SEISMIC PERFORMANCE ANALYSIS OF KUALA LUMPUR AIR TRAFFIC CONTROL TOWER BY FRICTION DAMPER

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To my beloved parents and family

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ABSTRACT

In structural earthquake engineering, different kinds of energy absorption devices were invented during last 30 years (Guan *et al*, 2004). And more than one-decade research has shown that, on account of the virtue of no power requirement, rapid response and coulomb friction principle of friction damper is one of best of them. It is used as plating friction for energy dissipation systems to reduce earthquake effect on structures. With laminated steel plates and bolt, the friction damper can provide high diagonal stiffness and flexibility in horizontal direction to ensure the mounting forces can be supported by the stresses induced on the structure and prevent excessive sideways from any horizontal loading especially when earthquake occur. This research is to study the performance of Air Traffic Control Tower of Kuala Lumpur International Airport (KLIA Control Tower) under low intensity earthquake effect of induced earthquake acceleration of 0.19g. The finite element modelling technique is used in this study to learn the behaviour of friction damper and vulnerability of loading from vertical and horizontal directions with the proposed application. Performances of the friction damper were examined based on their percentile capacity passing and inter-storey drift displacement, consisting of Beam Models and Shell Models with and without friction damper. Friction damper is designed within the lift-core and it is found that the usage of designed retrofitted friction damper increases the overall performance of the KLIA Control Tower. In general, this study indicates that the seismic risks should be considered in designing the tower for Malaysia construction and the application of the seismic retrofitting to this existing building is much needed to safeguard structure from external peak ground acceleration intensity. Therefore, it is discovered from the final analysis the friction damper is able to stiffen the structure from seismic loading in term of deformation and axial force from the intensity of 019g, 0.29g and 0.39g.

ABSTRACT

Dalam bidang kejuruteraan gempa bumi, pelbagai alatan penyerap tenaga bangunan telah dicipta selama tiga puluh tahun dahulu (Guan *et al*, 2004). Dari penyelidikan sedekad yang lalu, peralatan yang digunakan telah berubah bentuk daripada segi ketidakupayaan menggunakan tenaga, yakni, "friction damper" menggunakan prinsip coulomb merupakan antara yang terbaik dalam aplikasi penstabilan struktur. Ia digunakan dengan meletakkan pengalas besi pengesel bagi menyalurkan tenaga daripada sistem semasa gempar bumi. Dengan kepingan pengalas besi ini, "friction damper" dapat menberikan rintangan ketegaran dan kelonggaran pepenjuru dalam arah melintang, bagi membolehkan pemusatan tenaga disokong semasa tegasan pada struktur dan mengelakkan pesongan daripada beban melintang semasa gempar bumi. Kajian ini melibatkan kesan prestasi menara kawalan udara lapangan terbang antarabangsa kuala lumpur semasa gempar bumi pada keamatan 0.19g. Model elemen terhad digunakan bagi mengaji kelakuan "friction damper" dan kerentanan daripada bebanan melintang dan menegak. Prestasi "friction damper" dikaji berpandukan kepada peratus lulus keupayaan dengan beban kenaan dan pesongan setiap tingkat, daripada model-model Beam dan Shell model dengan aplikasi "friction damper". "Friction damper" diletakkan secara pepenjuru mengeliliingi dinding ricih. Daripada penggunaan "friction damper", didapati retrofit menambahkan prestasi Menara Kawalan KLIA. Secara umumnya, kajian ini menunjukkan risiko seismos patut dipertimbangkan dalam rekabentuk pembinaan di Malaysia dan aplikasi retrofit ini diperlukan bagi memastikan struktur bangunan dapat melindunginya daripada puncak keamatan pecutan tanah daripada gempar bumi. Justeru, dikenalpasti "friction damper" dapat menambahkan tegasan kepada struktur bangunan seismos dalam segi daya paksi, momen, daya ricih dan pesongan bertingkat dalam puncak pecutan 0.19g, 0.29g dan 0.39g.

