Jurnal Teknologi

Full Paper

SEISMIC TIME-HISTORY GROUND-MOTIONS FOR A SPECIFIC SITE IN JAKARTA

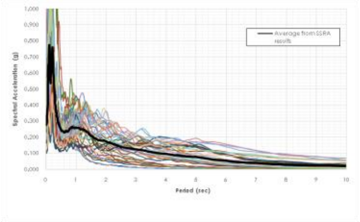
I Wayan Sengara*, Muhammad Addifa Yulman, Andri Mulia

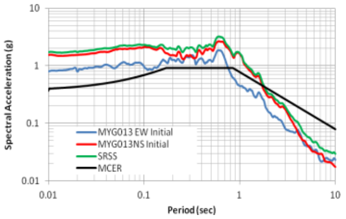
Geotechnical Engineering Research Group, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, 40132, Bandung, Indonesia

Article history
Received
3 August 2015
Received in revised form
31 August 2015
Accepted
23 September 2015

*Corresponding author
iws@geotech.pauir.itb.ac.id

Graphical abstract





Abstract

Indonesia has developed new seismic building code based on risk-targeted ground-motions adopting 1 % probability of building collapse in 50 years. The new seismic design criterion, which is presented in the code, have combined both seismic hazard and building fragility. For performance-based analysis of high-rise buildings, a complex non-linear time-history analysis is needed. This paper presents results of study on development of the time-history with emphasing on procedure of developing pairs of time-history at ground surface for spesific site in Jakarta with reference to 2012 International Building Codes and ASCE-SEI-7-10. The study involves generation of time-history from reference base-rock through site-response analysis to ground surface. Development of time-history at ground surface with a procedure involving Square Root of the Sum of the Square method (SRSS) in order to reasonably scaled time-histories through spectral matching technique is presented herein. The matched time-histories are developed from various strong-motion records representing different earthquake sources dominant to control the site evaluated from de-aggregation within seismic hazard analysis. This work also adopts baseline corrections in which velocity and displacement components of matched time-histories can be drifted to zero at the end of recorded seismic time.

Keywords: Seismic hazard, time-history, risk-targeted ground-motions, baseline correction, performance-based

Abstrak

Indonesia telah menghasilkan kod bangunan tahan seismik baru yang berasaskan pada *risk-targeted ground-motions* dengan mengambilkira keberangkalian 1 % keruntuhan bangunan dalam masa 50 tahun. Kriteria rekabentuk seismik, yang tertuang dalam kod tersebut, telah menggabungkan bahaya seismik dan kerentanan bangunan. Untuk analisis berdasarkan-prestasi dari bangunan pencakar langit, analisis *time-history* yang *non-linear* dan kompleks sangat diperlukan. Kertas kerja ini menyajikan hasil dari kajian pengembangan *time-history* dengan menekankan pada prosedur pembuatan pasangan time-history pada permukaan tanah untuk Jakarta dengan merujuk kepada pada 2012 *International Building Codes* and ASCE-SEI-7-10. Kajian ini melibatkan pembentukan *time-history* dari batuan dasarhingga permukaan melalui analisis *site-response*. Pengembangan *time-history* di permukaan dengan prosedur *Square Root of the Sum of the Square method* (SRSS) dalam rangka menskalakan *time-history* melalui teknik *spectral matching* juga ditunjuk. *Time-history* yang sepadan dikembangkan dari berbagai catatan *time-history* yang mewakili sumber-sumber gempa bumi dominan yang dinilai dengan analisis *de-aggregation*. Kajian ini juga menggunakan *baseline corrections* dimana komponenhalaju dan anjakan dari *time-history* yang sepadan dapat dibawa ke angka kosong pada catatan akhir masa seismik.

Kata kunci: Bahaya seismik time-history, risk-targeted ground-motions, baseline correction, berdasarkan-prestasi

1.0 INTRODUCTION

Previous international seismic design criteria stipulated in both Uniform Building Code (UBC) 1997 [1] and previous Indonesian Seismic Building Code (SNI-1726-2002) [2] are based only on the probability of exceedence (PE) of seismic hazard. The design criteria were previously developed on the level of hazard of 10% PE in 50 years. Yet, after several significant earthquakes hit Indonesia several years ago, the predicted accelerations based on these codes were smaller than the actual ones. A demand for updating seismic hazard map was then essentially needed. In 2011, a national research team, known as TEAM-9, has successfully developed new seismic hazard maps having 2% PE in 50 years hazard. One year later, new Indonesian Seismic Building Code (SNI-1726-2012) [3] including updated maps has been officially published to replacing the previous code. This code basically adopts ASCE-SEI-7-10 [4].

Additionally, the new Indonesian Seismic Building Code 2012 also adopts seismic design criteria which are not only based on seismic hazard but also building resistance. The ground-motions derived from the concept is called risk-targeted ground-motion (RTGM). The analysis developed herein is based on RTGM having a 1% probability of building collapse in 50 years with reference to ASCE-SEI-7-10 [4]. Since the new criteria are based on RTGM, then risk-targeted maximum considered earthquake (MCE_R) needs to be derived from maximum considered earthquake (MCE) seismic hazard and characteristics of the building in the form of its fragility. Furthermore, design spectral values are derived from two-third of the MCE_R. Seismic maps in the new 2012 Indonesian seismic building codes are with reference to Irsyam *et al*. [9] and Sengara *et al*. [5, 6].

In general, the response spectra are derived from 2 spectral values at 0.2 sec and 1.0 sec periods. For site specific spectra and design ground-motions of specific high or super high-rise buildings presented in this paper, the spectral periods of interest are selected to vary fom T=0 sec (PGA), T=0.2 sec, T=1 sec, T=2 sec, T=5 sec, and T=10 sec.

