

MAINTENANCE FACTORS IN BUILDING DESIGN

ROZITA BINTI ARIS

A thesis submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Construction Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

May 2006

Dedicated to my beloved husband Mohamad Rosli Haron, my children and parent, for their everlasting support and encouragement to complete the course of studies.

ACKNOWLEDGEMENT

First and foremost, Thank you to Allah for his blessings and bestow to me with patience, perseverance and high spirit.

I owe special thanks to Ir. Dr. Rosli Mohamad Zin as my supervisor for MAB0024. He has always been a very supportive person and his guidance and advices gave me many valuable lessons.

In this opportunity, I would like to convey a million thanks and appreciation to all my friends for their time in helping me to complete this thesis.

Finally, thank you to my beloved husband, children and my parents who always have strong faith in me and provide me with countless support in terms of time, materials and morals.

ABSTRACT

The degree to which the design of a building embraces maintenance considerations has a major impact on its performance. In Malaysia for instance, most designers claimed to have knowledge and experience on building maintenance aspects but only few are aware of the importance to consider maintenance factors during design stage. A survey was carried out on 38 designer firms (architectural, civil & structural consultant firms) and 30 maintenance firms located in Shah Alam and Kuala Lumpur districts. The aim was to find out the building defects and other maintenance problems that are heavily attributed to design deficiencies, inadequate information gathering, material limitations and lack of maintenance knowledge. The data were analyzed using SPSS (Statistical Package of Social Sciences). Findings show that main problems that the maintenance firms are currently facing are caused by building design deficiencies, poor construction quality and poor performance of building which is directly related to functional layout, choice of building material and choice of building equipment. It appears that designer firms consider maintenance factors like ease of cleaning, access to cleaning area and repair and replacement to be the least important when designing buildings. Lack of communication between designer firms and maintenance firms as well as building users or owners resulted in designer firms not fully aware of the maintenance-related problems frequently reported by building owners. Designers seem to be neglecting the benefits of designing for ease of maintenance that can prolong the building lifespan, reduce defects rate and therefore reduce maintenance costs. Therefore, it is important for project team management to develop awareness and policy from the very early start of project to ensure the concept for ease of maintenance can be understood and implemented successfully in local construction practice.

ABSTRAK

Rekabentuk bangunan yang mengambilkira aspek penyelenggaraan sewaktu fasa rekabentuk, mempengaruhi prestasi bangunan tersebut apabila ia beroperasi sepenuhnya. Di Malaysia contohnya, kebanyakan perekabentuk bangunan (yakni khususnya para arkitek dan jurutera rekabentuk) mendakwa mereka mempunyai pengalaman mencukupi dalam bidang penyelenggaraan tetapi masih ramai yang kurang mengambilkira aspek penyelenggaraan sewaktu sesebuah bangunan direkabentuk. Satu kajian tempatan telah dijalankan ke atas 38 buah syarikat rekabentuk (konsultansi arkitek dan/atau kejuruteraan awam/struktur) dan 30 buah syarikat penyelenggaraan bangunan di sekitar Shah Alam dan Kuala Lumpur. Tujuan kajian dijalankan adalah untuk mengenalpasti masalah-masalah penyelenggaraan bangunan masakini, khususnya masalah yang berpunca dari kegagalan rekabentuk, kekurangan maklumat, penggunaan bahan binaan yang tidak menepati fungsi bangunan dan kurangnya pengetahuan berkenaan aspek penyelenggaraan. Data yang diperolehi dianalisa menggunakan SPSS (Statistical Package of Social Sciences). Hasil kajian menunjukkan, masalah-masalah utama yang selalu dihadapi oleh syarikat penyelenggaraan bangunan masakini berpunca dari tiga sumber; kegagalan rekabentuk bangunan dari segi contohnya fungsi bangunan, pembinaan kurang berkualiti yang antaranya puncanya adalah kelemahan penyeliaan dan kegagalan atau kelemahan fungsi bangunan itu sendiri sewaktu dalam fasa pembinaan. Kurangnya interaksi antara pihak rekabentuk dan pihak penyelenggaraan mengakibatkan perekabentuk kurang peka dengan permasalahan yang dihadapi oleh syarikat penyelenggaraan dan pengguna bangunan di peringkat operasi. Oleh yang demikian, adalah penting bagi pengurusan sesebuah projek menitikberatkan isu-isu penyelenggaraan sedari awal lagi bagi mengurangi masalah tersebut di atas.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE PAGE	i
	CERTIFICATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF APPENDICES	xiv
1	INTRODUCTION	
1.1	Introduction	1
1.2	Problem Statement	2
1.3	Aim and Objectives	4
1.4	Brief Methodology	4
1.5	Scope of Work	6

