UNIVERSITI PUTRA MALAYSIA

THERMAL PERFORMANCE OF ROOFING SYSTEMS IN RELATION TO THE MEAN RADIANT TEMPERATURE IN MALAYSIAN RESIDENTIAL BUILDINGS

ALLEN LAU KHIN KIET

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By

ALLEN LAU KHIN KIET

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THERMAL PERFORMANCE OF ROOFING SYSTEMS IN RELATION TO THE MEAN RADIANT TEMPERATURE IN MALAYSIAN RESIDENTIAL BUILDINGS

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ALLEN LAU KHIN KIET

April 2008

Chair: Professor Dato' Ar. Elias @ Ilias bin Salleh, PhD

Faculty: Faculty of Design and Architecture

Malaysian housing industry is facing a huge challenge to provide environmentally sustainable housing developments. The main issue concentrates on thermal performance of building envelopes to improve thermal comfort and energy savings. The major problem of Malaysian domestic housing development is the over heating of roof space caused by inappropriate roofing systems and materials as the roof is the major source of heat gain. The excessive heat gained from the sun will be radiated from the roof space to the occupants through radiation.

Previous studies were done on the evaluation of thermal performance of roofing systems for residential buildings in Malaysia, based on air temperature measurement. However, there is no study focusing on the effect of roofing systems on Mean Radiant Temperature, which will have a direct impact on the thermal exchange between the roof and the occupants. Mean Radiant Temperature of a space is the measure of the combined effects of temperatures of surfaces within that space

such as roof, walls and floor. Therefore, the main objective of this study is to investigate the effect of roofing systems and materials on Mean Radiant Temperature for recommendations of roofing systems and materials for optimum thermal performance under Malaysian climate.

This research involved an observation survey on the common roofing systems and materials for recent domestic housing developments in Malaysia. This was followed by simulations of Mean Radiant Temperature by using the simulation software, Heat Transfer in Buildings HTB2 to evaluate thermal performance of various roofing systems and materials based on the observation survey. Field measurements on Mean Radiant Temperature at first floor level of a double storey terrace house in Kuala Lumpur were then carried out by using INNOVA thermal comfort measurement tools. The measured Mean Radiant Temperature was compared with the simulated Mean Radiant Temperature for validation of the software.

The results revealed that among common roofing systems and materials in recent Malaysian domestic housing industry, clay tile with double sided aluminium foil and plasterboard ceiling is able to produce the optimum thermal performance in relation to Mean Radiant Temperature. This is followed by concrete tile roofing system with double sided aluminium foil and plasterboard ceiling, and lastly metal deck roofing system with double sided aluminium foil, rockwool as insulation materials and plasterboard ceiling. From the simulation results, the most effective location for aluminium foil is below the roof tiles compared to on top of horizontal ceiling. However, it is recommended that with additional combination of double sided aluminium foil on top of plasterboard or rockwool as hybrid ceiling, it will

significantly reduce indoor Mean Radiant Temperature. This will reduce the heat exchange between the roof space and the occupants through radiation, and therefore optimising thermal performance of roofing systems under Malaysian climate.

In conclusion, this study demonstrates the importance of choosing appropriate roofing systems and materials for better thermal comfort through the understanding on the effect of roofing systems on Mean Radiant Temperature. The recommended roofing systems and configurations will become useful guidelines for developers, architects, and house owners to improve thermal comfort of residential buildings in Malaysia. Therefore, this study will contribute in promoting energy and cost savings in Malaysian housing industry, as well as the whole country's development.