For performance-based analysis of specific structures such as high-rise or super high-rise buildings, a design requires more complex dynamic non-linear analysis in which two horizontal components (pair) of time-histories must be simultaneously input in the structural modeling. An overestimate design would occur when the time-histories are spectrally matched to the single target spectra obtained from the ground surface MCE_R. It is essential that time-histories must be developed through proper method and procedure.

This paper attempts to continue a previous study reported in Sengara [7]. The study focused on developing risk-targeted based seismic design criteria for proposed super high-rise buildings in Jakarta. The work consists of probabilistic seismic hazard analysis (PSHA), de-aggregation analysis, risk-integral analysis, site-specific response analysis (SSRA), and spectral matching to target spectra. In particular, this paper presents the results of the study and time-history development process, with focusing on procedures for developing time-histories with reference to newly developed approach such as Baker *et al*, [8], PEER 2010 [9], including ASCE-7-10 [4], and 2012 International Building Code [10].

Since ground surface time-history development for performance-based analysis of building structures is an integrated process following PSHA and SSRA, review of PSHA and SSRA that has been presented in Sengara [7, 11] is also presented herein briefly. Two categories of time-history analysis processes have been investigated in this study. Firstly, it is based on time-history generation through spectral matching of target spectra of reference base-rock motions resulted from PSHA and the resulted ground surface time-history from SSRA. Secondly, ground surface time-history generation through spectral matching on pairs of accelerograms to target maximum spectra recommended from SSRA. These two analysis processes are presented sequentially and discussed.

2.0 SEISMIC HAZARD AND RISK ANALYSIS

2.1 Probabilistic Seismic Hazard Analysis

PSHA in this study was carried out to generate uniform hazard spectra (UHS) at reference subsurface base-rock for 2% PE in 50 years. The PSHA is computed by considering seismic source zones around 500 km of radius from the sites of interest. The current methodology has considered three-dimensional seismic source zones with adopting total probability theorem in which earthquake magnitudes (M), hypocenter distances (r) as continuous independent random variables affecting the intensity (I), in this case PGA or spectral acceleration, is adopted in this PSHA. The total probability theorem, H(a), is expressed as:

$$H\,(a) = \sum v_i \iint P[A > a|\, m, r]\ f_{Mi}(m)\ f_{Ri|\,Mi}(r,m)drdm \qquad (1)$$

Annual rate of earthquakes with magnitude higher than some threshold value of M_{oi} in source I is represented by v_i. Moreover, $f_{Mi}(m)$ and $f_{Ri|\,Mi}(r,m)$ are probability density functions on magnitude and distance, respectively. $P[A > a|\, m, r]$ shows the probability that an earthquake of magnitude m at distance r generates a peak acceleration A at the designated site being greater than a. This theorem is implicitly adopted in EZ-FRISK computer program [12] having been used in this study.

Target spectra at the base-rock are then generated from the results of de-aggregation analysis as part of the PSHA. The controlling magnitude and distance of the dominant earthquake from the analysis of each period of interest is adopted to generate response spectra using appropriate up-to date ground-motion prediction equations (GMPEs), including Next Generation Attenuations (NGA) for shallow crustal earthquake sources. According to ASCE-SEI-7-10 [4], site specific response spectra analysis needs to be performed based on input ground-motions being scaled to base motion period by period. In order to accommodate the requirement, in this study seven (7) input ground-motions are scaled to uniform hazard spectra (UHS) at 6 (six) periods of interest (T=PBA, T=0.2 sec, T=1.0 sec, T=2.0 sec, T=5.0 sec, and T=10 sec) are generated.

2.2 Risk-Targeted Ground-Motion

A new concept of including structural capacity into seismic design criteria has been introduced and developed in the new Indonesian Seismic Building Code 2012. The concept introduces risk-targeted ground-motion (RTGM) that corresponds to 1% probability of exceedence in 50 years. RTGM can be computed by a definite integration method in which curves of both hazard curve and probability of building resistance are split into thin vertical strips and treated as a rectangular shape. For each strip, the multiplication of the both probability is done. The risk is then defined as the sum of the multiplication process. McGuire [13] generally formulates the risk by following equation:

$$\text{Risk, } P_f = \int_0^{\infty} f_R(a)\, f_{E_m}(SA>a)\, da \qquad (1)$$

where f_R and f_{Em} are probability density function of structural resistance and earthquake load, respectively.

The earthquake part of the equation above can be presented with site-specific hazard curve. On the other hand the uncertainty of structural capacity can be further replaced with normal distribution using following equation:

$$f_R(a) = \frac{1}{a\beta\sqrt{2\pi}} \exp\left[-\frac{(\ln a - (\ln(RTGM) + 1.28\beta))^2}{2\beta^2}\right] \qquad (2)$$

According to the equations above, RTGM is calculated through numerical integration and iterative process. This methodology is as conducted by Luco *et al*, [14] with adopting generic fragility curve equation. Additionally, studies of RTGM for Indonesian area can be found in Sengara *et al*. [5, 6].

2.3 Site-Specific Response Analysis

Site-specific response analysis (SSRA) involves development of seismic input motion time-history at references of subsurface rock resulted form PSHA through de-aggregarption analysis which identifying controlling magnitude and distance of dominant earthquake for various periods of interest. It is essential to perform SSRA considering input motions that are scaled to the base motion period by period. In this study, each target spectra scaled to UHS for six (6) periods of interest (which are T= 0 sec, T=0.2 sec, T=1.0 sec, T=2.0 sec, T=5.0 sec, and T=10 sec) are generated. In this process, the target spectra has adopted conditional mean spectrum (CMS) method by Baker *et al*. [8] having been built in the EZ-FRISK computer program.

