

**GREEN ROOF PERFORMANCE STUDY USING
RUBBER CRUMB, OIL PALM WASTE MATERIAL
AND NATURAL FIBRES FOR STORMWATER
RUNOFF MITIGATION**



NURUL SHAHADAHTUL AFIZAH BT. ASMAN

**FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
2018**

**GREEN ROOF PERFORMANCE STUDY USING
RUBBER CRUMB, OIL PALM WASTE MATERIAL
AND NATURAL FIBRES FOR STORMWATER
RUNOFF MITIGATION**

NURUL SHAHADAHTUL AFIZAH BT. ASMAN



UMS
UNIVERSITI MALAYSIA SABAH

**THESIS SUBMITTED IN FULFILLMENT FOR THE
DEGREE OF MASTER OF ENGINEERING**

**FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
2018**

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL: **GREEN ROOF PERFORMANCE STUDY USING RUBBER CRUMB, OIL PALM WASTE MATERIAL AND NATURAL FIBRES FOR STORM WATER RUNOFF MITIGATION**

IJAZAH: **MASTER OF ENGINEERING (CIVIL ENGINEERING)**

Saya **NURUL SHAHADAHTUL AFIZAH BT. ASMAN**, Sesi **2015/2016** mengaku membenarkan tesis Sarjana ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat – syarat kegunaan seperti berikut:

1. Tesis ini adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat Salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan untuk membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/):

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan Oleh,

NURUL SHAHADAHTUL AFIZAH BT. ASMAN
MK1511029T

(Tandatangan Pustakawan)

Tarikh: 1 Jun 2018

(Prof. Ir. Dr. Abdul Karim Mirasa)
Penyelia

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been duly acknowledged.

23 February 2018

.....

Nurul Shahadahtul Afizah bt. Asman

MK1511029T



UMS
UNIVERSITI MALAYSIA SABAH

CERTIFICATION

NAME : **NURUL SHAHADAHTUL AFIZAH BT. ASMAN**

MATRIK NO : **MK1511029T**

TITLE : **GREEN ROOF PERFORMANCE STUDY USING RUBBER CRUMB, OIL PALM WASTE MATERIAL AND NATURAL FIBRES FOR STORMWATER RUNOFF MITIGATION**

DEGREE : **MASTER OF ENGINEERING (CIVIL ENGINEERING)**

VIVA DATE : **7 FEBRUARY 2018**

CERTIFIED BY



1. SUPERVISOR (CHAIRMAN)
Prof. Ir. Dr. Abdul Karim Mirasa

Signature

2. SUPERVISOR (COMMITTEE)
Salinah Dullah

3. SUPERVISOR (COMMITTEE)
Janice Lynn Ayog

ACKNOWLEDGEMENTS

Assalamualaikum.....

Alhamdulillah, grateful to Allah SWT. for HIS blessing and permission, from the encouragement and support from various parties throughout the start and finally I can complete my master's project.

First of all, I would like to express my deepest gratitude and appreciation to my supervisors, Prof. Ir. Dr Abdul Karim Mirasa, Miss Salinah Dullah, and Mdm. Janice Lynn Ayog for all their advice, guidance and support in this research work that leads to the completion of this master's thesis. Without their continued support and interest, this thesis would not have been done. Only Allah S.W.T can reimburse them. This research was supported by Universiti Malaysia Sabah under the Grant RAG0061-TK-2014. I also would like to thank Minister of Higher Education, MyBrain15 for the scholarship support during my master's studies and thanks to the Faculty of Engineering, University Malaysia Sabah for providing the hydraulics lab for laboratory work.

Special thanks. Mr Ruslan Chew, Mr Hataf and Mr Afflizailizam, the staff of Faculty of Engineering laboratory for providing me with the equipment and helps required during my whole investigation procedure. I also would like to thank Nicklos Jeffrin, Ag Sharizal Ag Sulaiman and Nurul Haidatul Lyanti Asman for helping me in my laboratory work. I would like to stretch my gratitude to my family especially my parents thanks for giving me strength and providing all my needs during my study in University Malaysia Sabah. I am very grateful and appreciate their patience and passion for giving me support, trusting in me during this whole time periods and for always being on my side.

