"I hereby declared that I have read this thesis an in my opinion this thesis is sufficient in terms of scope and qualify for the award of the Degree of Bachelor Mechanical Engineering (Structure & Material)"

Signature	:	……
Name of Supervisor	:	……
Date	:	……

AN EXPERIMENTAL STUDY ON BUILDING VIBRATION AT INDUSTRIAL CAMPUS (UTeM)

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A project report submitted in partial
fulfillment of the requirements for the award of
the Degree of Bachelor Mechanical Engineering (Structure & Material)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

May 2008

"I hereby declared that this is my own work except the ideas and summaries which I have clarified their sources"

Signature : ……

Author : ……

Date : ……

Special dedicate to my family, supervisor, and all my fellow friends to help me to accomplish my thesis.

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ABSTRACT

In this thesis, lightweight building vibration analysis will be performed at Academic Building in industrial campus of UTeM (Universiti Teknikal Malaysia Melaka). In this building, the vibration problem was typically caused by mechanically driven equipment such as Air Handling Unit (AHU). The vibration problem occurred since 2006 where the building was completed at 2005 which included marble slab damage and diagonal crack on the wall. Due to that, the objectives of this thesis are to study the building vibration and determine the natural frequency for a lightweight construction building. A conventional impact Bump Test was obtained to find out the natural frequency of the building by using hand-held vibration analyzer: Microlog CMVA 65. The Bump Test will conduct by follow the standard of ISO 4866 which is "Guide and measurement for vibration in buildings". All the collected vibration data will be uploaded from Microlog to Machine Analyst software, to allow the vibration spectrum to be generated and natural frequency of building can be determined. Besides that, the Non Route Test will be carried out in order to determine the forcing frequency which is generated by AHU. On the other hand, an alternative way to determine natural frequency is using theoretical method which is Raleigh Method. After all the data‟s are obtained, the comparison of the natural frequency will be analyzed that included different levels of the building. The important findings from the analysis which is the marble slab damage was due to resonance occurred in level 4 and 5 in same area (near with check point 6) as well as the crack line in level 6 is suspected cause by AHU and might be other reasons. In addition vibration control will be proposed in this project in order to prevent the disturbance or potentially damaging vibration from being transmitted to the building structure.

ABSTRAK

Dalam tesis ini, analisa terhadap getaran bangunan „*lightweight*" akan dilaksanakan dimana tujukan kepada Bangunan Akademi di Industri Kampus, UTeM (Universiti Teknikal Kebangsaan Malaysia). Biasanya, masalah getaran berpunca daripada peralatan mekanikal yang berputar, lazimnya AHU (Air Handling Unit). Masalah getaran seperti „*marble*" lantai pecah dan pecahan „*diagonal*" pada dinding berlaku sejak tahun 2006 dimana bangunan siap bina pada tahun 2005. Dengan itu, objektif bagi tesis ini adalah pembelajaran terhadap getaran pada bangunan dan penentuan frekuensi tabii pada bangunan „*lightweight*". Eksperimen „*Bump Test*" akan dijalankan untuk menentukan frekuensi tabii kepada bangunan dengan menggunakan „*Microlog CMVA 65*". „*Bump Test'* akan dijalankan mengikut ISO 4866 iaitu "Membimbing dan pengukuran untuk getaran di bangunan". Semua data getaran terkumpul akan dimuatnaik daripada „*Microlog*" kepada perisian „*Machine Analyst*", supaya spektrum getaran akan dihasilkan dan frekuensi tabii bagi bangunan dapat ditentukan kemudiannya. Seterusnya, eksperimen „*Non Route Test*" akan dijalankan demi penentuan getaran paksa yang berasal dari AHU. Di samping itu, kaedah alternatif untuk menentukan frekuensi tabii adalah menggunakan kaedah teori iaitu Kaedah „*Rayleigh*". Selepas penggumpulan segala maklumat yang berkaitan, frekuensi tabii akan dikaji termasuk perbezaan tingkat dalam bangunan. Penemuan penting daripada analisis adalah kerosakan kepingan marmar disebabkan oleh gema berlaku dalam tingkat 4 dan 5 dalam kawasan sama (dekat dengan titik semak 6) serta retakan pada tingkat 6 bukan disebabkan oleh AHU dan mungkin sebab lain. Tambahan, pengawalan getaran akan dikenalkan dalam projek ini demi pencegahan gangguan ataupun kerosakan getaran yang akan dikenakan kepada struktur bangunan.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