Further, input motions are generated by performing spectral-match of available representative strong-motion records to the target spectra. Spectral-matching technique proposed by [15], and [16] that are built in the EZ-FRISK 7.62 computer program [12] used for the analysis. Forty two (42) input base motions have been spectrally matched to the developed MCE_R target spectra, with initial earthquake strong-motions recorded worldwide correspond to de-aggregation analysis within the PSHA.

The result of the site response analysis result in recommended surface ground-motions that has considered the response to uncertainty in soil properties, depth of soil model, and input motions. In this study, the surface spectral accelerations analyzed through SSRA is conducted period by period using the generated seismic input motions at various aforementioned periods.

By considering PSHA, RTGM and site-specific response spectra analysis, ground surface maximum or design response spectra as target spectra for developing time-histories are presented further in this paper could.

3.0 PROCEDURE FOR DEVELOPING TIME-HISTORIES

Seismic time-history development needs to match target spectra at specific subsurface reference. With reference to [9], target spectra can be developed through two approaches. First is design response spectrum which is developed from building code procedures and resulted from uniform hazard spectrum (UHS) for reference site class or from site-specific response analysis. Second one is design response spectrum developed from site-specific scenario spectra preserving realistic spectrum shapes for controlling earthquakes. The ordinate at periods of interest will match with the same ordinate of design spectra (conditional mean spectra).

For comprehensive and representative earthquake ground-motions analysis, as well as with reference to ASCE-7-10, IBC2012, and Indonesian seismic building codes 2012, for three-dimensional structural dynamic analysis, input ground-motions need a minimum of two horizontal direction components. Since the two horizontal components of time-histories are difficult to be acquired, then artificial time-histories for the two components are able to be carried out. In addition, it is essential that time-histories must be selected from past earthquakes having similar magnitudes, fault distance, and source characteristics.

Since the result from PSHA only produces single design response spectra, direct spectral matching procedure using the two time-histories is considered to produce overestimate design. The aforementioned building codes require that each pair of the ground-motions shall be spectrally scaled from 0.2 sec to 1.5 *sec of* period. This technique results overconservative in which the corresponding ordinate of average spectrum is higher than design response spectra.

In this study, a procedure of generating two horizontal time-histories, which is consistent with design response spectra, is proposed [17]. The procedure of developing time-histories at the surface was carried out with spectrally scaling the pair of the selected time-histories. This scaling process could be carried out by adopting Square Root of the Sum of the Square (SRSS) method. Ratios at each period, K, was developed by dividing SRSS to the target spectra (MCE_R). Each component was then divided by the ratio at each period so that response spectra for each component would be lower than the given MCE_R. Finally, each initial recorded component was spectrally matched to the scaled target spectra.

The SRSS is formulated by using equation below:

$$SRSS(T) = \sqrt{Sa_{initial}(T)_E^{\,2} + Sa_{initial}(T)_N^{\,2}} \qquad (3)$$

Where $Sa_{initial}(T)_E$ and $Sa_{initial}(T)_N$ are spectral accelerations at each period for east and north initial time-histories, respectively. The ratio, K, can be calculated with the Equation (5), whereas the corrected target spectra for each component are defined by the Equation (6).

$$K(T) = \frac{MCER(T)}{SRSS(T)} \qquad (4)$$

$$Sa_{target}(T) = \frac{Sa_{initial}(T)}{K(T)} \qquad (5)$$

Detail procedures of developing time-histories involving PSHA and SSRA in this study is as follows:

1. Develop target spectra
    a. determine reference base-rock UHS at the site of interest;
    b. develop base motion MCE_R from UHS, including ground-motion directivity;
    c. Select appropriate 7 (seven) base-rock strong-motion time-histories with correspond to de-aggregation result for various periods of interest.
    d. perform spectral matching of base motions;
    e. carry out wave propagation analysis for the selected time-histories (SSRA);
    f. generate surface response spectra from the propagated time-histories;
    g. recommend design spectra as surface target spectra;
2. Develop surface time-histories for design purposes
    a. select a pair horizontal components of time-histories;
    b. calculate SRSS;
    c. compute ratio of K for each period of interest;
    d. compute new target spectra for each component of time-histories;
    e. perform spectral matching for each component in which initial time-histories are spectrally matched to the new target spectra;

4.0 SPECTRAL MATCHING PROCEDURE

As has been mentioned above, essential requirement in developing artificial time-histories is that the generated ground-motion time-histories need to match target spectra. This is done through spectral matching technique. The efficient and accurate estimation of response spectra would determine high-quality time-histories which are needed in dynamic non-linear analysis in performance-based analysis of buildings. The essential components of carrying out spectral matching are determination of target response spectra, time-histories selection, and spectral matching algorithm.

There are two approaches of spectral matching, which are:

a. Frequency domain method
   The Fourier amplitude spectra are adjusted based on the ratio of target spectra to the actual response spectra. Then Fourier phase of the initial ground-motions must be kept during adjustment. This approach has several weaknesses which are changing the non-stationary character of the ground-motions, not representing real earthquake input motion, and leading to increase the total energy in the input motion.
b. Time Domain Method
   Basic assumption of this methodology is algorithm usage that applies reserve impulse wavelet functions for modifying the initial ground-motions so that its response spectra are appropriate with target spectra. Application of wavelet functions in the time domain spectral matching procedure is becoming effective tool for analyzing localized variation of energy within ground-motions. Abrahamson [15] and Al Atik and

Abrahamson [16] used these techniques for developing the RSPMatch program and RSPMatch99 program.

