10CUEE CONFERENCE PROCEEDINGS
10th International Conference on Urban Earthquake Engineering
March 1-2, 2013, Tokyo Institute of Technology, Tokyo, Japan

DEAGGREGATION OF NEW NATIONAL SEISMIC HAZARD MAPS FOR INDONESIA

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Abstract: The new Indonesia Seismic Hazard Maps for revising the previous map in SNI 03-1726-2002 was published in July 2010. These maps developed by Team for Revision of Seismic Hazard Maps of Indonesia were based on probabilistic approach for 2% probability of exceedance (PE) in 50 years and deterministic approach by using three-dimensional seismic source models and by considering latest geological and seismological data and fragility curve of buildings. Seismic sources were represented by subduction, fault, and background zones. The new maps were developed based on PSHA method. A principal advantage of the probabilistic method is combining all the possible earthquakes affecting the site. This paper presents deaggregation of Indonesia Seismic Hazard Map 2010. Deaggregation for peak ground acceleration, 0.2-sec and 1.0-sec pseudo spectral acceleration (SA) is performed for 2% PE in 50 years (2475 years mean return period). The maps of mean and modal of magnitude and distance presented here are intended to provide information about the distribution of probabilistic seismic sources and to provide suggestions for seismic sources to use in developing artificial ground motion.

1. INTRODUCTION

Indonesia is located in a tectonically very active area at the point of convergence of three major plates and nine smaller plates creating a complex network of plate boundaries (Bird, 2003). The existence of interactions between these plates puts Indonesia in an earthquake prone region (Milson et al., 1992). Several great earthquake occurrences in Indonesia in the last six years inquire revision of seismic hazard parameters. Some of the great earthquakes are the 2004 Aceh Earthquake (Mw9.0-9.3) which was followed by tsunami, the 2005 Nias Earthquake (Mw 8.7), the 2009 Tasik Earthquake (Mw 7.3), and the latest 2009 Padang Earthquake (Mw 7.6). These earthquakes have caused thousands of casualties, destruction and damage to thousands of infrastructure and buildings, as well as billions of US dollars required for reconstruction and rehabilitation.

The Team for Revision of Seismic Hazard Maps of Indonesia has produced several new seismic hazard maps for Indonesia. The final model and maps were issued in 2010 as Summary of Study Team for Revision of Seismic Hazard Maps of Indonesia. The method and results given in this summary are the basis for BSN (National Standardization Agency) recommended seismic design provisions for the next edition of the Indonesian Earthquake Resistant Building Code SNI 03-1726 which will be issued in this year. This summary presented seismic hazard maps computed for sites on bed rock (Vs = 760 m/s2) at the 10% PE in 50 year and 2% PE in 50 year.

The seismic source models used in this study are subduction sources, fault sources, and background sources. Seismic hazard parameters for subduction considered recurrence relationship that includes truncated exponential model and pure characteristic model. For fault sources, truncated exponential model and characteristic model with aleatory uncertainty in the magnitude using a normal distribution sigma of ± 0.12 were used. For background source, only truncated exponential model were used in the development of hazard maps. Several attenuation functions including NGA and logic-tree were used. The detail information on seismic source models and seismic parameters for development seismic hazard maps appear in Asrurifak, 2010 and Fauzi, 2011.

This paper, in conjunction with Team for Revision of Seismic Hazard Maps of Indonesia, intends to convey information about the distribution of probabilistic seismic sources with explain typical values of earthquake magnitude and distance that are making the largest contributions to the seismic hazard maps. Identifying the predominant sources of hazard will lead to better choices for the design earthquake's characteristics. Performing deaggregations at more than one period will help to determine if one source dominates at all periods and clarify the need for one, or more than one, design earthquake (Halchuck and Adams, 2004).

2. PROBABILISTIC SEISMIC HAZARD ANALYSIS

PSHA was developed by McGuire (1976) is based on the probability concept developed by Cornell (1968). It is assumed that the earthquake magnitude M and distance R as a continuous independent random variables. In general, form of total probability theorem can be expressed in the following formula

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

where v_i is annual rate of earthquakes (with magnitude higher than some threshold value of M_{oi}) in source I, and $f_{Mi}(m)$ and $f_{Ri|Mi}(r,m)$ are probability density functions on magnitude and distance, respectively. $P[A > a| m, r$ is the probability that an earthquake of magnitude m at distance r produces a peak acceleration A at the site that is greater than a.