LIST OF NOMENCLATURE

SYMBOLS	DEFINITION
AHU	Air Handling Unit
UTeM	Universiti Teknikal Malaysia Melaka
ISO	International Standards Organization
PSM	Projek Saujana Muda
AMD	Active Mass Dampers
HMD	Hybrid Mass Dampers
FEM	Finite Element Method
Hz	Hertz
mm	Millimeter
s	Second
db	Decibel
m	Meter
FFT	Fast Fourier Transform
LCD	Liquid Crystal Display
FS	Full Scale
HFD	High Frequency Detection

Pa	Pascal
N	Newton
%	Percentage
FKM	Fakulti Kejuruteraan Mekanikal
FTMK	Fakulti Teknologi Maklumat & Komunikasi

LIST OF APPENDIX

CHAPTER I

INTRODUCTION

Most human activities involve vibration in one form or another. In the recent times, many investigations have been motivated by the engineering applications of vibration, such as the design of machines, foundations, structures and others more. In this thesis report, building vibration will be focused and both of the experimental and theoretical method will be introduced. However, before that, the fundamental of basic terminology of structural vibration will be discussed below.

Basically, the structural vibration analysis can be divided into two categories which is free vibration and force vibration. The definition for free vibration can be explained by natural response of a structure to some impact or displacement. The response is fully justified by the properties of the structure, and its vibration can be understood by examining the structure's mechanical properties. Meanwhile, for the force vibration, it is a response of a structure to be a repetitive forcing function that causes the structure to vibrate at the frequency of the excitation.

Free vibration analysis plays an important role in designing building structure especially for the first mode shape. This is because the first mode shape is a dominant component in wind and earthquake induced vibrations of building, (Lee, 2007). Thus, it is important to determine the natural frequency and mode shape of the building either applied numerical method or the theoretical method. There are several numerical method

can be applied to calculate the natural frequency and the mode shape which includes Fourth-order Sturm-Liouville Differential equation, Classical Power Series Method (method of Frobenius), Dunkerley's formula, Rayleigh's method, Holzer's method, Matrix Iteration method and Jacobi's method.

For the forced vibration, dynamic vibration is one type of force vibration where can be created by machinery. Hence, when either rotating or reciprocating machinery operating occur continuous in building, significant dynamic forces which either impactive or continuous in nature will be generated. A transient or continuous dynamic force typically excites the floor slab at its natural frequencies, (Mathivanan, 1995). Beside that, resonant motion also can be generated if machinery operated where forcing at frequencies coincident with floor slab and structural member natural frequency.

1.1 Objectives

The objectives of this thesis are defined as below:

(a) To study the vibration in building as the lightweight construction in new building has made these building more susceptible to vibration and vibration-related problems.

(b) To determine the natural frequency for the building based on ISO standard (ISO 4866)

1.2 Scopes

In order to fulfill the objectives of study, the scopes of work throughout the thesis are defined as follows:

(a) Plan layout of the buildings.

(b) Obtain the building natural frequency through vibration measurements.

(c) Comparison results between the experimental and theoretical method.

(d) Propose a vibration control option to prevent disturbing and/or potentially damaging vibration from being transmitted to a building structure.

1.3 Gantt Chart

ID	Task Name	Start	Finish	Duration
1	List of PSM title release & select title	7/9/2007	7/13/2007	5d
2	Confirmation of PSM title and supervisor	7/11/2007	7/19/2007	7d
3	PSM briefing & planning on PSM 1 & 2	7/16/2007	7/20/2007	5d
4	Searching for literature	7/19/2007	10/12/2007	62d
5	Studying literature & related source	7/19/2007	10/12/2007	62d
6	Introduction of project	7/30/2007	8/1/2007	3d
7	Planning the experimental for determination of natural frequency	8/20/2007	9/6/2007	14d
8	Update final drafting to project supervisor	9/19/2007	9/19/2007	1d
9	Submit PSM 1 report	9/27/2007	9/27/2007	1d
10	Preparation for project presentation	10/1/2007	10/18/2007	14d
11	Presentation for PSM 1	10/22/2007	10/26/2007	5d