Since the time domain method become a fundamental for further development of spectral matching procedure, the spectral matching procedure that was developed by [15] was adopted for this paper. Generally, the method has two important steps as follows:

1. Spectral match using impulse model 'Tapered Cosine', between 0.5 Hz and 100 Hz for a maximum of number iterations, stopping if the tolerance is less than 0.05. The damping factor for convergence is 0.5. The minimum eigenvalue for convergence is 0.0001.
2. Spectral match using impulse model 'Time-reserved oscillator response', between 0.1 Hz and 100 Hz for maximum of iterations, stopping if the tolerance is less than 0.05. The damping factor for convergence is 0.5. Use a maximum frequency of 100 Hz when subdividing with the target spectra.

Matched time-histories corresponding to target spectra must have similar shape with Initial time-histories. An initial time-history has zero acceleration, velocity, and displacement at the end of motion, yet drifting (value is not zero at the end of the motion) on velocity and displacement of matched time-histories sometimes might be occurred after performing spectral matching. This problem is caused by digitized acceleration time-histories that cannot be directly integrated in attempt to obtain velocity and displacement. However, the drifting can be solved by using baseline correction method.

Trifunac [18] mentioned some contributors studying on general problem digitization, baseline correction, and double integration of the accelerogram. According to Trifunac [18], a majority of the studies assume that zero acceleration base line forming parabolic curve. It has been generally agreed that the drifting is caused by the warping of the record and most of cases show that similar distortions are adjusted by the parabolic baseline.

Significant study on solving the drifting was reported by Pecknold and Riddell [19, 20]. They proposed a prefix acceleration impulse being added with time-histories. Chiu [21] also studied baseline correction by adding prefix impulse which was constructed by using polynomial function of an order of 3. Chiu [21] stated that the order of polynomial function depends on the initial acceleration, velocity, and displacement.

For this purposes, polynomial order of 5 has been used. Other parameters for performing baseline correction built-in [22] are given in Table 1.

Table 1 Options parameter for baseline correction built-in

Options Parameter	
Baseline Polynomial Order	5
End Taper,% of points	5
End Padding, number of points	200

5.0 CASE STUDY, SPECIFIC SITE IN JAKARTA

5.1 PSHA and Site Response Analysis for A Specific Site in Jakarta

PSHA with MCE$_R$ code requirement for Jakarta has already been performed by [11] and reported in [7]. For PSHA analysis, the major earthquake events 500 km around the Jakarta city have been considered. Seismic parameters were adopted from [23] with modification on maximum magnitude intensity of Megathrust seismic sources and addition on recurrence relationship. Maximum magnitude M9.0 was adopted (personal discussion with [24]), considering previous M 9.2 Banda Aceh Megathrust eathquake in December 2004 within the Sumatra subduction zones as well as M8.9 Tohuku Earthquake event within Megahtrust mechanism that occurred in Japan in March 2011. Logic tree and recent GMPEs, including NGA for Shallow Crustal have been adopted. After determining the UHS that has been adjusted to MCE$_R$ considering Risk Coefficient (Cr) and directivity factors of 1.1 and 1.3 for short and long periods, respectively. Base-rock 300 m below existing ground surface (Site Class B) motion MCE$_R$ spectra is resulted from the PSHA.

The forty two (42) base scaled input motions at various periods specified earlier were generated for wave propagation analysis considering shear wave velocity profile to a depth of 300 m baserock. Recommended surface MCE$_R$ spectra is developed based on maximum spectral accelerations for each periods range considered of the scaled based ground-motions.

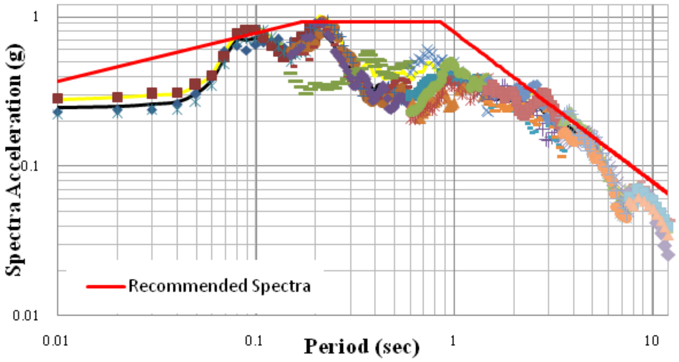


Figure 1 Target response spectra MCE$_R$ at ground surface for specific site in Jakarta [12]

Figure 1 shows plots of amplified spectral accelerations selected to represents response within ranges represented by scaled base motions for each period range. Average (in black line) and average+1SD (in yellow line) spectral acceleration plots are also shown. Please note that, the recommended surface ground-motions resulted from this SSRA already implicitly reflect consideration of sensitivity on response to uncertainty in soil properties, depth of soil model, and variations in input motions. The average or more conservatively the (average+1SD) spectra is considered to be the target spectra for surface MCE_R for design of the building structure. Since, design response spectra is commonly specified in the form of code based spectra, then envelope of the surface MCE_R target spectra (in ASCE-SEI-7-10 referred to as Smax) is also proposed as also shown in Figure 1.

Specific and representative strong-motions record need to be selected for SSRA to recommend surface MCE_R ground-motions. De-aggregation analysis that have been conducted in this study identifiy controlling magnitude and distance of the earthquake sources for each period of interest. For T=10 sec (that is relevant against natural period of structure under consideration), the de-aggregation analysis identify Megathrust earthquake with M8.5-M9.0 is controlling the seismic hazard, as show in Figure 2. Nevertheless, de-aggregation analysis for various range of periods identify different earthquake magnitudes and distances. In this study, selected strong-motion records for subduction sources among others are Chi-Chi 1999, Padang 2009, and Tohoku 2011. Table 2 shows selected strong-motion records associated with results of de-aggregation analysis. This selected strong-motions records are also used for spectral-matching time-history involving pairs of ground-motions.

