

UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate : HAFSAH BT YAHAYA (I.C NO: 800824-02-5338)

Registration/Matric No: BGC080004

Name of Degree : MASTER OF SCIENCE (BUILDING)

Title of Thesis : MAINTENANCE OF RAINWATER HARVESTING (RWH)
SYSTEM IN MALAYSIA

Field of Study : BUILDING MAINTENANCE

I do solemnly and sincerely declare that:

- (1) I am the sole author/writer of this Work;
- (2) This Work is original;
- (3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
- (4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
- (5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
- (6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate's Signature

Date

Subscribed and solemnly declared before,

Witness's Signature

Date

Name : ASSOCIATE PROFESSOR Sr Dr. AZLAN SHAH ALI
Designation : DEPUTY DEAN (HIGHER DEGREE), FAB, UM

Dedication

This dissertation is especially dedicated to family, especially to my beloved husband Adi Irfan Che Ani who becomes my strength and my inspiration in completing my thesis. Unforgettable to my children's Alya Batrisyia and Azri Danial, both of my parents and my parents in law and other family members who always give me their support in completing my master.

*Hafsah Yahaya
Universiti Malaya
January 2012*

ACKNOWLEDGEMENT

In the name of God, the most gracious, the most merciful

I have been advised that, instead of trying to name all the people who helped with the creation of this thesis, it would be better to just thank everyone born since Adam and Eve.

More than that, I would like to express my extreme gratitude to the people who have provided the most enthusiastic help to make this dissertation a success, a special gratitude dedicate to Associate Professor Sr Dr. Azlan Shah Ali as my supervisor for his never-ending advice and guidance during the preparation of this research.

Special recognition is also given to the buildings management who has given permission and information for me to carried out condition survey and questionnaire survey, for their valuable time, knowledge and sharing experience. This incredible amount of help has advanced the author's knowledge in this research.

Last but not least, I would like to thank my beloved husband Adi Irfan Che Ani who becomes my strength and inspiration in completing my thesis. Unforgettable to my children's Alya Batrisyia and Azri Danial, both of my parents and my parents in law and other family members who always give me their support during the preparation of this thesis.

Thanks again and May God Bless All of You.....

ABSTRACT

The application of Rainwater harvesting (RWH) system in Malaysia is still considered as a new phenomenon. However, with the support and effort of government in promoting the application of RWH in building, the number of building using the RWH is increased gradually. The system has been applied for various types of building such as housing, institutional and commercial. Even though the application of RWH is ongoing, there is no specific guideline in maintaining RWH. Maintenance performance is the key aspect in sustaining the RWH system. With the initial investment in installing the RWH, the organization must be able to monitor their investment in the form of maintenance performance. This will ensure the building owner achieve the value for money. The physical condition of RWH supports the ideas in tracking maintenance performance as a whole. Therefore, this research focuses on the improvement of maintenance management of RWH system with focusing on maintenance performance in Malaysia. This research used quantitative approach for data collection and data analysis. The conceptual framework of rainwater harvesting (RWH) system has been established before collection of the main data. There were two instruments implemented in this research namely physical condition survey and questionnaire survey. These instruments were developed based on the outlined conceptual framework. Condition survey has been carrying out to 16 buildings throughout the Peninsular Malaysia, and the data was analysed using CSP1 matrix. The results show only two buildings rated as dilapidated while fourteen buildings rated as good and fair. Questionnaire survey was distributed to three respondents for each building. A total of 48 respondents throughout Peninsular Malaysia were involved in the data collection. The data obtained later form a database and analysed using Statistical Package for Social Sciences (SPSS). The results of difficulties in maintaining RWH system in the building shows mean score less than 2.0, which consider as low. Both results demonstrated cross-combination finding via maintenance performance quadrant at the end of analysis and shows majority of buildings need improvement in terms of their maintenance management, while only two buildings regarded has as bad practice, which needs total refurbishment for the RWH system as well as the management. In conclusion, the physical condition of the RWH system is regarded good and safe implemented in the buildings. However, the maintenance of the system can be improved with a proper guideline and management policy by the organization involved. This is to ensure that the maximum value of installing the RWH system as well as ensuring the system performs to its intended design throughout the building's lifetime.