Finally, thanks to all who are involved directly or indirectly in the success of this thesis. Hopefully, your loyal service and kindness will be repaid in kind from Allah S.W.T.

Nurul Shahadahtul Afizah bt. Asman
23 February 2018

ABSTRACT

The purpose of this study is to investigate the green roof performance study using waste material and natural fibres for storm water runoff mitigation. The data were collected from different test bed under simulated rainfall with the intensity of 200 mm/h and testing were done for 0, 2 and 6% of slope. The design of green roof layers consists of waterproofing, drainage, filter, substrate and a vegetation layer. In this research, waste materials (WM) and natural fibres (NF) are used on the drainage and filter layer, respectively. Three stages involved during the data collecting process. Stage 1 is the drainage layer, followed by stage 2 (drainage layer with filter layer) and finally the stage 3 (drainage, filter, substrate and vegetation layer). A test bed with waterproofing layer as a control and three types of waste are selected for each test bed which is rubber crumbs, oil palm shells and polyfoam. Natural fibres as the filter layer in green roofs are placed on top of the drainage layer. Natural fibres chosen are coconut fibre, oil palm fibre and sugarcanes fibres. The plant used in the green roof is *Arachis pintoi*, which known for its hardy and vigorous growth across all seasons. Physical properties of materials are analysed to determine the diameter of fibres using a scanning electron microscope (SEM), the density of materials (specific gravity test) and, the water absorption of both natural fibres and waste materials. The weights of green roofs were measured before and after each stage for all the samples to determine the dry and wet weight of green roofs. The hydrological parameters recorded are the hydrograph and peak runoff, peak attenuation and water retention. The result indicates that the water retention percentages are higher as the slope increases and after the layer is added. For all simulation testing of green roofs made from WM and NF on hydrological performances, the water retention (RPI) are within the range of 31.92% to 87.09% and peak attenuation (PDPI) of 55.85% to 94.83%. OPSSF with a higher wet weight and live load of 19.19 kg/m² are acceptable. In conclusion, oil palm shells and sugarcanes fibres combinations perform the best hydrologically which have highest peak runoff, lowest peak attenuation and water retention compared to other combinations on 6% slope of green roof. The roof slope of 6% will give the best hydrological performance compared to the roofs laid flat or on 2% slope. Finally, the live load are higher that the control (drainage layer only) more than 34% on complete green roof systems.

ABSTRAK

KAJIAN PRESTASI BUMBUNG HIJAU MENGGUNAKAN SERBUK GETAH, KELAPA SAWIT SEBAGAI BAHAN BUANGAN DAN SERAT SEMULAJADI UNTUK MITIGASI LARIAN AIR HUJAN

Tujuan kajian ini adalah untuk menyiasat kajian prestasi bumbung hijau menggunakan bahan buangan dan serat semulajadi untuk mengurangkan larian air hujan. Data yang dikumpul dari katil ujian yang berbeza di bawah hujan simulasi dengan intensiti 200 mm/j dan ujian dilakukan untuk 0, 2 dan 6% cerun. Reka bentuk lapisan bumbung hijau terdiri daripada kalis air, saluran, penapis, substrat dan lapisan vegetasi. Dalam kajian ini, bahan buangan (WM) dan gentian semulajadi (NF) digunakan pada saluran dan lapisan penapis. Tiga peringkat yang terlibat semasa proses pengumpulan data. Tahap 1 ialah lapisan saluran, diikuti oleh tahap 2 (lapisan saluran dengan lapisan penapis) dan akhirnya tahap 3 (saluran, penapis, substrat dan lapisan vegetasi). Satu katil ujian dengan lapisan kalis air sebagai kawalan dan tiga jenis sisa dipilih untuk setiap katil ujian iaitu serbuk getah, kelapa sawit dan polyfoam. Serat semulajadi sebagai lapisan penapis di bumbung hijau diletakkan di atas lapisan saluran. Serat semulajadi yang dipilih adalah serat kelapa, gentian kelapa sawit dan serat tebu. Tumbuhan yang digunakan di bumbung hijau adalah *Arachis pinto*, yang terkenal dengan pertumbuhannya yang kuat dan bertenaga sepanjang musim. Ciri-ciri fizikal bahan dianalisis untuk menentukan diameter gentian menggunakan mikroskop elektron imbasan (SEM), ketumpatan bahan (ujian graviti spesifik) dan penyerapan air kedua-dua serat semula jadi dan bahan buangan. Berat bumbung hijau diukur sebelum dan selepas setiap peringkat untuk semua sampel untuk menentukan berat kering dan basah bumbung hijau. Parameter hidrologi yang direkodkan ialah larian hidrograf dan puncak, puncak pelemahan dan pengekalan air. Hasilnya menunjukkan bahawa peratusan pengekalan air lebih tinggi apabila cerun meningkat dan selepas lapisan ditambah. Bagi semua ujian simulasi bumbung hijau yang diperbuat daripada WM dan NF dalam prestasi hidrologi, pengekalan air (RPI) berada dalam lingkungan 31.92% hingga 87.09% dan puncak pengurangan (PDPI) sebanyak 55.85% kepada 94.83%. OPSSF dengan berat basah yang lebih tinggi dan beban hidup 19,19 kg/m² boleh diterima. Sebagai kesimpulan, gabungan minyak kelapa sawit dan gula serat melakukan hidrologi yang terbaik yang mempunyai larian puncak tertinggi, pelemahan puncak terendah dan pengekalan air berbanding kombinasi lain pada cerun 6% bumbung hijau. Cerun bumbung 6% akan memberikan prestasi hidrologi terbaik berbanding dengan bumbung yang rata atau pada cerun 2%. Akhirnya, beban hidup lebih tinggi iaitu kawalan (lapisan saluran sahaja) lebih daripada 34% pada sistem bumbung hijau yang lengkap.