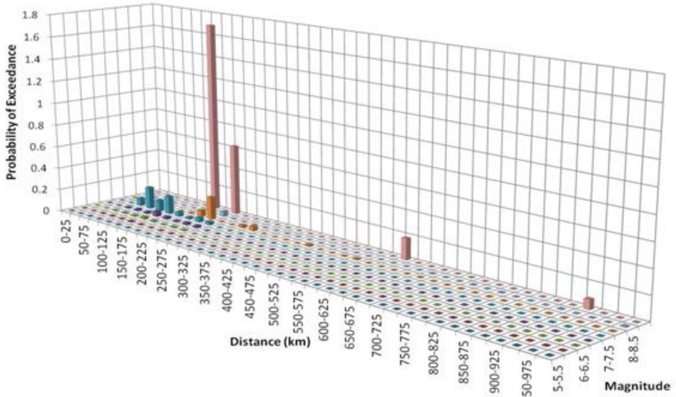


Figure 2 De-aggregation for 2 % PE in 50 Year at T =10 secs [7]

Forty-two surface response spectra directly resulted from SSRA is shown in Figure 3. Average of all the response spectra is also shown. The average of this direct response spectra can be identified to be lower compared to average spectra developed from selected maximum spectral values shown in Figure 1. Average and (average+1SD) of these surface response spectra are compared to recommended spectral envelope and they are shown in Figure 4. It is obvious that the response average is relatively much lower compared to recommended spectra envelope for wide range of periods higher than 1 sec.

5.2 Developed Time-histories

While the average response spectra shown in Figure 3 seems to be resulted from simulated ground-motions satisfying CMS for each period of interest, yet it is considered to be underestimated due to some of the spectral responses beyond its period range could be underestimated. Therefore, this average spectrum shown in Figure 3 is considered underestimate surface spectra. Nevertheless, time-history ground-motions could be selected. Seven dominant ground-motions could be recommended for time-history analysis of building with each of those is only appropriate for a specific period of the structural mode.

The average of seven (7) surface spectra is compared with recommended spectral envelope as shown in Figure 5. The spectral accelerations are reasonably close to the recommended spectral envelope for any periods that are larger than 3 Sec. Therefore, these seven (7) surface time-history ground-motions are considered representative for time-history ground-motions analysis of buildings.

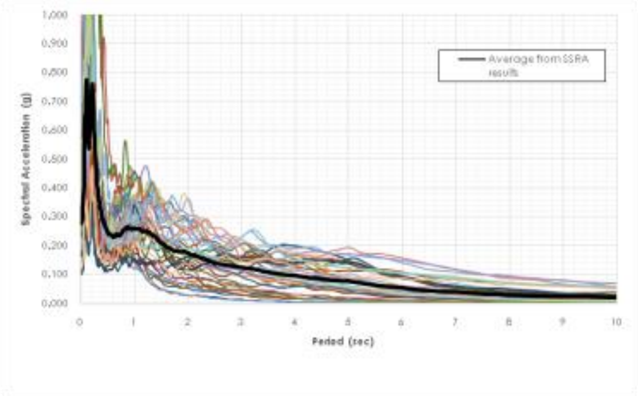


Figure 3 A Set of Surface Response Spectra resulted from Base Ground-motions Direct SSRA

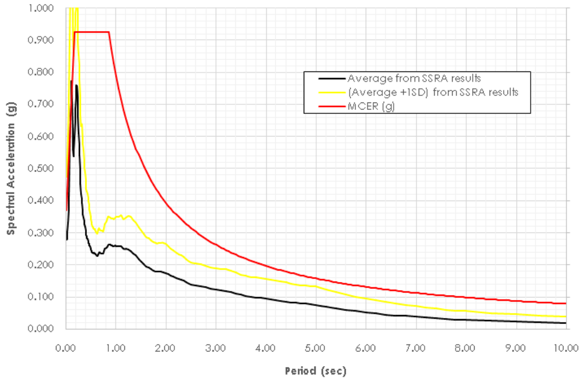


Figure 4 Comparison of Averaged Surface Spectra from SSRA to Recommended Surface Spectral envelope

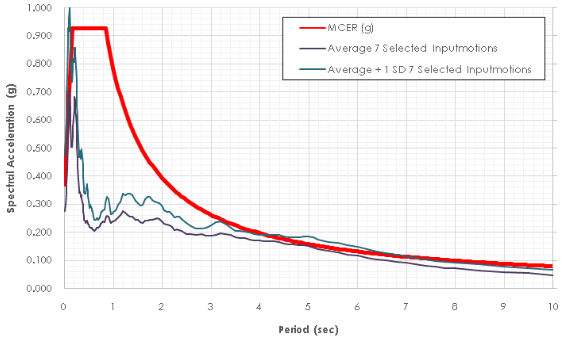


Figure 5 Comparison of averaged seven maximum Surface Spectra from SSRA to recommended Surface Spectral envelope

The de-aggregation shows that Megathrust mechanism is controlling the ground-motion of the designated site, with M8.5 - M9.0 and radius of 170 km. Therefore, pair of time-histories that have a similar seismic source characteristic was downloaded from a credible website. Chi-chi earthquake 1999 and Tohoku 2014 strong-motions have been selected due to its similarity.

