RESPONSE OF AIR TRAFFIC CONTROL TOWER WITH PENDULUM TUNED MASS DAMPER UNDER EARTHQUAKE LOADING

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DEDICATION

This project is dedicated to my beloved father, mother, my brother and sisters, Apies, Aziemah and Ain for being by my side and supportive in order to complete this project.

I also want to dedicate this project to my fellow friends for being supportive and motivated throughout the process of this report.

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ABSTRACT

The response of air traffic control tower under wind and earthquake excitation is important for the study of earthquake engineering. Pendulum tuned mass damper (PTMD) is one of the damper that can dissipate the energy through movement which balance the swing of the structure. Therefore, the objective of this paper is to compare the effectiveness of air traffic control tower Kuala Lumpur International Airport2 with and without pendulum tuned mass damper. Other than that is to determine the percentage reduction at tower head for 2 pendulums tuned mass dampers and 4 pendulums tuned mass dampers for time history analysis and response spectrum analysis in terms of axial force, shear force and bending moment. Besides to determine the internal forces, the objectives of this project also is to identify the percentage reduction at core wall for 2 pendulums tuned mass dampers and 4 pendulums tuned mass damper for time history analysis and response spectrum analysis in terms of stresses and to determine the percentage reduction at top for 2 pendulums tuned mass dampers and 4 pendulums tuned mass dampers for time history analysis and response spectrum analysis in terms of story drift. The results indicated that the PTMD is able to reduce the response of the tower and 4 PTMD work more effectively compare to 2 PTMD.

ABSTRAK

Reaksi menara kawalan udara dibawah pengaruh beban angin dan gempa bumi amat penting di dalam kejuruteraan gempa bumi. Bandul peredam jisim di tala adalah salah satu alat untuk mengurangkan reaksi bangunan dibawah pengaruh angin dan gempa bumi. Bandul peredam jisim ditala menghilangkan tenaga melalui pergerakan dimana bandul peredam jisim ditala akan seimbangkan pergerakan menara. Oleh itu, tujuan projek ini dijalankan adalah untuk membandingkan keberkesanan menara kawalan udara Lapangan Terbang Kuala Lumpur 2 dengan bandul peredam jisim ditala dan sebaliknya. Selain itu, untuk mendapatkan peratus pengurangan antara 2 bandul peredam jisim ditala dan 4 bandul peredam jisim di tala untuk kategori daya dalaman iaitu, daya paksi, daya ricih dan momen lentur. Disamping itu, selain daya dalaman, tujuan projek ini dibuat adalah untuk mendapatkan peratus pengurangan bagi tekanan di tingkat bawah bagi 2 bandul peredam jisim ditala dan 4 bandul peredam jisim di tala. Dan akhir sekali untuk mendapat peratus pengurangan bagi anjakan di tingkat paling atas bagi 2 bandul peredam jisim ditala dan 4 bandul peredam jisim di tala. Berdasarkan dari hasil analisa, mendapati 4 bandul peredam jisim di tala.lebih berkesan dalam mengurangkan tenaga berbanding 2 bandul peredam jisim ditala.

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LIST OF SYSMBOLS

φ	-	Amplitudes
ρ	-	Mass density
ζ (x-h)	-	Direct function
ω	-	rth eigenfrequency
C	-	Damping matrix
c_1	-	Damping capacity of main system
c_2	-	Damping capacity of tuned mass damper
C_1	-	Damping coefficient
f_{bi}	-	Frequencies
G	-	Acceleration of gravity
k_1	-	Stiffness of main system
k_2	-	Stiffness of tuned mass damper
K_1	-	Stiffness coefficient
K	-	Stiffness matrix
L	-	Pendulum length
m_1	-	Mass of main system
m_2	-	Mass of tuned mass damper

M	-	Total mass of the chimney
$m_{tot.}$	-	Total mass of the tower
m_1	-	m_2 mass of the equivalent oscillator
M_2	-	Pendulum mass
M	-	Diagonal mass matrix;
q_r	-	Generalized coordinates
Q_r	-	Generalized force
t	-	Time
T	-	Tension cable
x_1	-	x_1 (t) = response of main system
x_2	-	x_2 (t) = response of tuned mass damper
x_1 (t)	-	Horizontal displacement
$\ddot{x}$	-	Acceleration
$\dot{x}$	-	Velocity
x	-	Relative displacement with time;
$\ddot{x}_g$	-	Ground acceleration

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Recently, the construction projects in civil engineering have become rapid and modern. The tallest building in the world is changing year by year. Now, the Burj Khalifa is the tallest building in the world with the height of 828 m. This skyscraper has become the master piece of Dubai, but in the process to achieve this dream, there are lots of challenges they have to face. One of them is the dynamic loads that come from the wind and the earthquake. However, there is various ways to control the structural vibration such as modifying rigidities, masses, damping or shape and by provide passive or active counter force [G.W. Housner et al. 1997].

The 2011 tsunami in Japan has waked us up with magnitude 9.0 at the coast of Japan. This has become a huge natural disaster in Japan, and makes the civil engineers especially the structural engineers consider the seismic design in every civil engineering projects. However, design of the strength alone does not ensure the building will acts like the way we want, safe and comfort for the occupants. For example, a 47 story building in the San Francisco experienced peak acceleration of 10% g in the basement and 45% g on the top floor during the Loma Prieta earthquake 1989. This shows that, the acceleration in the upper stories is the result from the strong ground acceleration [G.W. Housner et al. 1997].