LIST OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
<i>ABSTRAK</i>	vi
LIST OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xvi
LIST OF SYMBOLS	xvii
LIST OF APPENDICES	xviii
CHAPTER 1: INTRODUCTION	1
1.1 Research Background	1
1.2 Research Problem	4
1.3 Research Objectives	5
1.4 Scope of Research	6
1.5 Research Significant	7
1.6 Thesis Layout	7
CHAPTER 2: LITERATURE REVIEW	9
2.1 Introduction	9
2.2 Green Roof (GR)	9
2.2.1 Green Roof Components	11
2.2.2 Design methods	18

2.2.3	Weight of Extensive Green Roofs (Design Load)	21
2.2.4	Effect of Slope on Green Roof Performance	25
2.2.5	Benefit/advantage of Green Roofs	25
2.2.6	Green roof disadvantages/ obstacles	27
2.2.7	Green Roofs in Malaysia	29
2.3	Waste Materials and Natural Fibres in Green Roof (GR) System	31
2.3.1	Drainage ability of materials	33
2.4	Selection of Vegetation layer	35
2.5	Hydrological Performance	37
2.5.1	Hydrograph Shape and Peak Runoff	38
2.5.2	Peak attenuation	39
2.5.3	Green Roof Stormwater Retention	41
2.6	Stormwater Runoff Mitigation	44
2.7	Summary	46
	CHAPTER 3: METHODOLOGY	47
3.1	Introduction	47
3.2	Experimental Setup	50
3.2.1	Material Preparation	50
3.2.2	Green Roof Component Preparation	53
3.2.3	Rainfall Simulator	55
3.3	Green Roofs Design	56
3.3.1	Test Bed Design	57
3.3.2	Preparation of Test Bed	58
3.3.3	Green Roofs Design and Layers	60
3.4	Testing Procedure	61
3.4.1	Properties of Materials	62

3.4.2	Hydrological Performances Test (ASTM E2777)	67
3.4.3	Weight of Green Roofs (ASTM E2397)	70
	CHAPTER 4: RESEARCH FINDING	73
4.1	Introduction	73
4.2	Properties of Materials	73
4.3	Hydrological performances	76
4.3.1	Runoff Hydrograph and Peak runoff	76
4.3.2	Peak attenuation	89
4.3.3	Water Retention	95
4.4	Weight of Green Roofs	102
4.4.1	Stage 1: Waterproofing with Drainage Layer	103
4.4.2	Stage 2: Waterproofing with Drainage and Filter Layer	105
4.4.3	Stage 3: Complete GR System	110
4.5	Summary	117
	CHAPTER 5: CONCLUSION	119
5.1	Conclusion	119
5.2	Future Research and Recommendation	122
	REFERENCES	123
	APPENDICES	129