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

THERMAL PERFORMANCE OF ROOFING SYSTEMS IN RELATION TO THE MEAN RADIANT TEMPERATURE IN MALAYSIAN RESIDENTIAL BUILDINGS

Oleh

ALLEN LAU KHIN KIET

April 2008

Pengerusi: Profesor Dato' Ar. Elias @ Ilias bin Salleh, PhD

Fakulti: Fakulti Rekabentuk dan Senibina

Industri perumahan di Malaysia sedang menghadapi satu kecabaran besar untuk menyediakan pembangunan perumahan yang berasaskan keseimbangan persekitaran. Isu utama dalam kecabaran ini menumpukan perhatian dalam prestasi terma sampul bangunan bagi meningkatkan keselesaan terma dan penjimatan tanaga. Masalah utama dalam sektor pembangunan perumahan di Malaysia adalah kepanasan melampau pada ruang bumbung yang disebabkan oleh sistem dan bahan-bahan pembuatan bumbung yang tidak sesuai. Ini adalah kerana bumbung adalah punca penerimaan haba yang utama. Haba berlebihan yang didapati daripada punca suria akan diradiasikan daripada ruang bumbung kepada penghuni melalui proses radiasi.

Kajian yang dahulu diusahakan untuk menilai prestasi terma bagi sistem bumbung bangunan kediaman di Malaysia dengan berasaskan pengukuran suhu udara. Bagaimanapun, tiada pengajian yang menumpukan perhatian dalam kesan sistem bumbung terhadap suhu radiasi purata yang mempunyai kesan terus terhadap

penukaran haba yang berlaku di antara bumbung dengan penghuni. Suhu radiasi purata bagi sesebuah ruang adalah suhu yang terkumpul daripada suhu-suhu permukaan dalam ruang tersebut seperti bumbung, dinding dan lantai. Oleh yang demikian, objektif utama bagi penyelidikan ini adalah untuk mengkaji kesan daripada sistem bumbung dan bahan-bahan pembuatan bumbung terhadap suhu radiasi purata dengan bertujuan untuk mencadangkan sistem dan bahan-bahan pembuatan bumbung yang mempunyai prestasi terma yang optima berasaskan cuaca Malaysia.

Penyelidikan ini melibatkan satu kajian ke atas bahan pembuatan dan sistem-sistem bumbung yang umum bagi pembangunan perumahan kebelakangan di Malaysia. Selepas pengajian ini, simulasi komputer ke atas suhu radiasi purata dengan menggunakan program simulasi komputer yang berjenama HTB2 telah diadakan untuk menilai prestasi terma bagi bahan-bahan pembuatan dan sistem-sistem bumbung yang berbagai jenis berdasarkan kajian yang telah diadakan. Seterusnya, pengukuran ke atas suhu radiasi purata bagi tingkat kedua di sebuah rumah teres di Kuala Lumpur telah diadakan dengan menggunakan alat pengukuran keselesaian terma yang berjenama INNOVA. Suhu radiasi purata yang diukur akan dibandingkan dengan suhu radiasi purata yang disimulasikan oleh program simulasi komputer yang berjenama HTB2. Ini adalah bertujuan untuk pengesahan prestasi program simulasi komputer tersebut.

Keputusan simulasi mendapati bahawa di antara sistem dan bahan-bahan pembuatan bumbung umum yang digunakan dalam pembangunan perumahan kebelakangan di Malaysia, jubin bumbung tanah liat bersama-sama dengan lapisan nipis aluminium

dua muka dan siling papan plaster dapat manghasilkan prestasi terma yang optima berasaskan suhu radiasi purata. Yang seterusnya adalah sistem jubin bumbung konkrit dengan lapisan nipis aluminium dua muka dan siling papan plaster. Prestasi terma yang paling rendah adalah pada sistem bumbung jenis logam dengan lapisan nipis aluminium dua muka dan bulu-bulu sebagai bahan insulasi dan siling papan plaster. Keputusan simulasi juga menunjukkan bahawa kedudukan lapisan nipis aluminium yang paling berkesan adalah di bawah jubin bumbung berbanding dengan di atas siling mendatar. Walau bagaimanapun, penyelidikan ini mencadangkan bahawa dengan penambahan lapisan nipis aluminium dua muka di sebelah atas papan plaster atau bulu-bulu sebagai siling hibrid berlapis, suhu radiasi purata dalaman akan dapat diturunkan dengan nyata sekali. Dengan ini, penukaran haba secara radiasi di antara ruang bumbung dan penduduk akan dapat dikurangkan. Justeru itu, prestasi terma sistem bumbung akan dapat dimaksimumkan.

