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SEISMIC BEHAVIOR OF TALL BUILDING STRUCTURES BY FRICTION DAMPER

ABDOLLAH VAEZ SHOUSHTARI

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

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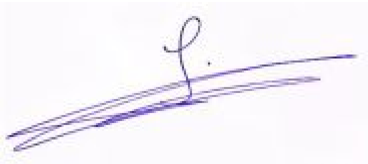
July 2010

I declare that this project report entitled *"Seismic Behavior of Tall Building Structures by Friction Damper* "is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

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To my beloved mother and father

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ABSTRACT

Large-magnitude long-distance earthquakes generated from Sumatra have significant potential engineering implications in Singapore and Malaysia Peninsula due to accentuation by resonance in buildings. Historical seismicity data of the region covering the past 100 years shows numerous occasions when low-intensity seismic waves reached Peninsular and hence no seismic provisions have been incorporated into building regulations to date. If part of input energy due to earthquake could be dissipated through special devices which can be easily be replaced, as necessary, after an earthquake, the structural damage could be reduced. These devices can be classified into three categories: viscous and viscoelastic dampers, metallic dampers, and friction dampers. The purpose of this study is to evaluate the seismic behavior of tall building structures by friction damper. The finite element modeling technique (SAP2000 Software) is used in this study to learn the behavior of structure equipped by friction dampers. Three different methods of analyzing (Free vibration, Response spectrum, and Time History analysis) have been done to achieve this purpose. In general, this study indicates that the response of structure such as story drifts, axial load of columns and beams, shear load and bending moment of beams, and base shear can be dramatically reduced by using friction damper devices. In addition, this study indicates that the seismic risks due to large-magnitude, long-distance earthquakes generated from Sumatra should be considered for the tall buildings in Malaysia and the application of the seismic retrofitting to existing buildings is much needed to safeguard structure from external peak ground acceleration intensity.

ABSTRAK

Jarak skala Richter gempa bumi besar jauh yang dihasilkan dari Sumatera mempunyai potensi implikasi kejuruteraan di Singapura dan Semenanjung Malaysia kerana resonansi diperbesarkan oleh bangunan. Data gempa yang merangkumi 100 tahun terakhir menunjukkan berbagai kesempatan ketika cepatan gempa-gelombang rendah mencapai Peninsular dan sehingga tidak ada peruntukan seismik telah dimasukkan ke dalam bangunan peraturan terkin. Jika bahagian daripada tenaga input akibat gempa bisa hilang melalui peranti khas yang dapat dengan mudah diganti, bila perlu, selepas gempa bumi, kerosakan struktur dapat dikurangkan. Alat ini dapat dikelompokkan menjadi tiga kategori: dan peredam viskoelastik kental, peredam metalik, dan peredam geseran. Objektif kajian ini adalah untuk menilai perilaku seismik struktur bangunan tinggi dengan peredam geseran. Teknik pemodelan elemen terhingga (perisian SAP2000) digunakan dalam kajian ini untuk mempelajari perilaku struktur dilengkapi dengan peredam geseran. Tiga kaedah yang berbeza dari analisis (Getaran Bebas, Respon spektrum, dan Analisis Perubahan Masa) telah dilakukan untuk mencapai matlamat ini. Secara umum, kajian ini menunjukkan bahawa respon struktur seperti anjakan, beban paksi dari tiang dan rasuk, beban ricih dan lentur, dan luncuran dasar dapat dikurangkan secara dramatik dengan menggunakan alat peredam geseran. Selain itu, kajian ini menunjukkan bahawa risiko seismik besar-besaran,-jarak panjang gempa bumi yang dihasilkan dari Sumatera harus dipertimbangkan untuk bangunan tinggi di Malaysia dan pelaksanaan penyesuaian gempa untuk bangunan yang ada sangat diperlukan untuk menjaga struktur dari intensiti gegaran tanah maksimum.

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LIST OF ABBREVIATIONS

		TITEL
IBC	-	International Building Code
NEHRP	-	National Earthquake Hazards Reduction Program
ADAS	-	Added Damping And Stiffness
SMRF	-	Special Moment Resisting Frame
FEMA	-	Federal Emergency Management Agency
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
FDD	-	Friction Damper Device
EC	-	Euro code 8
FE	-	Finite Element
2D	-	2 Dimensional
3D	-	3 Dimensional

RSA	-	Response Spectrum Analysis
THA	-	Time History Analysis
SEER	-	Engineering Seismology and Earthquake Engineering Research