LIST OF TABLES

	Page
Table 2.1: Characteristics of green roof types	11
Table 2.2: Example of green roof layers as defined by different authors	13
Table 2.3: Example thickness of extensive green roofs layers as defined by different authors	14
Table 2.4: Initial Design Considerations for Green Roof (GR) System	19
Table 2.5: ASTM and ANSI Standard for Green Roof	20
Table 2.6: Weight of GR for wet conditions of GR as defined by different authors	22
Table 2.7: Type of loadings in GR system with description	23
Table 2.8: Environmental Advantages of GR system	26
Table 2.9: Obstacles of GR	28
Table 2.10: A comparison of GR building assessment criteria	29
Table 2.11: GR implementation in Malaysia	30
Table 2.12: Finding on waste materials use as a drainage layer in GR	33
Table 2.13: Saturated hydraulic conductivity	34
Table 2.14: General information on Arachis pintoii	36
Table 2.15: Factors affecting GR water retention and runoff dynamics	38
Table 2.16: PDPI ratio or percentage of peak runoff reduction by different authors	40
Table 2.17: Media depth of GR and effect on annual water retention	432
Table 2.18: Percentage of Water Retention	423
Table 2.19: Trends on GR Stormwater research concern	45
Table 3.1: Materials preparation	50
Table 3.2: Sample Preparation for Testing	54

Table 3.3:	Key to Component Names	55
Table 4.1:	Properties of natural fibres used in GR layer	74
Table 4.2:	Properties of waste materials used in GR layer	75
Table 4.3:	Peak runoff of GR system	87
Table 4.4:	Peak attenuation of GR among drainage layer	90
Table 4.5:	Peak attenuation comparison of GR with different type of drainage and filter layer	91
Table 4.6:	Peak attenuation comparison of complete GR system on 0, 2 and 6% slope	93
Table 4.7:	Water Retention (RPI) among drainage layer	96
Table 4.8:	Water retention (RPI) comparison of GR with different type of drainage and filter layer on 0, 2 and 6% slope	97
Table 4.9:	Water retention capacity of complete GR system made from RWM and NF on 0, 2 and 6% slope	101
Table 4.10:	Percentage of live load increment from control (waterproof layer) among drainage layer of GR	104
Table 4.11:	Percentage of live load increment from control of drainage layer of GR with different type of drainage and filter layer	110
Table 4.12:	Percentage of live load increment from control of drainage layer of complete GR system made from RWM and NF	116
Table 4.13:	Summarized data on GR performance in term of hydrological study for complete GR system	117
Table 4.14:	Summarized data on the effect of slope for GR performance	117

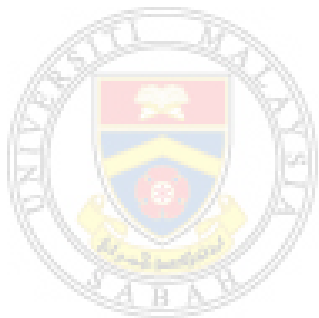
LIST OF FIGURES

	Page
Figure 2.1: Types of green roof	11
Figure 2.2: Cross-section of a representative extensive green roof system including typically used layers	12
Figure 2.3: RII on obstacles in adopting GR in Malaysia	27
Figure 2.4: Some of the implementation of GR in Malaysia: (a) Heriot-Watt University, Putrajaya, (b) Sime Darby Oasis, Damansara	31
Figure 2.5: Hydrograph shape of GR	39
Figure 3.1: Overall Methodology Flow Chart	48
Figure 3.2: Flow Chart for Each Stage	49
Figure 3.3: Materials preparation used in GR	51
Figure 3.4: Arachis pintoi (Vegetation used in the GR)	51
Figure 3.5: Process of sugarcane fibres production using hammer mill machine	52
Figure 3.6: Production of coconut fibre from coconut shell	53
Figure 3.7: Production of sugarcane fibre	53
Figure 3.8: Testing under a rainfall simulator	56
Figure 3.9: IDF curve for Inanam, Kota Kinabalu	56
Figure 3.10: Test Bed constructed on study area	57
Figure 3.11: Test bed design	58
Figure 3.12: Test bed design by parts	58
Figure 3.13: Process involved in the test bed preparation	59
Figure 3.14: Green roofs layer design	60
Figure 3.15: Experimental green roof system	61
Figure 3.16: Drainage Layer used in the GR: A. Oil Palm Shell,	