Sebagai kesimpulan, penyelidikan ini telah menunjukkan kepentingan untuk memilih sistem dan bahan-bahan pembuatan bumbung yang sesuai supaya meningkatkan keselesaan terma Ini dapat dicapai melalui pemahaman yang mendalam atas kesan sistem bumbung terhadap suhu radiasi purata. Sistem-sistem dan konfigurasi bumbung yang dicadangkan dapat dijadikan sebagai panduan yang berguna kepada pemaju-pemaju perumahan, arkitek-arkitek dan pemilih-pemilih rumah untuk meningkatkan prestasi terma bagi rumah-rumah kediaman di Malaysia. Dengan ini, penyelidikan ini akan menyumbang dalam penjimatan tenaga dan pembelanjaan dalam industri perumahan serta pemajuan seluruh negara kita.

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I certify that an Examination committee has met on **9 April 2008** to conduct the final examination of Allen Lau Khin Kiet on his Master of Science (Architectural Studies) thesis entitled "Thermal Performance of Roofing Systems in Relation to Radiant Heat in Malaysian Residential Buildings" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

Prof. Madya Dr. Hjh Rahinah Ibrahim, PhD
Timbalan Dekan
(Penyelidikan, Siswazah dan Pengantarabangsaan)
Fakulti Rekabentuk dan Senibina
Universiti Putra Malaysia
(Chairman)

Dr. Ar. Azizah Salim Syed Salim, PhD
Prof. Madya
Jabatan Senibina
Fakulti Rekabentuk dan Senibina
Universiti Putra Malaysia
(Internal Examiner)

Dr. Nor Mariah Adam, PhD
Prof. Madya
Jabatan Kejuruteraan Mekanikal dan Pembuatan
Fakulti Kejuruteraan
Universiti Putra Malaysia
(Internal Examiner)

Dr. K.S. Kannan, PhD
Professor
Centre for Energy Studies
Institute Sultan Iskandar
Universiti Teknologi Malaysia
(External Examiner)

HASANAH MOHD. GHAZALI, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 26 May 2008

This thesis was submitted to the Senate of 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:

Dato' Ar. Elias @ Ilias bin Salleh, PhD
Professor
Faculty of Design and Architecture
Universiti Putra Malaysia
(Chairman)

Ar. Lim Chin Haw
Lecturer
Faculty of Design and Architecture
Universiti Putra Malaysia
(Member)

Ar. Meor Mohammad Fared
Lecturer
Faculty of Design and Architecture
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 June 2008

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

ALLEN LAU KHIN KIET

Date: 9 April 2008

TABLE OF CONTENTS

		Page
ABSTRACT		ii
ABSTRAK		v
ACKNOWLEDGEMENTS		viii
APPROVAL		ix
DECLARATION		xi
LIST OF TABLES		xv
LIST OF FIGURES		xvii
LIST OF APPENDICES		xix
LIST OF ABBREVIATIONS		xx
CHAPTER		
1	**INTRODUCTION**	1
1.1	Research Background	1
1.2	Problem Statement	2
1.3	Point Of Departure	4
1.4	Aim, Objectives and Outcome of Research	7
1.5	Scope of Research	8
1.6	Significance of Research	10
1.7	Research Framework	11
1.8	Research Methodology	13
1.9	Thesis Organisation	16
1.10	Summary	18
2	**REVIEW OF MALAYSIAN CLIMATE AND THERMAL COMFORT**	20
2.1	Introduction	20
2.2	Climate of Malaysia	20
2.3	Thermal Comfort	23
2.3.1.	Definition and Theory	23
2.3.2.	Parameters of Thermal Comfort	24
2.3.3.	Thermal Comfort Indices	25
2.4	Summary and Conclusion	27
3	**REVIEW OF ROOFS AND THERMAL ISSUES**	29
3.1	Introduction	29
3.2	Heat Transfer and the Roof	29
3.2.1.	Thermal Properties of the Roof	30
3.2.2.	Heat Transfer through the Roof	32
3.3	The Implications of Roof on MRT Compared with Air Temperature	33
3.4	Ceiling Temperature of Roof	35
3.5	Calculation of MRT	36
3.6	Thermal Design and Analysis of Roof	37
3.7	Implications of Reflective Radiant Barriers and Mass Insulation Materials on Thermal Performance of Roof	40
3.8	Summary and Conclusion	44