2	MAINTENANCE	
2.1	Introduction	7
2.2	Maintenance Policy	9
2.2.1	What Maintenance Has To Achieve ?	9
2.2.2	What Is To Be Gain?	10
2.2.3	How Shall We Proceed ?	10
2.3	Maintenance Planning	10
2.4	Building Maintenance	12
2.5	Building Owner and Maintenance	13
3	BUILDING DEFECTS	
3.1	Introduction	16
3.2	Building Defects	18
3.3	The Effects of Design Defects on Maintenance	19
3.3.1	Shape or Form of the Building	20
3.3.2	Choice of Material or Finishes	20
3.3.3	Construction Techniques to Suit Design	21
4	DESIGN AND MAINTENANCE	
4.1	The Role of a Designer	24
4.2	Total Building Maintenance	25
4.3	Involvement of Maintenance Personnel during the Design Stage	26
4.4	Link Between Design and Maintenance	27
4.5	Characteristics of Building Design	28
4.6	Design for Ease of Maintenance Concept	30
4.7	Design Considerations for a Quality Building	31
4.8	Operational Lessons as Data for Feedback	34

5	RESEARCH METHODOLOGY	
5.1	Introduction	37
5.2	Literature Review	38
	5.2.1 Text Based Material	38
	5.2.2 Preliminary Interview	39
5.3	Research Setting	39
	5.3.1 Develop Questionnaire	40
	5.3.1.1 Maintenance Firms' Questionnaire	40
	5.3.1.2 Designer Firms' Questionnaire	41
5.4	Post Questionnaire and Interview	42
	5.4.1 Problems and Limitations	42
5.5	Data Collection and Analysis	43
5.6	Validation of Recommendation	44
5.7	Conclusion	44
6	RESULTS AND DISCUSSION	
6.1	Introduction	45
6.2	Maintenance Firm Questionnaire	46
	6.2.1 General Characteristics of Respondents	46
	6.2.2 Characteristics of Managed Buildings	49
	6.2.3 Maintenance-Related Problems	51
	6.2.4 Building Management Factors	56
	6.2.5 Interaction with Designer Firms	57
	6.2.6 Input to Designers	60
	6.2.7 Summary of Findings from Maintenance Firm Questionnaire	61
6.3	Designer Firm Questionnaire	63
	6.3.1 Designers' View in Building Equipment and Material	63

6.3.2 Designers' Existing Maintenance-Related Knowledge	65
6.3.3 Interaction with Maintenance Firms	68
6.3.4 Complaints on Maintenance-Related Problems	73
6.3.5 Summary of Findings from Designer Firm Questionnaire	77
6.4 Critical Factors When Designing A Building	79
7 CONCLUSION AND RECOMMENDATION	
7.1 Conclusion	81
7.2 Recommendations	83
REFERENCES	84 – 85
Appendices A - B	86 – 96

LIST OF TABLES

TABLE NO.	TITLE	PAGE
6.1	Number and Age of Building Managed by Maintenance Firms	50
6.2	Percentage of Complaints by Users according to Category of Complaints and Size of Building	55
6.3	Age of firms and Level of Training in Building Operation and Maintenance	67
6.4	Age of firms and Level of Knowledge in Building Operation and Maintenance	68
6.5	Age of Designer Firms and Communication With Maintenance Firms	71
6.6	Age of Business and Complaints Received from Building Owners	73
6.7	Comparison of Five Most Important Maintenance Factors in Designing building	77