	B. Rubber Crumbs, C. Polyfoam	62
Figure 3.17:	Filter Layer used in the GR: A. Sugarcanes fibre (SF), B. Oil palm fibre (OPF), C. Coconut fibre (CF)	62
Figure 3.18:	Scanning Electron Microscope (SEM) located at IBTP laboratory in University Malaysia Sabah (UMS)	63
Figure 3.19:	Equipment use for specific gravity test located at concrete laboratory Faculty of Engineering UMS	64
Figure 3.20:	Specimen (natural fibres and waste materials) under water absorption	67
Figure 3.21:	Sample was weighted after 24 hour	67
Figure 3.22:	Green roof during testing	68
Figure 3.23:	Green roof slope setup	68
Figure 3.24:	Model GR during testing	69
Figure 3.25:	Floor scale	72
Figure 4.1:	Scanning electron micrograph (SEM) showing single strand of coir fibre: A. Coconut fibre, B. oil palm fibre, C. Sugarcane fibre	74
Figure 4.2:	Waste materials used in GR drainage layer: A. Rubber crumb, B. Polyfoam, C. Oil Palm Shell	74
Figure 4.3:	Hydrograph and peak flow comparison among drainage layer: (a) 0% slope, (b) 2% slope, (c) 6% slope	78
Figure 4.4:	Hydrograph shape comparison of GR with different type of drainage and filter layer on 0% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	80
Figure 4.5:	Hydrograph shape comparison of GR with different type of drainage and filter layer on 2% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	81
Figure 4.6:	Hydrograph shape comparison of GR with different type of drainage and filter layer on 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	82
Figure 4.7:	Hydrograph shape of complete GR system made from RWM and NF on 0% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	84

Figure 4.8:	Hydrograph shape of complete GR system made from RWM and NF on 2% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	85
Figure 4.9:	Hydrograph shape of complete GR system made from RWM and NF on 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	86
Figure 4.10:	Peak attenuation ratio of GR among drainage layer	90
Figure 4.11:	Peak attenuation percentage comparison of GR with different type of drainage and filter layer on 0, 2 and 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	92
Figure 4.12:	Peak attenuation comparison of complete GR system made from RWM and NF on 0, 2 and 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	94
Figure 4.13:	Water retention percentage among drainage layer	96
Figure 4.14:	Percentage of water retention comparison of GR with different type of drainage and filter layer on 0, 2 and 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	98
Figure 4.15:	Percentage of water retention of complete GR system made from RWM and NF on 0, 2 and 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	100
Figure 4.16:	Mean weight of Green Roofs for dry and wet weight among drainage layer on 0, 2 and 6% slope	103
Figure 4.17:	Mean live load of GR among drainage layer on 0, 2 and 6% slope	104
Figure 4.18:	Mean weight comparison of GR with different type of drainage and filter layer on 0% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	106
Figure 4.19:	Mean weight comparison of GR with different type of drainage and filter layer on 2% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	107
Figure 4.20:	Mean weight comparison of GR with different type of drainage and filter layer on 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	108
Figure 4.21:	Mean live load comparison of GR with different type of drainage and filter layer on 0, 2 and 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	110

Figure 4.22: Mean weight comparison of complete GR system made from RWM and NF on 0% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	111
Figure 4.23: Mean weight comparison of complete GR system made from RWM and NF on 2% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	112
Figure 4.24: Mean weight comparison of complete GR system made from RWM and NF on 6% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	113
Figure 4.25: Mean live load comparison of complete GR system made from RWM and NF on 0% slope: (a) OPS with NF, (b) PF with NF, (c) RC with NF	115



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF ABBREVIATIONS

ANSI	-	American National Standards Institute
ASTM	-	American Society for Testing and Materials
C	-	Control
DL	-	Dead Load
GR	-	Green Roof
IBC	-	International Building Code
LL	-	Live load
NF	-	Natural Fibre
NRCA	-	National Roofing Contractors Association
OPF	-	Oil Palm Fibre
OPS	-	Oil Palm Shell
PDPI	-	Peak Discharge Performance Index
PF	-	Polyfoam
RII	-	Relative Importance Index
RPI	-	Retention Performance Index
R	-	Runoff
RC	-	Rubber Crumbs
SA	-	Surface Area
SF	-	Sugarcane Fibre
WBDG	-	Whole Building Design Guide
WM	-	Waste Materials