4 SURVEY ON DOMESTIC ROOFS 46
4.1 Introduction 46
4.2 Aim and Objectives 47
4.3 Scope of Observation Survey 47
4.4 Observation Method 48
4.5 Type of Common Roofing Materials for Recent Domestic Housing Developments in Malaysia 49
4.5.1. Roof Finish Materials 50
4.5.2. Reflective Insulation Materials 51
4.5.3. Mass Insulation Materials 54
4.5.4. Ceiling Materials 55
4.6 Thermal Properties of Common Roofing Materials 56
4.7 Thermal Performance of Common Roofing Systems and Configuration 62
4.8 Summary and Conclusion 70

5 SIMULATIONS OF ROOF THERMAL PERFORMANCE 72
5.1 Introduction 72
5.1.1. Background 72
5.1.2. Comparisons of Simulation Software 73
5.1.3. Conclusion 76
5.2 The Selected Simulation Software: Heat Transfer in Buildings HTB2 76
5.2.1. The Main Software Components 76
5.2.2. Input Data 78
5.2.3. Output Data 79
5.3 Simulation House 80
5.4 Simulation Day 81
5.5 Roof Models for Simulation 81
5.6 Summary and Conclusion 86

6 RESULT AND DISCUSSION 87
6.1 Result Analysis on Simulation of Mean Radiant Temperature 87
6.1.1. Common Roofing Materials 87
6.1.2. Common Roofing Systems and Configurations 98
6.1.3. Recommended Roofing Assembly and Configurations 101
6.2 Validation of HTB2 Software By Field Measurement 108
6.2.1. Introduction 108
6.2.2. Aim and Objectives 109
6.2.3. Scope of Field Measurement 109
6.2.4. Unit of Analysis 111
6.2.5. Measurement Tools 112
6.2.6. Measurement Methods 113
6.2.7. Validation Analysis 115
6.2.8. Conclusion 116

7 CONCLUSION AND RECOMMENDATION 118
7.1 Conclusion 118
7.1.1. Research Overview 118
7.1.2. Recommendation of Roofing Systems and Materials for Optimum Thermal Performance for Residential Buildings in Malaysia 119

7.2 Significant Contribution of Research 124
7.3 Recommendations for Future Study 125

REFERENCES 127
APPENDICES 133
BIODATA OF STUDENT 163
LIST OF PUBLICATIONS 165

LIST OF TABLES

Table		Page
3.1	Comparisons between reflective radiant barriers and conventional mass insulation materials	42
4.1	Record format for data collection during site visits	48
4.2	Common roofing materials and their major manufacturers and suppliers with average product price	50
4.3	Common roof finish materials and usage for recent domestic housing developments in Malaysia	51
4.4	Type and average price of radiant barriers from observation survey	52
4.5	Common reflective insulation materials and usage for recent domestic housing developments in Malaysia	52
4.6	Common mass insulation materials and usage for recent domestic housing developments in Malaysia	54
4.7	Common ceiling materials and usage for recent domestic housing developments in Malaysia	55
4.8	Thermal properties and characteristics of common roof finish materials	58
4.9	Thermal properties and characteristics of reflective insulation materials	59
4.10	Thermal properties and characteristics of mass insulation materials	60
4.11	Thermal properties and characteristics of ceiling materials	62
4.12	Thermal evaluations of common concrete tiled roofing system	64
4.13	Thermal evaluations of common clay tiled roofing system	67
4.14	Thermal evaluations of common metal deck roofing system	69
4.15	Comparisons of the thermal performance of common roofing systems and configurations	70
5.1	Concrete tiled roof models for simulations of MRT	83
5.2	Clay tiled roof models for simulations of MRT	84
5.3	Metal deck roof models for simulations of MRT	85

6.1	Common domestic roofing assembly systems and configurations based on the observation survey	99
7.1	Recommendation of roofing materials and configurations	120