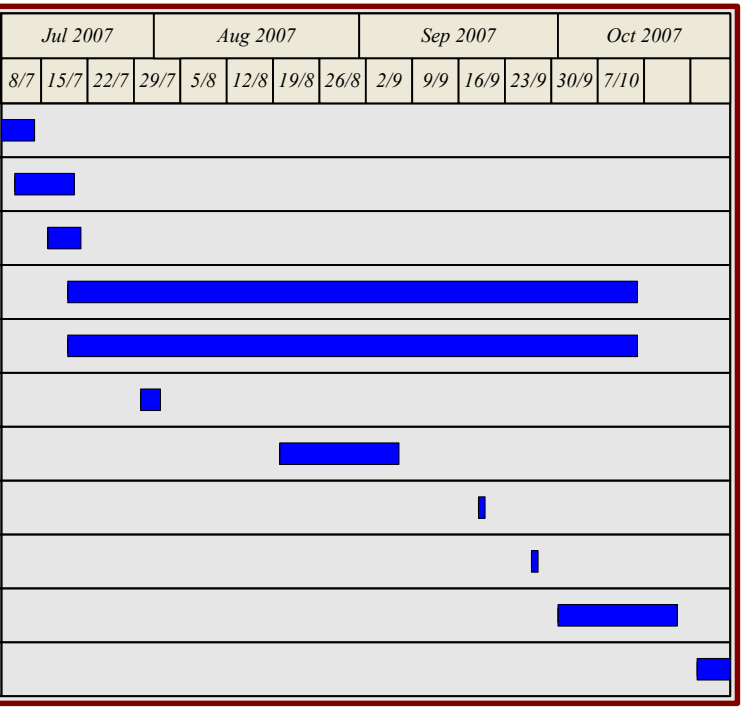

Figure 1.1: Gantt chart for PSM 1

ID	Task Name	Start	Finish	Duration
1	Launch PSM 2 & improve PSM 1	1/7/2008	2/13/2008	28d
2	Literature search	1/7/2008	3/14/2008	50d
3	Study of literature	1/14/2008	2/25/2008	31d
4	Study the theoretical calculation	1/15/2008	2/8/2008	19d
5	Conduct an experiment	1/15/2008	2/25/2008	30d
6	Analysis experimental results	3/3/2008	3/10/2008	6d
7	Compared the theoretical and experimental results	3/10/2008	3/17/2008	6d
8	Discussion & suggestion for improvement	3/3/2008	3/20/2008	14d
9	Summary of project	3/20/2008	3/25/2008	4d
10	Complete report submission	3/27/2008	3/27/2008	1d
11	Correction for PSM 2 report	4/8/2008	5/13/2008	26d
12	Preparation for presentation PSM 2	3/27/2008	4/14/2008	13d
13	Presentation on PSM 2	4/14/2008	4/18/2008	5d
14	Submission report with hard cover	5/13/2008	5/13/2008	1d

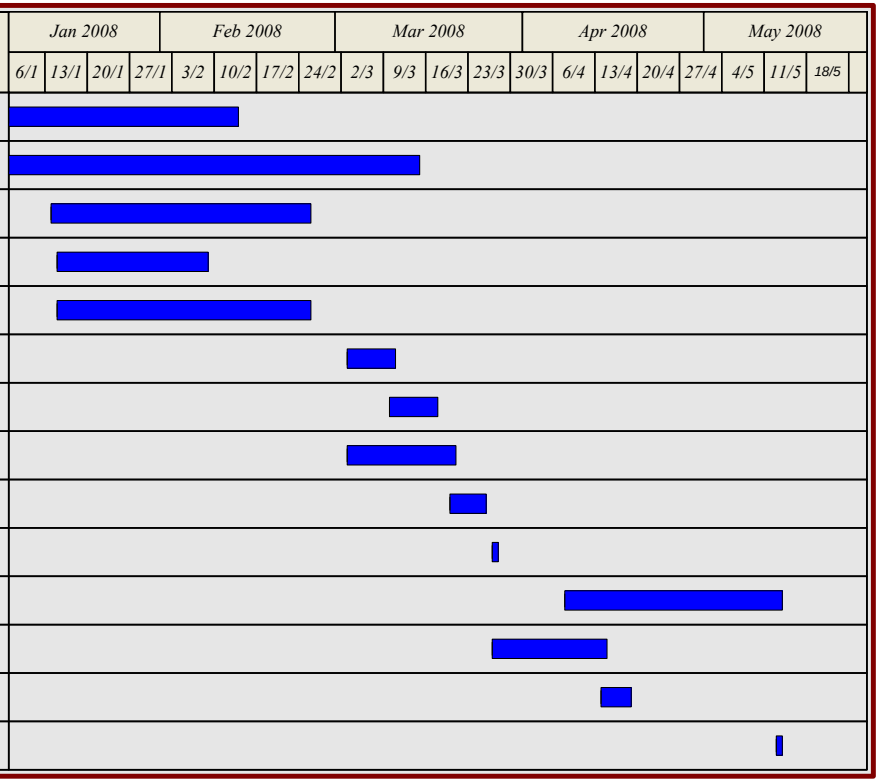

Figure 1.2: Gantt chart for PSM 2

1.4 Problem Statement

The campus buildings can be considered as a lightweight building with seven floor slab. This is due to the way of build, the material used, and the fundamental of the structure are similar with the requirement of lightweight building.