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Methodology Flowchart	5
4.1	Design considerations for a quality building	33
4.2	Proposed Design/Construction Maintenance Feedback	35
6.1	Factors in Managing Building Maintenance	48
6.2	Size of Buildings Managed by Maintenance Firms	51
6.3	Problems Faced by Maintenance Firms in Building Maintenance	52
6.4	Complaints received from Building Users	54
6.5	Important Factors According to Maintenance Firms in Managing Buildings	57
6.6	Communication between Maintenance and Designer Firms	59
6.7	Designers' Assessment to Building Performance	59
6.8	Input to Designers by Maintenance Firms	60
6.9	Criteria used by Designers in Specifying Materials for Buildings	65
6.10	In-house Training or Outside Seminars on Building Operation and Maintenance	67
6.11	Designers get Input from Future Building Managers	70

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
6.12	Engagement of Maintenance Consultants during Design stage	72
6.13	Complaints received from Building Users	74
6.14	Important Maintenance Factors according to Designer Firms in Managing Buildings	76

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Questionnaire for Maintenance Firm	86 – 90
B	Questionnaire for Designer Firm	91 – 96

CHAPTER 1

1.1 Introduction

With the increasing costs of new construction, the effective maintenance of the existing building stock has become even more important. Increasingly, building owners are beginning to accept that it is not in their best interest to carry out maintenance in a purely reactive manner, but that it should be planned and managed as efficiently as any other corporate activity. Inevitably, this has placed new demands on building owners, requiring them to adopt a more systematic approach to their work. This is where the concept of design for ease of maintenance comes in.

Modern buildings are designed to meet higher builder standards which demand longer life span and control of the decaying processes. This demand high maintenance budget. Therefore, it is of great importance to consider maintenance of building aspects during design stage for the future performance of the building. Somehow, with the help of modern technology, new inventions in building equipments and design software, building design becomes easier. With little input, all work will be computed by computer software.

This research reviews on the issues of design maintenance factors in civil and architectural design aspects and proposes eight critical factors for designers to take into

account during design stage. A design maybe executed perfectly well within the Code of Practice that have been enforced onto, but the building may fail to perform properly if these parameters are imperfectly set and/or neglected.

1.2 Problem Statement

Reports and researches have shown that some countries, especially developed nations like Singapore and United States, have already practice total building performance audit, benchmarking and quality management procedures in guiding developments towards improved maintainability (Chew *et al.*, 2004). Malaysia despite, being a developing country, are moving up quickly in every area, including building construction. We can be proud with our large and complex projects which are equipped with modern, latest technology in terms of aesthetic values, performances, energy saving and services offered. However, modern buildings are designed to meet higher building standards than in previous time, and this demand more long lasting durable building conditions. The influence of design on the maintenance of buildings is greater than ever before (Arditi *et al.*, 1999).

The costs of design and construction are minor compared to the total costs of a structure. Typically, 50% to 80% of the total cost will occur during (the) in-service life and the earlier design, development, construction and manufacturing activities maybe as little as 25% of what will subsequently be needed to operate, maintain and overhaul the new asset (Griffin, 1993). A large amount of the country's maintenance resources is being expended on corrective or remedial measures to buildings and their services due to design or construction defects. Therefore, by reducing the number of design defects, the amount of maintenance expenditure can be reduced (Assaf *et al.*, 1996).

Design firms often claim themselves quite knowledgeable in maintenance issues, using the statement that their personnel is exposed to training in these matters at one time or another. In addition to that, property managers and maintenance consultants are consulted in designing some projects, mostly in the schematic and preliminary design phases only. Somehow, reliance on the design's staff to occasional maintenance training is not sufficient to design a building with longer life cycle without incorporating the factors that contribute a higher level of ease for future maintenance works. Without proper rules and guidelines that need to be followed during design stage, the objective of extending the life span building with low maintenance budget cannot be achieved (Arditi *et al.*, 1999).