More conservative spectrally matched time-histories for design recommendation and meeting code requirements, the SRSS average of 7 (seven) generated pairs horizontal ground-motions need to be higher than recommended target spectra, then in this study, second approach to use recommended spectral envelope as target spectra has been made.

Adopting the procedures described in Sections 3 and 4, the selected time-histories (for this case is Chi-Chi strong-motion records) are firstly converted as response spectra. These response spectra are known as initial spectra. Secondly, the SRSS is computed using the given initial spectra. Figure 6 shows initial and SRSS spectra. Ratio,K, is then determined using Equation (5) for each period. Figure 7 shows the ratio of K for each period. Afterward, each component of initial spectra is divided by the ratio at each period. These new response spectra are known as component target spectrum. Finally, each initial spectrum is spectrally matched to each target spectrum. Figure 8 shows both component target spectra, while Figure 9 to 10 present spectral matching results of the both components, and Figure 11 to 12 present matched time-histories, with successful baseline correction as induced by zero deviation of the velocity and displacement at end of the simulated earthquake. Similar process has also been made for 6 other pairs of ground-motions correspond to list of ground-motions in Table 2.

6.0 CONCLUSIONS

Procedures for the development of time-history ground-motions, adopting most recent advances in generating earthquake ground-motions has been studied and investigated. Time-histories input motion needed for performance-based structural analysis has been developed employing two approaches. The first approach is by obtaining direct time-history and response spectra from site-response analysis from base motion MCE$_R$ target spectra scaled at six different oscillatory periods. The resulted spectral responses are considered to be reasonable and representing dominant earthquake ground-motions through systematic approach integrating PSHA, SRA, and spectral matching procedures. Whereas, the sec approach that is based on using recommended spectra envelope as target spectra seems to be conservative, since it somehow would tend to make all the earthquakes ground-motions time-history to match a single target. This approach is considered to be not appropriate since no earthquake event from an earthquake source would have all maximum spectral acceleration at entire periods. Therefore, this approach is applied if no PSHA and SSRA is conducted and the spectral target is only derived from building codes.

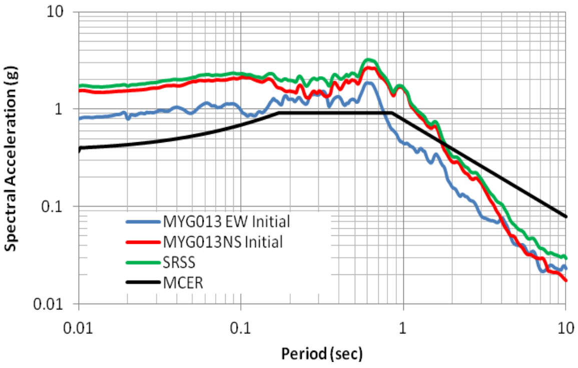


Figure 6 Computed SRSS of the Response Spectra and Surface Target Spectra-MCE$_R$

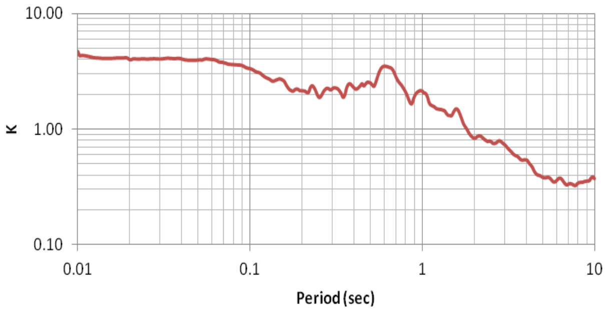


Figure 7 Variation of K Ratio for MGY013

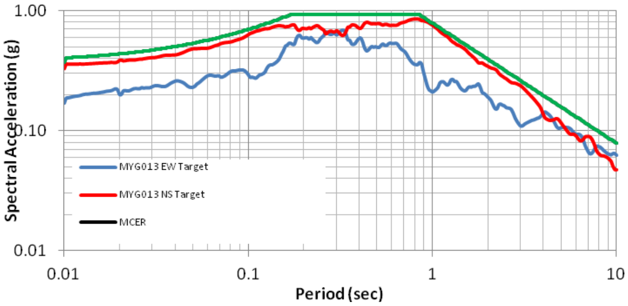


Figure 8 Graph for MYG013-EW Target, MYG013-NS Target, and SRSS from c Target and MYG013-NS Target

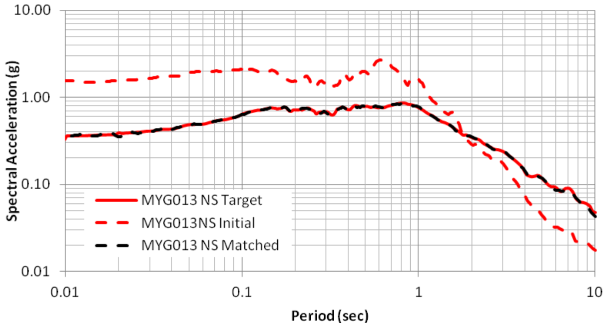


Figure 9 Spectral matching of MYG013-NS

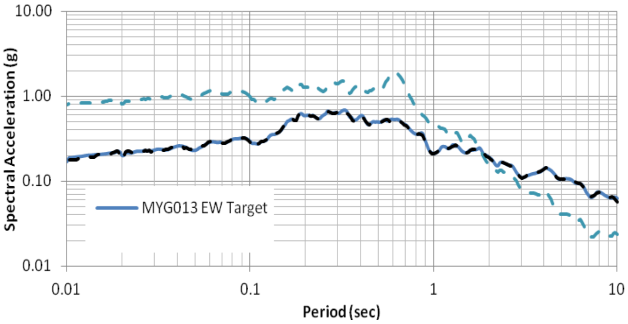


Figure 10 Spectral matching of MYG013-EW

Acknowledgement

The authors are thankful for the support by PT. Grahamas Adisentosa that has provided necessary data for the investigation of ground-motions. Numerous input by Dr. Ramin Goleshorki from Langan International is highly appreciated. The authors also thank the assistance of P. Sumiartha in conducting some of the supporting analysis.