ABSTRAK

Aplikasi sistem penuaian air hujan (RWH) sistem di Malaysia masih dianggap sebagai suatu fenomena baru. Walau bagaimanapun, dengan sokongan dan usaha kerajaan dalam menggalakkan penggunaan RWH dalam bangunan, bilangan bangunan yang menggunakan RWH meningkat dari semasa ke semasa. Sistem ini telah digunakan untuk pelbagai jenis bangunan seperti perumahan, institusi dan komersil. Walaupun aplikasi RWH sedang digunakan, namun tiada garis panduan khusus dalam menyenggara RWH. Prestasi penyenggaraan adalah kunci utama dalam mengekalkan sistem RWH. Dengan pelaburan awal dalam memasang RWH, organisasi mesti berupaya untuk memantau pelaburan mereka dalam bentuk prestasi penyenggaraan. Ini bagi memastikan pemilik bangunan mencapai nilai untuk wang mereka. Keadaan fizikal bagi RWH menyokong idea dalam melaksanakan pemerhatian terhadap prestasi penyenggaraan secara menyeluruh. Sehubungan dengan senario ini, kajian ini fokus terhadap penilaian prestasi penyenggaraan RWH di Malaysia. Kajian ini menggunakan pendekatan kuantitatif untuk pengumpulan data dan analisis data. Sistem rangkakerja konsep penuaian air hujan (RWH) telah dibina terlebih dahulu sebelum meneruskan kerja-kerja pengumpulan data utama. Terdapat dua instrumen yang digunakan untuk kajian ini iaitu ukur kondisi dan soal selidik. Instrumen ini dibangunkan berdasarkan rangka kerja konsep yang telah digariskan. Kerja ukur kondisi telah dijalankan terhadap 16 bangunan di seluruh Semenanjung Malaysia dan data dianalisis menggunakan CSP1 matriks. Keputusan menunjukkan hanya 2 bangunan yang dinilai sebagai usang manakala (14) bangunan lagi dinilai sebagai baik dan sederhana. Tinjauan soal selidik pula telah dijalankan keatas 3 orang responden dari setiap bangunan dimana jumlah keseluruhan adalah 48 responden dianalisis dengan menggunakan Statistic Package for Science Social (SPSS). Keputusan dari kesulitan dalam penyenggaraan sistem RWH dalam bangunan itu menunjukkan min skor di bawah nilai 2.0 yang boleh dianggap sebagai rendah. Kedua-dua keputusan menunjukkan data kombinasi bersilang melalui kuadran prestasi penyenggaraan pada akhir analisis dan majoriti bangunan keperluan peningkatan dari perspektif organisasi mereka. Manakala hanya 2 bangunan mempunyai amalan tidak berkesan yang memerlukan perubahan secara keseluruhan baik dari perspektif sistem RWH itu sendiri ataupun organisasi mereka. Kesimpulannya, sistem RWH adalah baik dan berfaedah untuk dilaksanakan di dalam sesebuah bangunan tetapi ianya mestilah disertakan bersama-sama dengan amalan penyenggaraan yang berkesan. Ini bagi memastikan nilai maksimum penggunaan sistem RWH dan perkhidmatan yang terbaik bersesuaian dengan rekabentuk jangka hayat sesebuah bangunan.

TABLE OF CONTENT

<i>Declaration</i>	<i>ii</i>
<i>Dedication</i>	<i>iii</i>
<i>Acknowledgement</i>	<i>iv</i>
<i>Abstract</i>	<i>v</i>
<i>Abstrak</i>	<i>vi</i>
<i>Table of Content</i>	<i>vii</i>
<i>List of Figure</i>	<i>x</i>
<i>List of Table</i>	<i>xi</i>
<i>List of Abbreviation</i>	<i>xii</i>

1.0 INTRODUCTION

1.1	Preface	1
1.2	Problem Statement	2
1.3	Research Foundation	3
1.4	Objectives of the Study	4
1.5	Research Methodology	4
1.6	Research Scope	6
1.7	Research Outline	7
1.8	Significance of the Study	8
1.9	Summary	10

2.0 RAINWATER HARVESTING PRACTICES

2.1	Preface	11
2.2	An Overview of Rainwater Harvesting in Malaysia	12
2.3	Previous Research About Rainwater Harvesting	15
2.4	The Concept of Rainwater Harvesting	25
	2.4.1 The Background of Rainwater Harvesting	27
	2.4.2 The Element in Rainwater Harvesting System	29
2.5	Rainwater Harvesting Practice in The World	35
2.6	Rainwater Harvesting Practice in Malaysia	43
2.7	Rainwater Harvesting Implementation Issue in Malaysia	47
2.8	Summary	51

3.0 THE CONCEPTUAL DEVELOPMENT OF RAINWATER HARVESTING EVALUATION

3.1	Preface	52
3.2	The Rainwater Harvesting Maintenance Evaluation Practices	53
3.2.1	Building Performance Evaluation	54
3.2.1.1	Building Performance Levels, a Development of Hierarchy of Users; Needs and Priorities	56
3.2.1.2	Development in Building Assessment Techniques	56
3.2.1.3	Office and Commercial Building Performance	57
3.2.2	Building Condition Survey	59
3.3	Developing Rainwater Harvesting Maintenance Evaluation Framework	62
3.4	Summary	67

4.0 RESEARCH METHODOLOGY

4.1	Preface	68
4.2	Research Design	69
4.2.1	Research Process	69
4.2.2	Population	72
4.2.3	Formulation of Research Instrument	74
4.2.4	Method of Data Collection and Analysis	75
4.2.4.1	Condition Survey	76
4.2.4.2	Questionnaire survey	77
4.2.4.3	Combination of Analysis- RWH Maintenance Performance Quadrant	78
4.3	Summary	80