A critical individual that should be consulted at all stages especially during the early design is a maintenance manager or consultant. These individuals provide insight to the effects of changes made to the systems and particularly how the systems will interface. If the system is unfamiliar to the designers as well as to the building owner's regular maintenance staff, then it is critical for the design team to consult the system manufacturer to provide information relevant to the education and training required for the proper operation and maintenance of the systems being considered.

Therefore, this research was conducted and hope to become a useful reference for local architects and design engineers to incorporate crucial maintenance factors during design phase to ensure a successful implementation of design for maintenance concept, particularly for future projects in Malaysia.

1.3 Aim and Objectives

The aim of this study is to enhance the quality of designs produced by the local architects and engineers through incorporation of design for ease of maintenance concept at the design stage. In achieving this aim, two objectives have been outlined. They are:

- (i) To identify building defects that are related to poor maintenance consideration during design stage
- (ii) To identify critical maintenance factors in civil and architectural designs

1.4 Brief Methodology

The first step of the study was identifying research problem which covered the significance, objective and scope of study followed by exploratory research of the literature. Information was gathered through two sources. Firstly through journals, books and reports and secondly through preliminary interviews which took place through telephone conversation.

Questionnaire for maintenance and designer practitioners were later developed using the information obtained from potential respondents and were handed over to respondents by hand, facsimile, email and by mail. After three weeks, the researcher received back the questionnaires either through post or collected by hand whereby hand-collection gave the researcher the opportunity to conduct interview sessions with the respondents.

The data were then compiled, analyzed and discussed with the assistance of frequency and analysis index and from there, the researcher concluded the findings together with recommendations to improve the problem.