Table 2 Selected Strong-Motion records associated with De-aggregation Analysis

Period (sec)	Mechanism	Code Catalog	Source	Earthquake	Magnitude	Epicentral Distance
5	Megathrust	ILA051-N	PEER [22]	Chi - chi Earthquake 20 September 1999	7.62	160.21
		MYG013110311146EW.at2	K-NET [25]	Tohoku Earthquake 11 March 2011	9.00	170.00
10	Megathrust	TAP075-N	PEER [22]	Chi - chi Earthquake 20 September 1999	7.62	160.21
		MYG12110311146EW	K-NET [25]	Tohoku Earthquake 11 March 2011	9.00	170.00
	Benioff	Padang 30-11-2009	Rusnardi, *et al* [26]	Padang Earthquake, 30 September 2009	7.60	81.00
	Shallow Background	A-ORR000	PEER [22]	Whittier Narrows-01 Earthquake 10 January 1987	5.99	77.07
	Shallow Crustal	SER270	PEER [22]	Landers Earthquake 29 June 1992	7.28	75.20

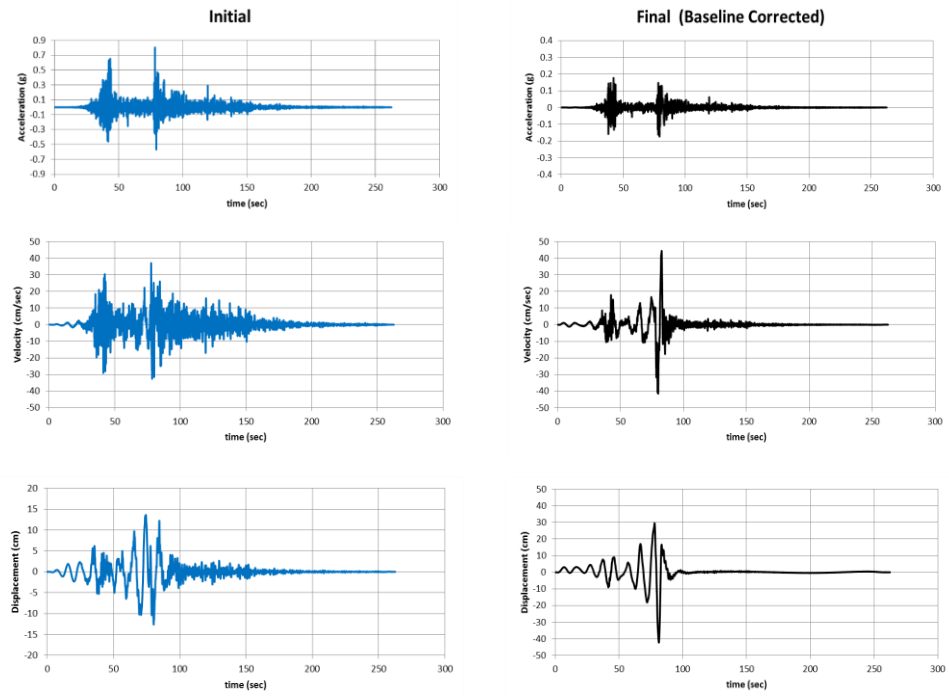


Figure 11 Matched Time-histories / input motion of MYG130-EW

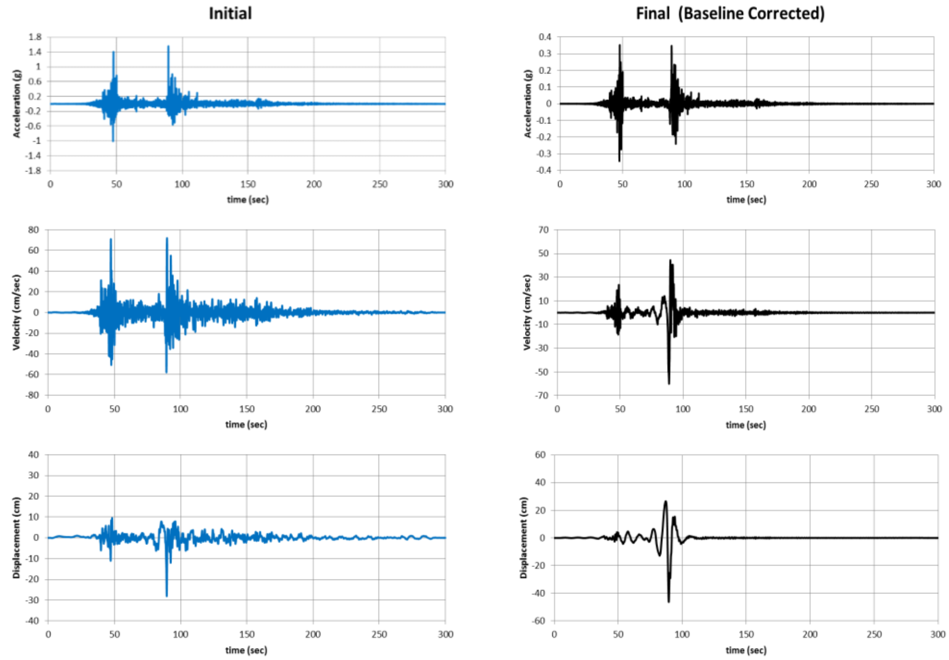


Figure 12 Matched Time-histories / input motion of MYG013-NS

References

[1] Uniform Building Code. 1997. *International Conference of Building Officials.*

[2] Standar Nasional Indonesia. 2002. Tata Cara Perencanaan Ketahanan Gempa untuk Bangunan Gedung (SNI 03-1726-2002). Badan Standardisasi Nasional.