LIST OF SYMBOLS

		TITEL
m	-	Meter
cm	-	Centimeter
mm	-	Millimeter
kN	-	Kilo Newton
$kN/_{mm^2}$	-	Kilo Newton per millimeter square
$N/_{mm^2}$	-	Newton per millimeter square
$kg/_{cm^2}$	-	Kilogram per centimeter square
$kg/_{cm^3}$	-	Kilogram per centimeter cube
g	-	Gravitational ground acceleration
U_1	-	Global X-direction
%	-	Percentage
$\ddot{x}$	-	Ground acceleration
$\dot{x}$	-	Ground velocity
x	-	Ground displacement
t	-	Time/period
Hz	-	Hertz
k	-	Linear elastic stiffness

m	-	Mass
c	-	Damping coefficient
$\ddot{u}$	-	Structural acceleration
$\dot{u}$	-	Structural velocity
u	-	Displacement
±	-	Approximation
δ	-	Inter story drift
b	-	Brace
d	-	Damper
f	-	Shear force/friction coefficient
N	-	Applied normal force
Δt	-	Time step
f_y	-	Strength of reinforcement
$\acute{f}_c$	-	Strength of concrete
E	-	Modulus of elasticity
G	-	Shear modulus
ν	-	Poisson ratio
y_e	-	Yield strength
U_e	-	Ultimate strength
p	-	Axial force
M	-	Bending moment
V	-	Shear force
i.e.	-	Initialism; “In other words”

sgn	-	Signum Function

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CHAPTER 1

INTRODUCTION

1.1 General

Tall buildings are subjected to vibrations. These vibrations can be due to wind forces, earthquake excitations, machine vibrations, or may other sources. In some cases, especially under strong earthquake excitations, these vibrations can cause the structural damage or even collapse of structure. For the structures that have high inherent or natural damping, the likelihood of damage will be decreased. 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 devices may be used to control the response of structure.

1.2 Background

Among the natural phenomenon that human kinds have worried about that, earthquakes are the most distressing ones. The place and the time of occurrence of earthquake are unpredictable and therefore this makes them disaster phenomenon.

During a major earthquake, a large amount of input energy due to earthquake is pumped into the building. The manner in which this energy is consumed in a structure determines the level of damage. The building codes recognize that it is economically not feasible to reconcile this energy within the elastic capacity of materials.

The scale of designing in conventional building codes is to design structures to resist moderate earthquakes without significant damage and avoid collapse during major earthquakes. The primary emphasis is on life safety. The reliance for survival is placed on ductility to dissipate energy during inelastic deformations causing bending, twisting and cracking. Recent earthquakes have clearly demonstrated that conventional construction, even in technologically advanced countries, is not unaffected to destruction.

The most feared effects of earthquake are collapse of structures especially tall building structures due to high displacement of stories. One of the key problems with this explanation is to reduce the structural response by increasing the dissipation of input energy due to earthquake. In the other words, if the amount of energy getting into the structure can be controlled and a major portion of the energy can be dissipated mechanically independent of primary structure, the seismic response of the structure and damage control potential can be considerably improved. These objectives can be delivered by adopting new techniques of base isolation and energy dissipation devices. Damper devices are the most popular instruments for increasing the dissipation of input energy.

The main goals of any structural design are safety, serviceability and economy. Achieving these goals for the design of structures in seismic regions is very important and difficult. Uncertainty and unpredictability of when, where and how an earthquake will be happen, will increase the overall difficulties. The goal of this project is studying the seismic behavior of tall building structures by friction damper.

According to the increment of population every year, tall building structures have significant role in countries. Therefore, the design of these buildings should be more accurate than other buildings. In the other words, the design of tall building structures in seismic regions is more challenging, (Council on tall buildings and urban habitat, 1995).

Finite Element Method (FFM) is a numerical method that can be used to solve different kinds of engineering problems in the stable, transient, linear or nonlinear cases (Bathe, 1996). Among finite element method software's, SAP2000 is known as one of the most precise and practicable software in industry and university researches. It is used for dynamic analysis such as earthquake and water wave loading on structures.

1.3 Problem Statement

Large-magnitude long-distance earthquakes generated from Sumatra have significant potential engineering implications in Singapore and the Malaysia Peninsula due to accentuation by resonance in buildings. In addition, as the high of building increases, the weight of structure will be increased as well as the fundamental period of building, therefore, the displacements of stories or story drifts as well as story shears increase. In the other words, Long-distance earthquakes generated from Sumatra have been a cause for concern in recent years for countries in the Indo-China region including Singapore, Malaysia and Thailand. In addition, Long-distance earthquakes have long period, therefore, as it mentioned earlier, tall buildings have long period too and then phenomenon of resonance may be occurred. For example, long-period seismic waves generated by large-magnitude earthquake events could be amplified by some four to six folds as a result of resonance. (Balendr. T. et al. 2005). One criticism of much of the literature on above explanation is that, although, Malaysia is located in low seismic activity area but the active earthquake fault line through the centre of Sumatra just lies 350 km from Peninsular.

