SEISMIC FRAGILITY OF TALL CONCRETE WALL STRUCTURES IN MALAYSIA UNDER NEAR-FIELD EARTHQUAKES CONSIDERING INADEQUATE SPLICE LENGTH

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DEDICATION

All the praises and thanks be to Allah! I dedicate this thesis to my beloved parents who have raised me to be the person I am today. Thank you for all your unconditional love, guidance and supports in my life. To my dear wife and my only cute daughter Frangis. Additionally, to my sisters and brothers, especially my two beloved younger brothers Mohammad Dawood and Mohammad Jawid whom I lost two years ago on the same day. You are always in my heart and I am living my life with your memories. And lastly special thanks to my supervisors, Dr. Sophia C.Alih and Dr. Mohammadreza Vafaei for their sincere guidance and helps in this research study.

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ABSTRACT

Malaysia is located in low to moderate seismicity region in terms of earthquake events and mostly engineers design the structures under the gravity and wind loads and for the most part they don't consider the codes requirements for the seismic loads. In this study the seismic performance of tall concrete wall buildings under the near field earthquake considering inadequate lap splice length effects has been discussed. In this study two RC buildings (A & B) having same height and plan but different in configuration are selected. Each building has 25 stories with story height of 3.2 m. The first 5 storeys of the building A and the first 3 storeys of building B have been considered as parking areas. The structural system of the parking levels for both buildings consists of columns and beams while the structural system of the upper levels vary and contain only flat slab and shear walls without columns. Using ETABS software the failure mechanism, Inter-Storey drift demands as well as drift capacities of the two reference buildings have been obtained under a set of fifteen Near-Field earthquake records from the process of Incremental Dynamic Analysis (IDA). Four fragility curves have been generated for four 2D frames which were extracted from main 3D models. Eventually, it has been concluded from the fragility curves that inadequate lap splice compared with sufficient condition imposes considerable effects on seismic behaviour of the structures, which by reducing the ductility make the structures less resisting and prone to premature failure against earthquake excitations

ABSTRAK

Malaysia terletak di kawasan seismik berintensiti rendah hingga sederhana dan secara amnya jurutera merekabentuk struktur di bawah beban graviti dan angin dan mereka tidak mempertimbangkan syarat kod untuk beban seismik. Dalam kajian ini, prestasi bangunan tembok konkrit tinggi telah dibincangkan yang mengalami gempa bumi tempatan dengan mengambil kira kesan panjang sambungan yang tidak mencukupi. Dalam kajian ini dua bangunan RC (A & B) yang mempunyai ketinggian dan pelan yang sama tetapi berbeza dalam konfigurasi telah dipilih. Setiap bangunan mempunyai 25 tingkat dengan ketinggian antara lantai sebanyak 3.2 m. 5 tingkat pertama bangunan A dan 3 tingkat pertama bangunan B telah dianggap sebagai kawasan parkir. Tempat letak kereta untuk kedua-dua bangunan terdiri daripada tiang dan rasuk sementara tingkat atasnya berbeza-beza dan hanya mengandungi papak rata dan dinding ricih. Dengan menggunakan ETABS mekanisme kegagalan, permintaan anjakan antara lantai dan juga kapasiti anjakan dari dua bangunan rujukan telah diperoleh menggunakan lima belas rekod gempa tempatan menggunakan IDA. Empat lekukan kerapuhan telah dihasilkan untuk empat bingkai 2D yang diekstrak dari model 3D utama. Akhirnya, dapat disimpulkan dari lekukan kerapuhan bahawa panjang sambungan yang tidak mencukupi memberikan kesan yang besar terhadap tingkah laku gempa struktur, yang dengan mengurangkan kemuluran menjadikan struktur kurang tahan dan rentan terhadap kegagalan pramatang terhadap gempa.

