Sc. Arch. Omran Subhi Moesas for providing me with the all needed of the data, information and materials for this research.

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

Q-value	Total heat transfer rate
U-value	Heat transfer coefficient
k	Thermal conductivity
R	Thermal Resistance
A	Area of surface
T_{es}	Roof exterior surface temperature
T_{is}	Roof interior surface temperature
T_r	Room interior air temperature
W/m^2	Watts over a square meter surface
Btu/(hr.ft.F)	British Thermal Units per hour.foot.fahrenheit
K	Kelvins
℃	Celsius
$W/m^2.K$	Watts over square meter. Kelvin
W/(K·m)	Watts over kelvin. Meter
HVAC	Heating, ventilation, and air conditioning
TETD	Total equivalent temperature difference
TFM	Transfer function method
HB	Heat balance method
CLTD	Cooling load temperature difference method
FEM	The Finite Element Method
RF	Roof type
Temp	Temperature
SE	Standard Error
εΩ	Surface emissivity SI radiometry units

CHAPTER 1

INTRODUCTION

In this chapter a background about this study will be displayed. As well as research questions, objectives, scope and limitations of the study, and problem statement will be stated in this chapter. Furthermore, the adopted methodology and research structure are also shown at the end of the chapter.

1.1 Research background

During summer, one of the biggest problems in Iraq is high temperatures which the temperatures could reach 50 °C and above in southern Baghdad provinces such as Basra and Najaf (S. N. S. Kharrufa, 2018). Very high temperatures in the summer characterize Iraq and moderate in the winter, in which the highest value in June, July, and August is between 43 ° C to 50 ° C and one °C to 8°C in January (Figure 1.1) (S. N. S. Kharrufa, 2018). As a result, the excessive use of air-conditioners to get a comfortable environment inside the room, particularly during the summer, is apart from the fact that there is a shortage of electricity in Iraq (Istepanian, 2014; Mahmoud, 2022) which causes power shutdowns as a result of power consumption by air-conditioning specifically. Hence, the roof is one of the essential elements of a building. Roof with walls and ventilation are the most critical parameters in a building that contributes to the heating load in old and non-insulated buildings (J. Huang et al., 1999). Therefore, if the heat flux through the roofs can be limited, it is possible to provide a thermally comfortable indoor climate, reduce air-conditioners usage and power consumption, reduce cooling demands, and improve the energy efficiency of the contrary houses to achieve sustainable status. Finally, by using Comsol Multiphysics software, it is possible to define the heat gain through roofs and study the impact of low-cost, low-technology roof cover on the interior roof surface and room temperature inside the current houses in Najaf city in Iraq.

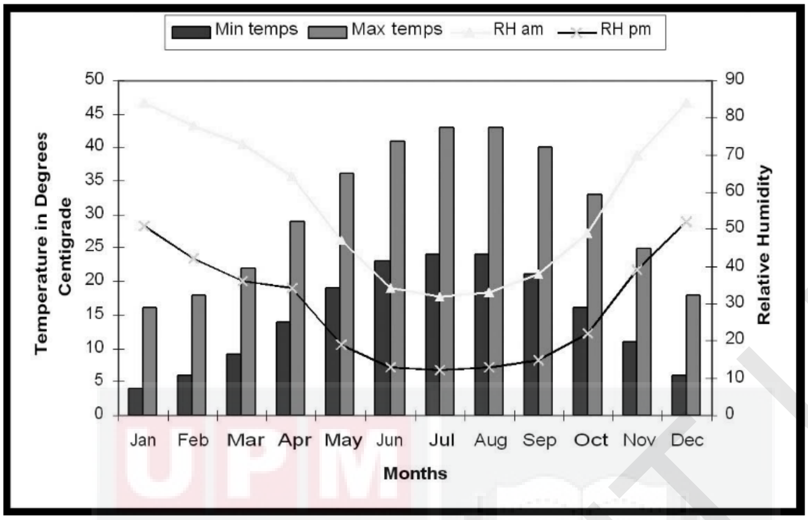

Figure 1.1 : Baghdad average monthly humidity and temperatures
(S. N. S. Kharrufa, 2018)

