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ASSESSMENT OF BUILDING FRAGILITY CURVE DUE TO EARTHQUAKE EXCITATION

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ASSESSMENT OF BUILDING FRAGILITY CURVE DUE TO EARTHQUAKE EXCITATION

by

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LIST OF SYMBOLS

S_a	Specific spectral acceleration
T	Period
y	Realized condition of ground motion
P_f	Probability
$\Phi[.]$	Standardize normal distribution
$\bar{\mu}_R$	Median capacity based on engineering judgment
β_R	Standard deviation based on engineering judgment
$\bar{\mu}_E$	Median from sample
β_E	Standard deviation from sample
R	Structural capacity
S	Structural response
$F_S(.)$	Cumulative probability distribution of *S*
f_R	Probability density function of *R*
$P_{D\|\text{MMI}}\left[d\|\text{MMI}\right]$	Probability reaching or exceed at specified MMI
$P_{D\|S_a}\left[d\|S_a\right]$	Probability reaching or exceed at specified spectral acceleration
$f_{S_a\|\text{MMI}}\left[S_a\|\text{MMI}\right]$	Conditional probability density function of spectral acceleration at specified MMI
λ	Mean of ln*x*
ς	Standard deviation of ln*x*
m_R	Median capacity
x	Demand
ξ_R	Logarithmic standard deviation

X	Lognormal distributed ground motion index (e.g PGA)
μ	Mean of natural logarithm
σ	Standard deviation of natural logarithm
D_{as}	Seismic demand (aftershock)
C	Structural capacity
S_d	Median of demand
$\beta_{d\|IM}$	Dispersion of demand
S_c	Median of capacity
β_c	Dispersion of capacity
β_m	Modeling uncertainty (β_m = 0.2)
$\mu_{i,k}$	Median of fragility curve from $DS=i$ to $DS \geq k$
sd	Spectral displacement
sd_{ds_i}	Mean value of lognormal distribution which corresponding damage state threshold
β_{ds_i}	Standard deviation of natural logarithm of spectral displacement of ds
$\hat{C}$	Median structural capacity
$\hat{D}$	Median structural demand
$\beta_{D\|SI}$	Uncertainty in D
β_c	Uncertainty in C
β_m	Modeling uncertainty
t_d	Duration of the ground motion
i	Storey level

n	Number of storey
u_i	Storey drift
h_i	Storey height
β	Log-standard deviation of IM
μ	Mean of IM
λ_k	Lognormal mean
ζ_k	Lognormal standard deviation for realization *k*
G_k	Dead load
Q_k	Live load
a_g	Design ground acceleration on type A ground ($a_g = a_{gR} \cdot \gamma_I$)
S	Soil factor
T_B	Period of the constant spectral acceleration branch (lower limit)
T_C	Period of the constant spectral acceleration branch (upper limit)
T_D	The value defining (beginning of the continuous displacement response range of the spectrum)
$S_d (T)$	Design spectrum
q	Behavior factor
a_{gR}	Peak ground acceleration on type ground A (assume 0.5 g)
γ_I	Important factor
H	Height of building (from top of basement or foundation)
m	Total mass of the building
F_i	Horizontal force acting on storey *i*
F_b	Seismic base shear
m_i, m_j	Storey masses

z_i, z_j	Heights of the masses
R_{jb}	Joyner-Boore distance
M_w	Magnitude
D	Damage
Δ	Displacement of maximum storey

LIST OF ABBREVIATIONS

2D	2 Dimension
3D	3 Dimension
CP	Collapse Prevention
DC	Damage Control
DCM	Displacement Coefficient Method
DCM	Medium Ductility Class
DS	Damage State
EC2	Eurocode 2
EC3	Eurocode 3
EC8	Eurocode 8
FF	Far Field
IDA	Incremental Dynamic Analysis
IM	Intensity Measure
IO	Immediate Occupancy
LS	Life Safety
MRCF	Moment-Resisting Concrete Frame
MRSF	Moment-Resisting Steel Frame
NDA	Nonlinear Dynamic Analysis
NF	Near Field
NSA	Nonlinear Static Analysis

NTHA	Nonlinear Time History Analysis
OP	Operational Phase
PBSD	Performance Based Seismic Design
PEER	Pacific Earthquake Engineering Research
PGA	Peak Ground Acceleration
POA	Pushover Analysis