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LIST OF ABBREVIATIONS

ASCE - American Society of Civil Engineers
FEMA - The Federal Emergency Management Agency
ATC - Air Traffic Control
BS - British Standard
PGA - Peak Ground Acceleration
IO - Immediate Occupancy
LS - Life Safety
IBC - International Building Code
CP - Collapse Prevention
IDA - Incremental Dynamic Analysis
ETABS - Extended Three-Dimensional Building System

LIST OF SYMBOLS

${S_E}^2$	Standard error of demand drift
DS	Standard error of demand drift
SI	Seismic intensity
ϕ	Standard normal distribution
$\lambda_{D/SI}$	Natural logarithm of the median demand drift given the seismic intensity from the best fit power law
λc	Natural logarithm of the median of drift capacities for particular damage state
$\beta_c \beta_m$	Uncertainties related to capacity and modelling

CHAPTER 1

INTRODUCTION

1.1 Problem Background

The countries which are located in the Southeast Asia, have had a fast growth in terms of economic viewpoints in recent span of time. As the regions in the Southeast Asia which fall in the low to moderate seismic zones have not been struck by disaster caused by earthquake excitations, hence for the design of the structures within these regions the effects of seismic forces have not been taken into account (Shoushtari, Adnan, and Zare 2016) . Construction of reinforced concrete buildings in Malaysia is widely common and since this country lies in Southeast Asia hence, mostly engineers in the design process do not include seismic forces. Therefore, it is significant to carry out an assessment of structures in order to estimate potential losses which can be induced by earthquake excitations.

From the view point of seismicity, the earth is categorized into high, moderate and low seismic regions. As stated above the researches show that Malaysia lies in the stable zone with regard to earthquake events. However this statement is overruled due to happening of earthquakes especially in east Malaysia. The seismic sources in Malaysia are characterized by near-field due to local events and far-field due to earthquake waves come from Sumatra (Balendra and Li 2008). In 2015 an earthquake with a magnitude 6.0 in scale of Richter which was counted as the most powerful earthquake striking Malaysia since 1976 occurred in Sabah, Ranu. Happening of recent earthquake in east Malaysia in fact classified the country into low to moderate seismicity regions and created the idea of considering the impact of earthquake loadings in the design codes for the future (Moffed and Mohamed 2019).

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As Malaysia rapidly moving in the path of modernization and development, the construction of tall buildings is also increasing. Damages to tall buildings can cause substantial economic effects and endanger human’s life. Hence, for the purposes of mitigating such damages there are loss models which are utilized to predict the potential damages caused by earthquakes. Among the loss models, fragility curves are quite essential means for evaluation of performance and vulnerability of structures against various levels of seismic events. In fact, fragility curves are statistical tools which under the ground shaking shows the likelihood of a structure exceeding or reaching certain damage level

1.2 Problem Statement

As stated previously Malaysia is assumed to be in the safe zone with respect to earthquake events therefore, for the most part designers do not consider the effects of earthquake when designing buildings(Abas 2001). Despite being in a stable zone the 2015 earthquake which struck Ranu at east of Malaysia caused damages to all those buildings were designed only under the gravity and wind loads.

After the inspections and investigations of damaged buildings, it was revealed that there had been many reasons behind the scenario like lack of skilled workers during construction stages, poor engineering design, nonexistence of enough steel bars, poor detailing of bars and improper usage of materials. Therefore, knowing these points opened the way for engineers and researchers to adopt stricter measures for considering the natural hazards that have a huge impact on buildings in the future.

Using fragility relations can help engineers to assess the effects of earthquake on buildings and enables them to have an estimation of damages as well as reduce risks due to earthquakes in future. For an existing building the risk can be mitigated by considering some approaches like reinforcement jacketing, FRP assembling and steel jacketing, and for the new buildings modifications can be brought to the rules and regulations of seismic design. (Mwafy 2012).

As the past studies demonstrate, in Malaysia the fragility curve has been developed for certain type of low to moderate rise structures (Saruddin & Nazri 2015; Ahmadi et al. 2014). As far as the tall buildings are concerned, there is no study so far to address the seismic fragility with respect to inadequate lap splice length effects in Malaysia.

Hence, considering inadequate lap splice length effects, this study focuses on seismic fragility (using fragility relations) of tall concrete wall structures under near field excitations of earthquakes in Malaysia.

1.3 Research Objectives

Following are the objectives for this research:

(a) To study the mechanism of failure of the reference buildings under the near-field earthquake considering inadequate lap splice length effects.

(b) To determine seismic inter-story demands of the reference buildings considering inadequate lap splice length effects by conducting Incremental Dynamic Analysis.

(c) To develop fragility curves of the reference buildings subjected to near-field earthquakes considering inadequate lap splice length effects.

1.4 Research Scope

In this study the following scopes are observed:

(a) The compressive strength of the concrete is 40Mpa.

(b) The yield strength of the reinforcement is 460Mpa.

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