1.2 Problem statement

The roof is the part of the house that gets the most daily heat gain; it will face the sunlight from sunshine to sunset and affected by the relevant heat absorbed by roofs. During summer, houses in Iraq have to face a problem in which the temperatures reach more than 50°C in some cases; therefore, the roofs will be the most significant source of heat gain in summer, considering the shortage of electricity in Iraq. In addition, there are many studies conducted about improving thermal resistance efficiency in roofs through the green roof or evaporative roof techniques. However, most of these studies did not evaluate the original roof's heat insulating efficiency, and the vast needs for maintenance and operating demands for these systems are high. Therefore, investigating different roofs' and low-cost, low-technology roof cover efficiency in reducing heat gain during the summer in houses in Iraq becomes an essential issue.

1.3 Research Questions

The research questions can be addressed as follows:

1. How to assess heat gain through roofs?
2. How is the roof efficiency in reducing heat gain?
3. How is the efficiency of low-cost low-technology roof cover model in decreasing heat gain through the roof?

1.4 Research objectives

The objectives of this research are as follows:

1. To investigate house traditional roofs (Roof types) efficiency in reducing heat gain by assessing heat gain through roofs in contemporary houses through computer simulations using "Comsol Multiphysics" software.
2. To retrofit house traditional roofs (Roof types) with a low-cost, low-technology roof cover model by using double-skin roofs strategy.
3. To examine the impact of the new roof cover model in reducing roof heat flux through computer simulations by using "Comsol Multiphysics" software.

1.5 Scope and limitations of study

This study is concerned about assessment of roof efficiency in reducing the heat gain through its thermal transmittance "U-value" that affects the amount of the total heat gain rate, which will be assessed by simulation in "COMSOL Multiphysics" software, and to find a new model of low-cost low-technology roof cover and examine its efficiency in reducing roof heat gain by using the same mentioned software. Thus, this research focused on studying the heat insulation efficiency of roofs of contemporary houses in Najaf province in Iraq.

1.6 Research methodology

In order to achieve the research objectives and answer the research questions, this research embraces a quantitative research approach. In order to assess the actual condition, the study was based on a simulation process using COMSOL MULIPHYSICS software. The study aimed at different rooms' roofs of two houses with a built area of 137 m^2 (two stories) at Najaf city. The simulation was conducted for 72 hours during summer (27th, 28th, and 29th July), the performance of roofs without and with K-span roof cover was evaluated.

The research process or phase consists of three main stages:

1. Collecting data of the roofs of the selected rooms for each house, such as the construction materials, roof dimensions, and layers.
2. The second stage was modeling and simulating the selected rooms' roofs using Comsol Multiphysics software to exclude the following parameters, roof exterior surface temperature, roof interior surface temperature, room air temperature, total heat flux through the roof, and heat transfer coefficient (U-value).

3. In this stage, the selected roofs were retrofitted with K-span roof cover (low-cost, low-technology roof cover) and simulated with the same mentioned software, and excluded the same previous parameters.
4. The low-cost, low-technology roof cover is a second roof skin which protects the original roof exterior surface from direct solar radiation with zero energy wastage using simple technology.
5. The final stage was the validation stage for both simulation and results; simulation was validated by comparing between software simulation results of roof's exterior and interior surfaces temperatures and the results of the field measurements represented by thermometer readings, while the results of the new model were validated through comparison with hand calculations of U-value and Total heat flux.

1.7 Research structure

The thesis consists of six chapters. The introduction to the research is presented in Chapter 1. It involves a brief introduction on Iraq's hot season, temperatures during the summer, and a general idea on Iraqi house roofs, the problem statement, objectives, limitations of the study, and methodology. Chapter 2 explores the literature issues on Iraqi climate and the issues and treatments of thermal comfort to identify the study gaps. It also discusses significant past studies to evaluate thermal insulation of roofs and treatments, specifically in Iraqi houses and roofs of residential buildings and houses in different countries. Chapter 3 explores in detail the research methodologies employed in the study. The results of field measurements and simulation results and the confirmation of results are presented in Chapter 4. In Chapter 5, the results from all data collection methods are evaluated and discussed. In Chapter 6, the main findings are concluded in line with the objectives of the research, and possible future research recommendations are outlined.

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