PENILAIAN LENGKUNG KERAPUHAN SESUATU BANGUNAN DISEBABKAN OLEH PENGUJAAN GEMPA BUMI

ABSTRAK

Tujuan utama kajian ini ialah membentuk lengkung kerapuhan untuk rangka tetap dan tidak tetap berdasarkan perbezaan jenis bahan struktur, ketinggian dan rekod pergerakan tanah. 6 set rangka konkrit dan keluli telah digunakan dalam kajian ini dengan ketinggian yang berbeza iaitu 3-, 6-, dan 9-tingkat untuk rangka tetap dan tidak tetap. Setiap struktur rangka direka berdasarkan Eurocode 2 dan 3 dengan bantuan Eurocode 8 untuk beban gempa bumi. Perisian SAP2000 telah digunakan sebagai perisian utama untuk analisa. Analisa pushover (POA) telah dijalankan untuk mendapatkan prestasi struktur berdasarkan beban statik. Daya corak segi tiga telah digunakan untuk menghasilkan hubungan dasar ricih-hanyut. Manakala, analisis dinamik tambahan (IDA) dijalankan dengan menggunakan tiga rekod pergerakan tanah bagi setiap medan dekat dan medan jauh. Di samping itu, gempa bumi Ranau telah dipertimbang dalam kajian ini untuk dua jenis keadaan; gempa bumi tunggal dan gempa bumi berulang. Keputusan daripada analisa IDA akan digunakan sebagai parameter utama untuk membentuk rangka kerapuhan. Lengkung IDA dibandingkan dengan 5 tahap prestasi seperti dinyatakan dalam kajian Xue et al. (2008) iaitu fasa operasi (OP), penghunian serta merta(IO), kawalan kerosakan (DC), keselamatan hayat (LS) dan runtuh pencegahan (CP). Berdasarkan keputusan daripada kajian ini, keputusan POA menunjukkan rangka tetap menghasilkan permintaan yang lebih tinggi berbanding rangka tidak tetap untuk struktur konkrit dan keluli. Daripada keputusan IDA, rangka tetap menunjukkan prestasi yang lebih

baik untuk kedua-dua bahan di bawah rekod medan dekat dan medan jauh. Berdasarkan lengkung kerapuhan dihasilkan untuk medan dekat dan medan jauh, rangka tidak tetap menunjukkan kebarangkalian yang lebih tinggi untuk mencapai tingkat prestasi untuk rangka konkrit. Sementara itu, rangka tetap keluli menunjukkan kebarangkalian yang lebih tinggi untuk mencapai tahap prestasi.

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ABSTRACT

In this study, the main objective is to develop fragility curve of regular and irregular moment-resisting frame based on different types of structural material, height, and ground motion records. 6 sets of concrete and steel frames were used in this study and varied in terms of heights which are 3-, 6- and 9-storey for regular and irregular frame. Each structure frames was designed based on Eurocode 2 and 3 with the aid Eurocode 8 for earthquake loading. The SAP2000 was used as the main tool to carry out the analysis. A pushover analysis (POA) was performed to get the performance of the structure due to static load. Triangular load was used to produce base shear-drift relationship. Then, an incremental dynamic analysis (IDA) was carried out with 3 ground motion records for each set near and far field. In addition, the Ranau earthquake also considered in this study for two types of case; single and repeated earthquake. While to develop the fragility curve, the result from IDA will be used as the main parameters. The IDA curves were compared with five level of performance level from Xue et al. (2008) study which are operation phase (OP), immediate occupancy (IO), damage control (DC), life safety (LS), and collapse prevention (CP). On the basis of the result of this thesis, it can be concluded that from POA result showed regular frames demonstrate a higher demand compared to irregular frames for concrete and steel frames. From the IDA results, it was proven that regular frames perform better for both materials under near and far field records. Based on the fragility curves developed for the near and far field records, irregular frames

showed a higher probability of reaching or exceeding the performance level for concrete frame. On the other hand, regular steel frames showed a higher probability of reaching and exceeding the performance level.

CHAPTER ONE

INTRODUCTION

1.1 Background

Nowadays, the issue of Malaysia's safety from earthquakes has been raised after an earthquake hit East Malaysia. As recorded on 5th of June 2015 at 7.15 am, a moderate earthquake of 6.0 Richter scale struck Ranau, Sabah. The shaking was felt throughout the west coast of Sabah. It was the strongest earthquake affecting Malaysia since 1976. This happened when there is a friction between the tectonic plates of Borneo, Philippines and Australia (Doksil, 2015). What happened in Sabah proved that Malaysia has to consider the earthquake load in the design of buildings and provide earthquake awareness to public. Figure 1.1 shows the damages that occurred during the Ranau earthquake in Sabah.

Figure 1.1 Damage during the Ranau Earthquake

Generally, building damage is the main source of seismic loss when an earthquake hits, and buildings designed before the introduction of seismic resistance might have a relatively higher chance of being damaged. These damages will have a major impact to both, the country and citizens. A sudden shaking of the ground could destroy everything in the blink of an eye. Thus, an evaluation of the seismic performances of these buildings will provide some practical references for reducing loss during earthquakes.

In addition, some of buildings in Malaysia are designed in irregular shapes. Figure 1.2 shows some examples of irregular building in Malaysia.

(a) TM Tower

(b) Mitraland Building

(c) Tune Hotel, Cyberjaya

(d) Maxis Tower

Figure 1.2 Example of irregular building in Malaysia