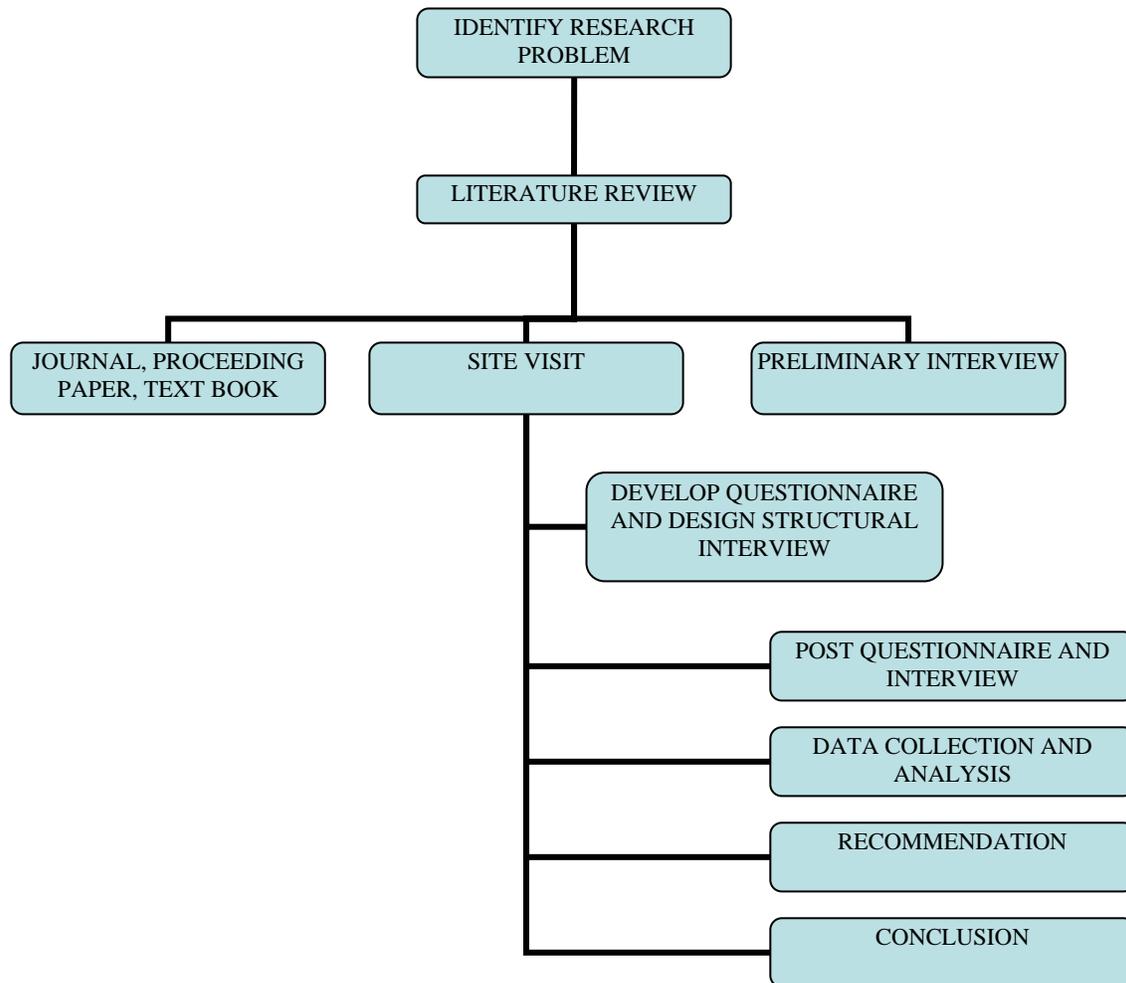


Figure 1.1 Methodology flowchart

1.5 Scope of Work

This research was focused on building construction, mainly on building deficiencies due to poor design practices as well as to come up with factors for a better understanding and hence assist them to come up with a good design which incorporate maintenance factors. Information and data were collected from local library and journals.

Structured interviews was conducted on building design firms within the Shah Alam and Kuala Lumpur districts. Interviews was carried out using questionnaires. Questionnaires had been distributed randomly to approximately 100 respondents which include consultancies (Architectural, Civil & Structural) and maintenance organizations/contractors within Shah Alam and Kuala Lumpur districts. The target is to

- (i) find out the design firms' existing level of maintenance-related knowledge
- (ii) identify the factors they consider when designing building
- (iii) determine the most critical factors to design with consideration of the ease of maintenance concept.

General Services Administration Public Buildings Service. Maintenance Practices and General Information for Federal Buildings. Section 1: Introduction and Maintenance Standard List. General Overview

The GSA Maintenance standard is arranged by sections according to building equipment groups or building components. A four (4) tier system is used to easily identify the type of building group, equipment type and frequency for performing maintenance on these systems. The format is as follows: 1. Tier 1 identifies the building component system or type of building equipment group, i.e. Electrical (ELEC), Heating Ventilation, Air Conditioning (HVAC). Keywords. Building maintenance Defects Maintenance strategy Building performance Building condition Value management Maintenance management functions. This is a preview of subscription content, log in to check access. References

Maintenance factors in building design. M.Sc. Thesis, Universiti Teknologi Malaysia. The building maintenance issues for precast concrete system can cause by many factors either in design, manufacturing or even installation stage. Thus, this study will investigate the building maintenance factors for precast concrete system in design, manufacturing and installation stage. This survey study had successfully identified 23 building maintenance factors and 5 major defects from the study of the literature and interviews. The result of the analysis from the software package SPSS version 19.0 had showing that building maintenance factors and the defects had strong positive linear correlation 2.0

Factors Affecting Building Maintenance Previous studies revealed the effects of numerous factors affecting residential building maintenance. Assaf (1996) opined that design and construction faults that affect maintenance of buildings are defects in civil design, defects in architectural design, defects due to consultants firm's administration and staff, defects due to construction.

19. Civil and Environmental Research ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol.3, No.8, 2013. www.iiste.org. drawings, defects due to construction inspections, defects due to construction, defects due to