LIST OF SYMBOLS

Δt	-	Duration of the test
ρ	-	Bulk density (kg/m ³)
ρ_w	-	Water density at 24°C (1000 kg/m ³)
A	-	Cross-section area of the flow
H	-	Hydraulic pressure difference
K_s	-	Saturated hydraulic conductivity
L	-	Length of sample in column
M_a	-	Mass in air
M_w	-	Mass in water
SF	-	Sugarcane Fibre
SG	-	Specific gravity
V	-	Cumulative volume of percolated water
W	-	Water absorption capacity
W_d	-	Weight during dry conditions
W_w	-	Weight during wet conditions
W_{sw}	-	Weight of soaked
W_{ad}	-	Weight of air dried

LIST OF APPENDICES

	Page
Appendix A.1 Annual Maximum Rainfall Data (mm) for 32 years for 5min, 10min, 15min, 30min, 45min, 60min, 120min, 180min, 360min, 720min, 1440min (Department of Irrigation and Drainage, Sabah)	129
Appendix A.2 Calculation of return period, xT (mm) for Annual Maximum Rainfall for 32 years	140
Appendix B Simulator Rainfall (Precipitation) - Rain gauge	143
Appendix C Properties of materials used in Green Roofs	145
Appendix D Green Roof Experiment Measurement Runoff Data	146
Appendix E Calculation of peak runoff (mm) and peak attenuation (%)	152
Appendix F Stormwater Retention Capacity	153
Appendix G Green Roofs Weight on Dry and Wet Conditions (kg)	155
Appendix H Calculation of Mean Dry Weight, Wet Weight and Live Load	159
Appendix I List of Publications	160

CHAPTER 1

INTRODUCTION

1.1 Research Background

The United Nations (2012) predicted that the developing countries population will rise from 5.9 billion in 2013 to 8.2 billion in 2050. Hence, to cater for space expansion due to population rise, urbanization such land clearing and deforestation increase the impervious surface on urban catchments. Additionally, studies indicate global warming may cause increased frequency of rainfall events, leading to increased localized and flash floods (Berndtsson, 2010). Sustainable Urban Design System (SUDS), Best Management Practices (BMPs), Low impact Development (LID) and Water Sensitive Urban Design (WSUD) offers new insight to reduction controls, such as green roofs, can provide temporary storage spaces and promoting infiltration, thus mimic pre-development natural hydrologic functions.

In general, green roof are usually formed by the following layers (Pérez, Vila, Rincón, Solé, and Cabeza, 2012):

- Vegetation layer: upper layer in the GR system which consists of a plant that intercepts the water during rainfall.
- Substrate layer: usually top soil or garden soil. It is the physical support for the plants, where it provides nutrients and should have the capacity to retain water.
- Filter layer: usually geotextiles membranes. It allows water to cross but not of the substrate small particulates that could clog the cavities in the drainage layer.
- Drainage layer: must be able to retain water when it rains, while ensuring good drainage and aeration of the substrate and roots.

- Waterproofing layer: protects the building from the roots and water.

Green roofs are typically divided into two main engineering categories: intensive and extensive (Berndtsson, 2010). Intensive green roofs are recognized with deep substrate layers, which can support larger plants, require frequent maintenance and the total depth is more than 150 mm. Extensive green roofs are established with thin substrate layers, supports smaller plants and typically maintenance free. The total depth of an extensive green roof is normally less than 150 mm (Berretta, Poë, and Stovin, 2014; Carter and Rasmussen, 2006; Mentens et al., 2006; Molineux, Fentiman, and Gange, 2009; Ouldboukhitine, Belarbi, and Djedjig, 2012; Pérez et al., 2012; Rincón et al., 2014; Stovin et al., 2012; VanWoert et al., 2005; Voyde, Fassman, and Simcock, 2010; Wong and Jim, 2014). The extensive green roof also much favored for retrofitting purposes and light-weight compared to intensive green roof. Voyde et al. (2010) fixed its target maximum wet weight somewhat arbitrarily set at 100 kg/m² as its green roof design goal and work backwards to calculate the depth of the substrate layer (50 mm). Rincón et al. (2014) found that the green roofs used in the research to the conventional roof with gravel one (918 kg or 102 kg/m²). In striving to find the optimum and sustainable extensive green roof design, the issue of the live load in wet conditions is hence, very important.