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LIST OF ABBREVIATIONS

TITLE

KLIA	-	Kuala Lumpur International Airport
DYMM SPB	-	Duli Yang Maha Mulia Seri Paduka Baginda
ICC	-	International Code Council
IBC	-	International Building Code
SBC	-	Standard Building Code
UBC	-	Uniform Building Code
BOCA	-	Building Officials and Code Administrators, Inc
NEHRP	-	National Earthquake Hazards Reduction Program
TM	-	Trademark
ADAS	-	Added Damping and Stiffness
CA	-	United State of California
SMRF	-	Special Moment Resisting Frame
FEMA	-	Federal Emergency Management Agency
RCDF	-	Rural Communications and Development Fund
SMA	-	Shape Memory Alloys
RC	-	Reinforced Concrete
SBC	-	Slotted Bolted Connection
PED	-	Passive Energy Dissipation
VE	-	Viscoelastic
SDOF	-	Single-Degree-of Freedom
U.S.	-	United State of America
DBE	-	Design Basis Earthquake
MCE	-	Maximum Considered Earthquake
SEER	-	Engineering Seismology and Earthquake Engineering Research

LIST OF SYMBOLS

TITLE

km^2	-	Kilometre square
m	-	Meter
mm	-	Milimetre
KN	-	Kilo Newton
N/mm^2	-	Newton per millimetre square
KN/mm^2	-	Kilo Newton per millimetre square
g	-	Gravitational ground acceleration
U1	-	Global x-direction
FE	-	Finite Element
2D	-	2 Dimensions
3D	-	3 Dimensions
in	-	Inch
kips	-	Kilo pounds
%	-	Percentage
^{o}C	-	Celsius degree
°F	-	Fahrenheit Degree
$\ddot{x}$	-	Ground Acceleration
$\dot{x}$	-	Ground Veloctiy
x	-	Ground Displacement
t	-	Time/Period
Hz	-	Hertz
k	-	Linear elastic stiffness

m	-	Mass
c	-	Damping coefficient
Γ	-	Integro-differential operator
u	-	Displacement
$\pm$	-	Approximation
δ	-	Inter story drift
b	-	Brace
d	-	Damper
f	-	Shear Force/Friction coefficient
λ_i	-	Structural Dynamics Motion
$\dot{U}$	-	Velocity
N	-	Applied Normal Force
Δt	-	Time Step
fy	-	Strength of Reinforcement
fc'	-	Strength of Concrete
E	-	Modulus Elastic
G	-	Shear Modulus
v	-	Poisson Ratio
α	-	Coefficient of Linear Thermal Expansion
y_e	-	Yield Strength
U_e	-	Tensile Strength
P	-	Axial Force
M	-	Bending Moment
V	-	Shear Force
T	-	Torsion
i.e.	-	Initialism; “in other words”
sgn	-	Signum Function

CHAPTER 1

INTRODUCTION

1.1 General

Control towers are subjected to vibrations, especially the structure have the slender proportion and concentrated mass on top of the structure. These vibrations may arise from wind forces, earthquake excitation, machine vibrations, or many other sources. In some cases, especially under strong earthquake excitations, these vibrations can cause the structural damage or even structural collapse. The higher the inherent or natural damping in structures, the lower the likelihood the damage will be excessive. However, for structures subjected to strong vibrations, the inherent damping in the structure is not sufficient to mitigate the structural response. In many situations, supplemental damping may be used to control the response.

1.2 Location

Kuala Lumpur International Airport (KLIA) is located 50 kilometres south of Kuala Lumpur in Sepang, Selangor. Occupying a site of 100 km^2, it is the world's largest airport, with five 4,000-metre-long runways. The development of the airport is to achieve the prominence of a fully developed industrial nation of 2020 vision of developed status, therefore, is a great important of locale yardstick. The Figure 1.1 indicated below shows the control tower and its immediate surrounding;

Figure 1.1: KLIA Air Traffic Control Tower (picture by Kara H., 2007)

1.3 Historical Background

The area was formerly covered with forest and palm oil and rubber plantations, thus, sparsely populated. The relatively flat terrain met aeronautical requirements.

The choice of site for the airport reflected the perceived need for decentralisation, to spread growth beyond Kuala Lumpur and the Klang Valley. Besides, it is not affected by the monsoon, as it is protected by soaring mountain ranges.

The project came into being in the late 1990s, to relieve the strain on the existing Sultan Abdul Aziz Shah Airport. KLIA is currently designed to handle around 25 million passengers and one million tonnes of cargo a year. It is to be developed in three phases, building up to a final capacity of 100 million passengers per annum (Kara H., 2007).