5.0 DATA ANALYSIS AND FINDINGS

5.1	Preface	81
5.2	Condition Survey	81
5.3	Questionnaire Survey	85
5.3.1	Internal Consistency of the Scale	85
5.3.2	Profile of Respondents	86
5.3.3	Maintenance of RWH System	90
5.3.3.1	Maintenance Approach Implement for RWH in the Building	90
5.3.4	Demographic Influence on Preferred Coaching Behaviors	94
5.3.4.1	The Relationship between Difficulties and Involvement in Maintaining RWH System	96

5.3.4.2	The Relationship between Difficulties in Maintaining RWH System and Operation of the Building	96
5.3.4.3	The Relationship between Difficulties in Maintaining RWH System and RWH Installation	97
5.4	Discussion of Findings: Quadrant Analysis	98
5.5	Summary	100

6.0 CONCLUSION AND RECOMMENDATION

6.1	Preface	101
6.2	Objectives Achievement	102
6.3	Main Conclusion of the Study	105
6.4	Recommendation for Further Research	106

REFERENCES 108

APPENDICES

Appendix A	117
Appendix B	121
Appendix C	122
Appendix D	123
Appendix E	125
Appendix F	141

LIST OF FIGURE

Figure 2.1:	Rainwater Collection Category	16
Figure 2.2:	Main area of previous research about RWH	19
Figure 2.3:	Elements of Rainwater Harvesting System (RWH)	29
Figure 2.4:	Examples of first flush diverters	31
Figure 2.5:	Development of Rainwater Harvesting System Implementation in Malaysia	45
Figure 2.6:	Development of Rainwater Harvesting System Inhibit Factors	48
Figure 3.1:	Conceptual Framework of Rainwater Harvesting Maintenance	62
Figure 4.1:	Research Process	71
Figure 4.2:	Photograph/sketch box	125
Figure 4.3:	Defect plan tags	125
Figure 4.4:	Executive Summary	126
Figure 4.5:	RWH Maintenance Performance Quadrant	79
Figure 5.1:	Photograph/sketch box of JPS SPT defects	82
Figure 5.2:	Photograph/sketch box of Pasar Taman Permai defects	83
Figure 5.3:	Photograph/sketch box of Municipal Courts and Food Court defects	83
Figure 5.4:	Category of respondent	86
Figure 5.5:	Involvement in maintaining RWH System	87
Figure 5.6:	Operation of the building	87
Figure 5.7:	RWH system installation	88
Figure 5.8:	Type of delivery system	89
Figure 5.9:	Numbers of trees	89
Figure 5.10:	Performance of RWH System	91
Figure 5.11:	Maintenance Performance Quadrant of RWH in Malaysia	98

LIST OF TABLE

Table 2.1:	Previous research about RWH in relation to RWH research area	20
Table 2.2:	List of Rainwater Harvesting Projects in Malaysia	46
Table 4.1:	Population for this research and data collection status	73
Table 4.2:	Condition Assessment Protocol 1	121
Table 4.3:	Priority Assessment	121
Table 4.4:	The matrix	121
Table 4.5:	The descriptive value according to score	121
Table 4.6:	Overall building ratings	121
Table 4.7:	Schedule of Building Condition	122
Table 5.1:	Summary of Condition Survey Protocol (CSP) 1	84
Table 5.2:	Reliability coefficients	86
Table 5.3:	Maintenance approach	90
Table 5.4:	Routine inspection	91
Table 5.5:	Problem in maintaining RWH System	92
Table 5.6:	Part of RWH element	92
Table 5.7:	Defect occurred for RWH System	93
Table 5.8:	Saving water consumption	93
Table 5.9:	Breakdown	94
Table 5.10:	Degree of difficulties	94
Table 5.11:	Summary of result of univariate ANOVA (The relationship between difficulties and involvement in maintaining RWH System)	95
Table 5.12:	Summary of result of univariate ANOVA (The relationship between difficulties in maintaining RWH System and operation of the building)	96
Table 5.13:	Summary of result of univariate ANOVA (The relationship between difficulties in maintaining RWH System and RWH system installation)	97

LIST OF ABBREVIATION

AGWF	Australian Government Water Fund
ANOVA	Univariate Analysis of Variance
BPE	Building Performance Evaluation
CP BS101	Code of Practice for Building Inspection report
CSP1 Matrix	Condition Survey Protocol (1) Matrix
DID	Department of Irrigation and Drainage
DPAK	Dasar Pengurusan Aset Kerajaan
<i>et al.</i>	[et alia]: and others
FOMCA	Federation of Malaysian Consumer Association
GBI	Green Building Index
IBPE	International Building Performance Evaluation
JBA	Jabatan Bekalan Air
JPS	Jabatan Pengairan dan Saliran
KeTTHA	Ministry of Energy, Green Technology and Water
LA	Local Authority
MHLG	Ministry of Housing and Local Government
NAHRIM	National Hydraulic Research Institute of Malaysia
NCARB	National Council or Architectural Registration Boards
NUP	National Urbanization Policy
PCRWR	Pakistan Council of Research in Water Resources
POE	Post-Occupancy Evaluation
RWH	Rainwater harvesting
SPSS	Statistical Package for Social Sciences
TAM	Total Asset Management