Historical seismicity data of the region covering the past 100 years shows numerous occasions when low-intensity seismic waves reached Peninsular; the acceleration of the infrastructure is estimated to be about 3% gravitational acceleration. Neither casualty nor significant damage has been recorded from these events and hence no seismic provisions have been incorporated into building regulations to date. Consequently, there is generally little attention to design and detailing for ductile behavior of the structure in the region.

In addition, according to studies, the damping ratio of structures is generally less than 10%, and also, by increasing the height of structures, damping ratio will be decreased, (Amr. S. E., and Luigi. D. S., 2008). Therefore, the amount of elements that are needed to resistant the lateral loads increase, so, the cost of construction increase dramatically.

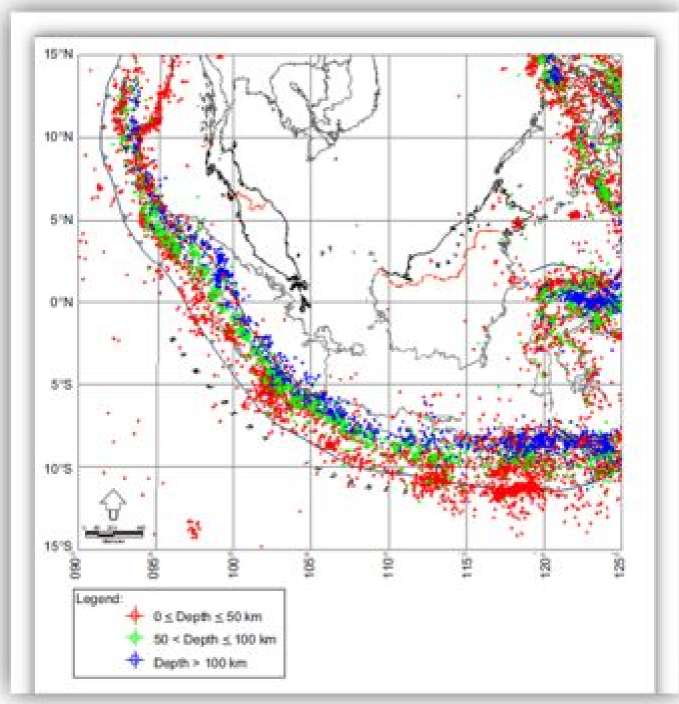

Figure 1.1 Historical earthquakes around Peninsular Malaysia, (Azlan. A, et al, 2005)

1.4 Objectives

The objectives of this study can be listed as follows:

a) Remodeling of a tall building structure (Luth Headquarters building) by friction damper.
b) Determining the effects of large-magnitude, long-distance earthquakes generated from Sumatra on seismic behavior of tall buildings of Malaysia Peninsula.
c) Studying the seismic behavior of existing tall building structure by friction damper, when seismic activity occurs using time history, response spectrum and free vibration analysis.

1.5 Scope of study

a) Earthquake characteristics
b) Response of tall building structures
c) Damper characteristics (Types of damper devices)
d) Evaluation of response of tall building structures equipped by friction damper

1.6 Organization of Study

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

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

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

Stage 2: Literatures, collecting data and modeling of structures

Initial study should be done to understand the behavior of the tall building structure and best solution for retrofitting it. Knowing the performance of the tall building structure subjected to earthquake loading is essential to assume the structure behave according to literature findings. Obtaining the information of model before head and spearhead the modeling technique is part of the requirement in successful overall analysis.

Stage 3: Verification of retrofitting devices and modeling

The purpose of this stage is to identify appropriate and application of retrofitting devices, which is the friction dampers devices. In addition, the theoretical background of the frame equipped by friction damper device is also included to verify the concept of work on the device. Material properties and analysis methods have been determined to obtain correct mode shapes. The structure with and without damper has been modeled by SAP2000 software to verify the response of structure with appropriate earthquake signals. In other words, the models are proposed with (damped) and without (UN damped) friction damper for comparison purposes.

Stage 4: Vulnerability assessment of modeling and response analysis

The response spectrums and Time histories analysis have been done to find responses of the two models.

Stage 5: Discussion and conclusion

Summary of the project according to the different analysis methods and the proposed retrofitting device will be presented. Comments on the further improvement to the study are to be enumerated.