1.4 Air Traffic Control Tower

Air traffic control tower is crucial to airborne instruction for safe departure and arrival of passengers and cargoes. KLIA tower comprises of 13-storey concrete circular frame lift-core with terminal, as well as shopping department in supplement to the ground level existing buildings. Overall height varied to 124m, and width of 8m diameter is fixed throughout liftcore, but expanded at top floors. The tower different functions consist of top level of 23rd to 30th.

Tremendous concern has been from architectural value to exhibit adequate strength, redundancy and ductility. Similarly, the earthquake resistance of the existing structures was significantly less than that required by the current building codes. Since airports are of post disaster importance, extremely recommended that the air tower structures be upgraded along with the oncoming new expansion (Malhotra et al., 2004).

Conventional methods of seismic rehabilitation with concrete shearwalls or rigid steel bracing were not considered suitable for this air tower as upgrades with these methods would have required expensive and time consuming foundation work (Cho and Kwon, 2004). Supplemental damping in conjunction with appropriate stiffness offered an innovative and attractive solution for the seismic rehabilitation of this tower. This can be achieved by introducing Friction Dampers in steel bracing.

1.5 Problem Statement

Currently, Malaysia has never been using friction damper devices in retrofitting or designing. The vibration from seismic loading has not concerned the local construction practitioner simply there is lack of knowledge. The purpose is to make sure that the application will salvage the seismic action onto the overall structure of the control tower.

Bearing with this complication, it is identified that the problem is persisted on four fronts, basically,

1. Air traffic tower (control tower) at Kuala Lumpur International Airport need to be analysed for seismic resistance, since the behaviour of the structure has not been understood.

2. Earthquake is subjected to 0.19g in Kuala Lumpur (Adnan, et al., 1998), Malaysia, therefore, earthquake design should be incorporated in analysis, but it has not been done before in Malaysia construction industry. Therefore, it applies to the existing structure of the control tower as well.

3. Strengthening of structure and the dissipating energy with seismic resistance devices (friction damper) is not fully apprehended, and revised.

4. Finite Element modelling technique in 3 dimension has not been used before. Therefore, to emulate the real behaviour by eigenvector is a new way to understand the behaviour of the tower.

1.6 Objective

The objectives of the study are;

1. To propose friction damper arrangement in the structure,
2. To model the structure in finite element software of SAP2000,
3. To examine the seismic vulnerability of the structure,
4. To identify friction damper energy dissipation, and
5. To understand the behaviour of the structure.

1.7 Scope

This study can be divided into three main areas;

1. Performance of overall control tower at KLIA.
2. Response of seismic acceleration at induced 0.19g is imposed at U1 direction only.
3. Performance of Pall friction damper.

1.8 Organization of Report

The study procurements of the objectives and scopes are explained as below;

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

It is to verify the feasibility of the study outcomes and planning of methodologies in efficient dissertation of input and output.

***Stage 2*:** **Literatures, collecting data and modelling of structures.**

Initial study has to understand the behaviour of the tower and best solution for retrofitting it. Knowing the performance of the tower structure in an earthquake loading is essential to assume the structure behave according to literature findings. Obtaining the information regarding the model beforehand to spearhead the modelling technique is part of the requirement in successful overall analysis.

***Stage 3*:** **Verification of retrofitting devices and methods of finite element modelling.**

The purpose of the process is to identify suitable and applicable retrofitting devices, which is the friction damper and proposal of location to retrofit. Theoretical background of the device is included to verify the concept of work on the device. Material properties and design methods have to be determined to obtain correct mode shapes. Beam and shell element in multi-degree of freedom is used in 3D Finite Element models with SAP2000 computer programs. While, quadruple models are to be erected as the overall tower system, namely, undamped and damped Beam Model, undamped and damped Shell Model, in verifying of the correct earthquake signals.

The models are proposed with (damped) and without (undamped) friction damper for comparison purposes.

***Stage 4*:** **Vulnerability assessment of modelling and response analyses.**

The finite element analyses primarily based on linear material behaviour are compared with the hand calculation to check for the capacity. The characteristics of stiffness are evaluated in the present of friction damper. Response spectrum of KL-Rapid time history analysis is argued in this methodology.

***Stage 5*:** **Discussion and conclusion.**

Summary on the project with regards to the low intensity earthquake at 0.19g of the proposed retrofitting device will be finalised. Comments on the further improvement to the study are to be enumerated.