The most complete and recognized set of green roofs standards and guidelines are the "Guideline for the Planning, Construction and Maintenance of Green Roofing". These guidelines are published by the German organization Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) and are commonly referred to as the German FLL Guidelines. In addition to FLL guidelines, in North America the industry of green roof has developed further guidance, specific to North American design and construction procedures. A sampling of these codes and standards include International Building Code (IBC), American Society for Testing and Materials (ASTM), National Roofing Contractors Association (NRCA), Whole Building Design Guide (WBDG) and American National Standards Institute (ANSI) (ISWMM, 2015). The standard guide for green roof systems are based on ASTM E2777-15.

Several studies have been previously conducted to study various aspects of green roofs runoff performance using conventional materials on flat roofs, where this topic as far from being exhausted as the research area. Specifically, due to the need for sustainable practices to be implemented in construction, new studies can be conducted in the area of green roof performance for stormwater runoff using green and economical materials in the green roof layers with different percentage of green roof slope. The green roof limitations are access to the rooftop, installation cost and building capacity to support structure.

The success of the extensive green roof in mitigating stormwater runoff lies on its water retention capacity and runoff dynamics. One of the factors influencing green roof water retention capacity and runoff dynamics is the roof slope (Berndtsson, 2010). However, the different studies on slope influences on green roofs runoff retention capacity bring different results. VanWoert et al. (2005) observes that runoff retention may depend on a slope. The effect of runoff retention can be seen with the influence of roof slopes coupled with other factors such as the design of green roof layers and the presence of different type drainage materials.

Green roofs may work as a source control measure as they have capability of retaining the rainfall by and distributing the runoff slowly through the green roof layers. This technology helping in reducing the runoff discharges which contributing to reduce flash floods. It is proven by several research that highlight the importance of green roof application including the ability of green roof to retain stormwater (VanWoert et al., 2005), delay peak discharge time (Carter and Rasmussen, 2006) and attenuate peak discharge volume (Mentens, Raes, and Hermy, 2006; Stovin, Vesuviano, and Kasmin, 2012).

Potential applications can be gained by implementation of green roofs using natural fibres and waste materials which are (i) external or internal thermal reduction for thermal comforts in residential buildings; (ii) reducing noise and air pollutions in urban catchments; (iii) sustainable green materials to be used in producing green roofs and green buildings; (iv) green roofs can be way to reduce

stormwater runoff and flooding in urban catchments in Malaysia; and (iv) using green and economical waste materials in green roof is sustainable and may lead to cost-savings in building constructions.

1.2 Research Problem

Green building technology is currently a popular research around the world. As cited Anne (2010) his her research stated that the engineers and scientist are focusing on green building by trying to reduce the energy consumption and global warming. However, most of these researches done by the United States and European nations might not be suitable to be applied in Malaysia buildings setting. Other than that, green building technologies has not achieve a abundant attention from local researchers to create the green technology that could be adapted by engineers and contractors to be practical into typical building in Malaysia.

Malaysia climate considered as a dry hot all over the year with heavy rain on specific periods. Due to its geographical location with an average rainfall over 2000mm per year, is prone to suffer from floods and flash floods especially during cyclical monsoon cold surge episodes which are characterized by extreme rainfall from roughly November to February (Ayog, 2017).

Green roofs are the new technology of green building which represented by the vegetative layer of the roof. The conventional roof of buildings in Malaysia is made from zinc. As part of this project, the performance of green roof would be investigated for the hydrological performance in term of (i) runoff hydrograph and peak runoff, (ii) peak attenuation and the water retention.

Many researchers have studied the cooling effect of the green roof without focusing on an alternative to replacing the conventional material in the green roof system. In the same time, Malaysia is facing a waste material problem because there is not enough technology to reduce this waste material by recycling or reusing as substitution material in other material's component. The best practice is