Due to that, the campus building faced the minor vibration problem since 2006 where it was completed at 2005. Until now, the proper solution hasn't come out in order to solve the vibration issue. The short term corrective solution had been investigated was every time the vibration issue occurred (will discuss at the following paragraph), the contractor people will be called up and they will come to investigate and then solve the problem "temporarily" (refer to Appendix C). For an example, when they found that the marble slab was crack, then they just replace it.

Varies of problems occurring which was induced by vibration issues had been found. Firstly the marble slab where stick on the floor was damaged like after applied shearing compressive force but the reason is still under investigation. Beside, a critical crack line at the concrete wall had been found in lecturer room at level five and six. Furthermore, minor vibration can be felt by the librarian (from the survey) and suspected that the vibration was emitted from AHU (Air Handling Unit).

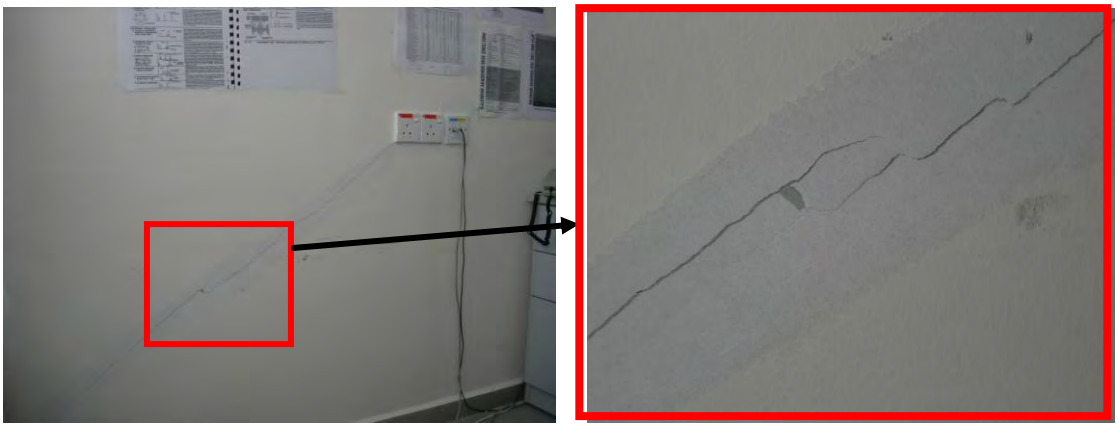

Figure 1.3: Diagonal Crack Line in Lecturer Room at Level Six

In this thesis, the vibration issue on the campus building was carrying out and analysis on the building structure will also be focused to figure out the real cause or so called forced excited vibration. In the measurement and assessment of machinery induced vibration buildings, it is often necessary to determine the inherent fundamental natural frequencies of the building's structural members, typically floor slabs in the vertical mode. The methodology of experimental and theoretical will be carried out. For the experimental analysis, the Microlog CMVA 65 is used to determine the natural frequency of the campus building and all the procedures are according or comply with International Standards Organization (ISO). Meanwhile, the natural frequency of the building will be obtained theoretically by using Rayleigh method. The comparison result between experimental and theoretical will be done and some Isolation System will be introduced in case the resonance happens.

CHAPTER II

LITERATURE REVIEW

A general literature review on building vibration is first presented. Besides, this will followed by a review of the studies on characteristics of building vibration and using different method to analyze the building. Some of the review on vibration isolation and damping treatment for building will be included.

Mathivanan and Leong, (1995) analyzed the machinery induced vibration building by referring to some of the standard such as ISO DP 4866, German standard DIN 4150 and ISO 2631. Besides, they concentrate on vibration problems in building where machinery and manufacturing processes are located within buildings as well as the mechanical building services equipment mounted on elevated floors. Three different cases had been analyzed which includes textiles weaving machines, leisure ride equipment and building services equipment where each of the equipment will generate the vibration and increase the potential result in structure damage. For textiles weaving machines, a water jet activated will generate the floor slab vibration due to the continuous reciprocating motion. In addition to that, for leisure ride equipment, an example of building vibration induced by pneumatic actuators and ride structure was induced into vibrations, consistent with the ride motion simulation. A pneumatic isolation system was installed, together with additional structural framework to support the entire ride installation on pneumatic isolation. Lastly, for building services equipment, the example is chilled water pump vibration in a chiller plant room for a high