[3] Standar Nasional Indonesia.2012. *Tata Cara Perencanaan Ketahanan Gempa untuk Bangunan Gedung (SNI 03-1726-2012)*. Badan Standardisasi Nasional.

[4] American Society of Civil Engineers Standards. ASCE SEI-7-10, 2010. Virginia, USA: Minimum Design Loads for Buildings and Other Structures. Sructural Engineering Institute ASCE.

[5] Sengara IW., Irsyam, M., Sidi, I.D., Mulia, A., Asrurifak, M., Hutabarat, D. 2012. *Development of Earthquake Risk-Targeted Ground-motions for Indonesian Earthquake Resistance Building. Bandung: Research Report*. Geotechnical Engineering Research Group. Faculty of Civil and Environmental Engineering. Institut Teknologi Bandung, Indonesia.

[6] Sengara IW., Irsyam, M., Sidi, I.D., Mulia, A., Asrurifak, M. and Hutabarat, D. 2015. Development of Earthquake Risk-Targeted Ground-motions for Indonesian Earthquake Resistance Building Code SNI-1726-2012. *12th International Conference on Applications of Statistics and Probability in Civil Engineering* (ICASP12). Vancouver Canada. July 12-15.

[7] Sengara, IW. 2012. Investigation on Risk-Targeted Seismic Design Criteria for a High-Rise Building in Jakarta-Indonesia. *World Conference on Earthquake Engineering Proceedings*. Lisboa. 24 - 28 September 2012.

[8] Baker, J. W., Lin, T., Shahi, S. K. and Jayaram, N. 2011. New Ground-motion Selection Procedures and Selected Ground-motions for the PEER Transportation Research Program. *PEER Report 2011/03*. California: Pacific Earthquake Engineering Research Center. College of Engineering – University of California Berkeley.

[9] Pacific Earthquake Engineering Research Center. 2010. Tall Building Initiative Guidelines for Performance Based Seismic Design of Tall Buildings. *Report N0. 2010/5.*

[10] International Code Council. 2012. *International Building Code.*

[11] Sengara, IW., Sumiartha, P., Handayani, G. and Yulman, M. A. 2012. Report on Probabilistic Seismic Hazard and Site-Specific Response Analysis to Derive Seismic Design Criteria for Signature Tower – Jakarta, a Report submitted to PT. Grahams Adisentosa. Bandung: PT Georeka Indonesia.

[12] Risk Engineering. 2011. EZ-FRISK *(Software for in-depth Seismic Hazard Analysis) User's Manual*. Colorado:Risk Engineering.

[13] McGuire, R.K. 2004. *Seismic Hazard ad Risk Analysis, Engineering Monograph on Miscellaneous Earthquake Engineering Topics.* Boulder: Colorado: Risk Engineering Inc.

[14] Luco, N., Ellington, B.R., Hamburger, R.O., Hooper, J.D., and Kimball, J.K. 2007. Risk-Targeted versus current Seismic Design Maps for Conterminous United States. *SEAOC Convention Proceedings*.

[15] Abrahamson, N.A. 1992. *Non-stationary Spectral Matching. Seismol*. Res. Lett. 63(30).

[16] Al Atik, L. and Abrahamson, N. 2010. An Improved Method for Non-stationary. Earthquake Spectra. *Earthquake Engineering Research Institute*. 26(3):601–617.

[17] Goleshorki, R. 2013. Personal Discussion.

[18] Trifunac M.D. 1971. Zero Baseline correction of Strong-Motions Accelerograms. *Bulletin of the Seismological Society of America.* 61(5):1201-1211.

[19] Pecknold, D. A. and R. Riddell. 1978. Effect Of Initial Base Motion On Response Spectra. *J. Eng. Mech. Div. ASCE.* 104: 485-491.

[20] Pecknold, D. A. and R. Riddell. 1979. Closure To Discussion On Effect Of Initial Base Motion On Response Spectra. *J. Eng. Mech. Div. ASCE.* 105: 1057-1060.

[21] Chiu, H. 2012. A Compatible Basline Correction Algorithm for Strong-Motion Data. *Terr. Atmos. Ocean. Sci.* 23(2):171-180.

[22] PEER Strong-motion Database: http:peer.berkeley.edu/.

[23] Irsyam, M., Sengara, IW., Aldiamar, F., Widiyantoro, S., Triyoso, W., Natawijaya, D.H., Kertapati, E., Meilano, I., Asrurifak, M., Ridwan, M. and Suhardjono. 2010. Development of Seismic Hazards Map of Indonesia for Revision of SNI 03-1726-2002.*A Summary Report submitted to Australia-Indonesia Facility for Disaster Reduction (AIFDR) and Badan Nasional* Penanggulangan Bencana (BNPB). Jakarta; Institute for Research and Community Services. Institut Teknologi Bandung.

[24] Natawidjaja, Danny H. 2014. *Personal Discussion*.

[25] K-NET, NIED : http://www.k-net.bosai.go.jp/ Rusnadi, et al. 2009. Strong-motion Data of Padang Earthquake.