Time after time, the researchers find way to solve the problems. One of them is the base isolation. This technology have been found in the 1960s with the objective is to bring the structure on the sufficiently flexible base, so that it will filters out the high frequencies of the ground motion and lengthens the natural period about 2s [G.W. Housner et al. 1997]. After some time, they realize that certain structure is not suitable to use the base isolation, for example, slender high-rise buildings. The base isolation is suitable for the use to protect the fragile contents of hospitals and computer facilities.

For the flexible structure, such as high-rise buildings, the damping device like the viscous damper, tuned mass damper and the liquid mass damper are more suitable. This is because; it will increase the energy dissipation and reduction of motion. The World Trade center in New York and other building in California implement the auxiliary dampers in their buildings.

1.1 Research Background

The air traffic control tower is one of the important operations in the airport. The air traffic control tower is provides the service, who is actually direct the aircraft on the ground and in the air. The air traffic control tower, of Kuala Lumpur International airport is the second tallest control tower in the world after Suvarnabhumi Airport control tower. Other than to direct the aircraft on the ground and in the air, it also provide the air traffic controllers, radar systems and high tech air space computer systems.

Most of the control towers in the world are design to take the lateral or seismic load. But, still based from the human consideration of the people who work on the top floor of the airport tower might be highly stressful mental condition due to the vibration of the structure [Y.Tamura et al. /J. 1993]. Because of this, there are several research been done, in order to overcome and hopefully to avoid the long term effect especially to the workers. In Japan, some of the researchers have already done a research on the effectiveness of tuned liquid damper.

Due to the same reason, human discomfort and the stability of the structure, they proposed to implement the tuned liquid damper in the control tower at the Tokyo International Airport. The advantages of this damper are low initial cost, maintenance free and efficiency from very low amplitude vibrations around human perception thresholds to large amplitude vibrations [Y.Tamura et al. 1993].

1.2 Problems Statement

1. The air traffic control tower faces some huge vibration during the take off of the air craft. Some of the glasses in the building have already broken and, afraid that the building near the control tower and the control tower itself does not been design to take the dynamic load.
2. The air traffic control tower is subjected to the vibration which is may come from the wind excitation, earthquake and machine vibration. However, if the natural damping in the structure is higher, the lower the likelihood the damage will be excessive. However, if the structure faces a strong vibration such as that come from the earthquake, the structure may collapse. This is because the natural damping is not sufficient in order to resist the load. Therefore, it is a need to install the supplemental damping in order to avoid severe damages.

3. Currently, the runaways tend to be expanded due to the huge jet planes and the increase number of flights, even for local. Therefore, the height of the airport tower needs to be higher. From the basic principle, at the top level, for high rise building, the force will be larger compared to short structure.
4. In the past research, they only implement tuned liquid damper in the control tower, but the effectiveness of pendulum type of damper remains an important issue for study.

1.3 Objectives

The objectives of this study are:

1. To compare the effectiveness of air traffic control tower Kuala Lumpur International Airport2 with and without pendulum tuned mass damper.

2. To determine the percentage reduction at tower head for 2 pendulums tuned mass dampers and 4 pendulums tuned mass dampers for time history analysis and response spectrum analysis in terms of axial force, shear force and bending moment.

3. To identify the percentage reduction at core wall for 2 pendulums tuned mass dampers and 4 pendulums tuned mass damper for time history analysis and response spectrum analysis in terms of stresses.

4. To determine the percentage reduction at top for 2 pendulums tuned mass dampers and 4 pendulums tuned mass dampers for time history analysis and response spectrum analysis in terms of story drift.

1.4 Scope of work

The scopes of work for this project are:

1. The performance of air traffic control tower at KLIA is considering wind and earthquake loadings.
2. This project is not considering the soil interaction of the structure.
3. Linear analysis will be performed to determine the response of the structure.
4. In this analysis, the standard code that been used is BS8110.

1.5 Organization of Report

The study of the objectives and scopes are explained as below:

Stage 1: Clarification of the project on the objectives and scopes of the study

This stage is to verify the feasibility of the objectives and scopes of the project and planning of methodologies in an efficient way.

Stage 2: Literatures, collecting data and modeling of structures

This stage is to understand the behavior of the structure and performance of every type of damper. Other than that, to determine the best solution for retrofitting the structure under wind and earthquake loads. Furthermore, obtaining the information of the structure and damper before proceed to the analysis parts is a requirement to success in this project.

Stage 3: Verification of retrofitting devices and methods of finite element modeling

At this stage, the process is to identify the best damper that can be installed in the structure which is pendulum tuned mass damper. The theoretical background of the damper is included to verify the performance of the damper. To obtain the correct mode shapes, the material properties and design methods have to be determined. This project is in multi degree of freedom, and be analyze using the 3D Finite Element models with SAP2000 computer programs.

Stage 4: Vulnerability assessment of modeling and response analyses

The linear material behavior is used in the finite element analyses are compared with the hand calculation to verify the capacity. The characteristic of present pendulum tuned mass damper is used to analyze the structure under the wind and earthquake load.

Stage 5: Discussion and conclusion

The results and discussion on the project with regards of wind and earthquake load of the proposed damping device will be finalized. Comment and further recommendation to the study are suggested.

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