LIST OF FIGURES

Figure		Page
1.1	Roofing system and materials	9
1.2	Thermal radiation of roof	10
1.3	Flow chart of research activities	12
2.1	Map of Malaysia and the South East Asian region	21
3.1	Heat transfer of roof	30
3.2	Definition of MRT	34
4.1	Map of Selangor and Kuala Lumpur	46
4.2	Constructional composition of roof	48
4.3	Hybrid ceiling	61
4.4	Concrete tiled roofing assembly system for recent domestic housing developments in Malaysia	64
4.5	Clay tiled roofing assembly system for recent domestic housing developments in Malaysia	66
4.6	Metal deck roofing assembly system for recent domestic housing developments in Malaysia	68
5.1	Input data file organization for HTB2	78
6.1a and 6.1b	Thermal performance of roof finish materials in the aspect of MRT	88
6.2a and 6.2b	Effect of aluminium foil on the thermal performance of roofing systems, in the aspect of MRT	90
6.3a and 6.3b	Effect of rockwool on the thermal performance of roofing system, in the aspect of MRT	92
6.4	Simulations on reflective and mass insulation materials	94
6.5a and 6.5b	Effect of reflective insulation and mass insulation on MRT	94
6.6a and 6.6b	Effect of ceiling materials on the thermal performance of roofing system, in the aspect of MRT	97

6.7a and 6.7b	Thermal evaluations of common domestic roofing systems and configurations in Malaysia	100
6.8	Simulations on different locations of aluminium foil	102
6.9a and 6.9b	Effect of the location of aluminium foil on thermal performance of roofing system, in the aspect of MRT	102
6.10	Simulations on different locations of rockwool	104
6.11a and 6.11b	Effect of the location of rockwool on thermal performance of roofing system, in the aspect of MRT	105
6.12	Simulations on improved thermal insulation at ceiling level	107
6.13a and 6.13b	Thermal evaluations of improved thermal insulation at ceiling level compared with common plasterboard ceiling	107
6.14	Globe thermometer of the INNOVA thermal comfort measurement set	110
6.15	Air temperature transducer of the INNOVA thermal comfort measurement set	110
6.16	The double storey terrace house for field measurements	111
6.17	INNOVA thermal comfort transducers and data logger	113
6.18a and 6.18b	Position of the INNOVA thermal comfort measurement set marked “x” in the master bedroom	114
6.19	INNOVA thermal comfort measuring set equipped with transducers and data logger	115
6.20	Validation of HTB2 software	115

LIST OF APPENDICES

Appendix		Page
A1.0	Roofing systems and materials for recent domestic housing developments in Malaysia	135
B1.0	INNOVA Measured First floor Mean Radiant Temperature (MRT) and Air Temperature for Double Storey Terrace House on 23 March 2007	145
C1.0	Malaysian Weather Data (HTB2)	146
C1.1	Malaysian Weather Data (HTB2)	147
C1.2	HTB2 Simulated First floor Mean Radiant Temperature (MRT) and Air Temperature for Double Storey Terrace House on 23 March 2007	148
C1.3	Simulation Result of MRT (HTB2)	149
C1.4	Simulation Result of MRT (HTB2)	150
C1.5	Simulation Result of MRT (HTB2)	151
D1.0	TERREAL CoolMax – aluminium foil	152
D1.1	TERREAL CoolMax – aluminium foil	153
D1.2	VINTAGE – aluminium foil	154
D1.3	CAMEL – woven-metalised foil	155
D1.4	MONIER – CoolBoard	156
D1.5	VINTAGE – Victory pressed concrete roof tile	157
D1.6	MONIER – Cool Roof	158
D1.7	MONIER – Cool Roof	159
E1.0	Malaysian Weather Data for 2007	160
E1.1	Malaysian Weather Data for 2007	161
E1.2	Malaysian Weather Data for 2007	162

LIST OF ABBREVIATIONS

Abbreviation	Unit	Meaning
MRT	ºC	Mean Radiant Temperature
ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
HTB2	-	Heat Transfer in Buildings version 2
CFD	-	Computer Fluid Dynamics
N	º	North
E	º	East
RH	%	Relative Humidity
ET	-	Effective Temperature
BDT	ºC	Dry Bulb Temperature
WBT	ºC	Wet Bulb Temperature
GT	ºC	Globe Temperature
CET	-	Corrected Effective Temperature
PMV	-	Predicted Mean Vote
PPD	%	Predicted Percentage of Dissatisfied
BS	-	British Standards
PVC	-	Poly vinyl chloride
RBS	-	Radiant Barrier System
ISO	-	International Organization for Standardization
CR1	-	roof design option for simulation
CR2	-	roof design option for simulation
CR3	-	roof design option for simulation
CR4	-	roof design option for simulation

CR5	-	roof design option for simulation
CR6	-	roof design option for simulation
CY1	-	roof design option for simulation
CY2	-	roof design option for simulation
CY3	-	roof design option for simulation
CY4	-	roof design option for simulation
CY5	-	roof design option for simulation
CY6	-	roof design option for simulation
MD1	-	roof design option for simulation
MD2	-	roof design option for simulation
MD3	-	roof design option for simulation
MD4	-	roof design option for simulation
MD5	-	roof design option for simulation
MD6	-	roof design option for simulation

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Oleh

ALLEN LAU KHIN KIET

April 2008

Pengerusi: Profesor Dato' Ar. Elias @ Ilias bin Salleh, PhD

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permukaan dalam ruang tersebut seperti bumbung, dinding dan lantai. Oleh yang demikian, objektif utama bagi penyelidikan ini adalah untuk mengkaji kesan daripada sistem bumbung dan bahan-bahan pembuatan bumbung terhadap suhu radiasi purata dengan bertujuan untuk mencadangkan sistem dan bahan-bahan pembuatan bumbung yang mempunyai prestasi terma yang optima berasaskan cuaca Malaysia.

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Keputusan simulasi mendapati bahawa di antara sistem dan bahan-bahan pembuatan bumbung umum yang digunakan dalam pembangunan perumahan kebelakangan di Malaysia, jubin bumbung tanah liat bersama-sama dengan lapisan nipis aluminium dua muka dan siling papan plaster dapat manghasilkan prestasi terma yang optima berasaskan suhu radiasi purata. Yang seterusnya adalah sistem jubin bumbung

konkrit dengan lapisan nipis aluminium dua muka dan siling papan plaster. Prestasi terma yang paling rendah adalah pada sistem bumbung jenis logam dengan lapisan nipis aluminium dua muka dan bulu-bulu sebagai bahan insulasi dan siling papan plaster. Keputusan simulasi juga menunjukkan bahawa kedudukan lapisan nipis aluminium yang paling berkesan adalah di bawah jubin bumbung berbanding dengan di atas siling mendatar. Walau bagaimanapun, penyelidikan ini mencadangkan bahawa dengan penambahan lapisan nipis aluminium dua muka di sebelah atas papan plaster atau bulu-bulu sebagai siling hibrid berlapis, suhu radiasi purata dalaman akan dapat diturunkan dengan nyata sekali. Dengan ini, penukaran haba secara radiasi di antara ruang bumbung dan penduduk akan dapat dikurangkan. Justeru itu, prestasi terma sistem bumbung akan dapat dimaksimumkan.

Sebagai kesimpulan, penyelidikan ini telah menunjukkan kepentingan untuk memilih sistem dan bahan-bahan pembuatan bumbung yang sesuai supaya meningkatkan keselesaan terma Ini dapat dicapai melalui pemahaman yang mendalam atas kesan sistem bumbung terhadap suhu radiasi purata. Sistem-sistem dan konfigurasi bumbung yang dicadangkan dapat dijadikan sebagai panduan yang berguna kepada pemaju-pemaju perumahan, arkitek-arkitek dan pemilih-pemilih rumah untuk meningkatkan prestasi terma bagi rumah-rumah kediaman di Malaysia. Dengan ini, penyelidikan ini akan menyumbang dalam penjimatan tenaga dan pembelanjaan dalam industri perumahan serta pemajuan seluruh negara kita.