The seismic hazard analysis was performed using this following procedure: 1) conducting literature review on geology, geophysics and seismology to identify activity of seismic sources in and around Indonesian region, 2) collecting and processing recorded earthquake data for entire Indonesian region, 3) modeling seismic source zones based on the advance models appropriate with USGS software, 4) determining seismic parameters which include a-b values, maximum magnitudes, and slip-rates, 5) calculating spectral acceleration based on the total probability theorem, 6) mapping spectral hazard includes peak ground acceleration (PGA) and short period (0.2 s) and 1.0 s period spectra values.

Software for PSHA used in this study obtained from the USGS. A site spacing of 0.1 degrees in latitude and longitude and area between 94°E to 142°E longitudes and 12°S to 8°N latitude were used in the analysis. The ground motion parameters obtained from this study computed for sites on bed rock (Vs = 760 m/s2). The verification seismic models and parameters in this research with Team for Revision of Seismic Hazard Maps of Indonesia are shown in Fauzi, 2011.

The method of deaggregation of hazard is separates the contributions into a limited number of bins of (annular) distance, magnitude, and ground-motion uncertainty (McGuire, 1995). For this research the distance annular width, ΔR, is 5 km and the magnitude bins is 0.5. For subduction sources, the maximum considered source to site distance is 1000 km. For fault and background sources, the maximum considered source to site distance is 200 km. Using PSHA result, the relative contribution of sources to the overall hazard results at the given site are deaggregated in different types of bins to determine and understand. The integration of the PSHA is carried out and the final results are presented often in terms of 3D M-R-ε bins or even geographical deaggregation (4D) (Harmsen and Frankel, 2001).

The mean distance and mean magnitude presented here are the weighted mean values of R and M, respectively, for all sources that contribute to hazard at each grid location. The modal distance and modal magnitude are the (R, M) pair having the largest contribution in the hazard deaggregation at each grid location. The maps develop using the grid increment of 0.1 degrees in both latitude and longitude and in area between 94°E to 142°E longitudes and 12°S to 8°N latitude so that deaggregations seismic hazard are performed for more than 96,600 sites. Software for Deaggregation PSHA used in this study obtained from the USGS.

4. SEISMOSECTONIC MODEL

Seismic parameters used in this study were derived from published journals, proceedings, previous researches conducted by team members, and latest information obtained during this study. This study has then compiled and integrated previous and current studies. Earthquake source parameters were determined based on earthquake catalog, geological, and seismological information of active faults. The earthquake catalog covered earthquake period between 1900 to 2009, relocated catalog by the year 2005, and area between 90oE to 145oE longitudes and 15oS to 15oN latitudes.

Seismic sources were divided into subduction, fault, and background zones by considering recurrence relationship that includes truncated exponential model, pure characteristic model, and both models. Geometry of fault and subduction were represented by three-dimensional (3D) models based on the result of tomography and slip-rates of faults were determined by considering the results of GPS measurement. Background source zones were modeled using gridded seismicity based on spatially smoothed earthquake rates. The earthquake catalog was used for developing gridded seismicity starting from 1900 to 2009 and the updated Engdahl catalog up to 2009 was used for control geometry of subduction. Several well-known attenuation functions were selected in accordance with the mechanism of seismic source including the Next Generation Attenuation (NGA). Logic tree was also applied to account for epistemic uncertainty including recurrence model, maximum magnitude, and several attenuation functions.

3. RESULTS AND DISCUSSION

One purpose of deaggregation analysis is to find plausible (R,M) pairs from which to choose accelerograms, A(t), for input to seismic design programs for structural response (Harmsen, et. Al 2003). The maps of mean and modal magnitude and distance for 10% probability of exceedance (PE) in 50 yr are shown in Figure 1 to Figure 4. Maps of mean and modal magnitude and distance for 2% probability of exceedance (PE) in 50 yr are shown in Figure 5 to Figure 8.

The analysis result showed that the maps of modal results are associated the highest contribution, for the areas near the fault, magnitude and distance of fault control. In areas far from the fault, the magnitude and distance from the subduction control and for areas far from faults and subduction, gridded seismicity model control. The mean magnitude and distance associated with the average of contribution from multimodal / multi scenario earthquake.

The mean and modal maps showed different values of pair magnitude and distance so that most sites receive contributions from a broad distribution of source magnitudes and distances.

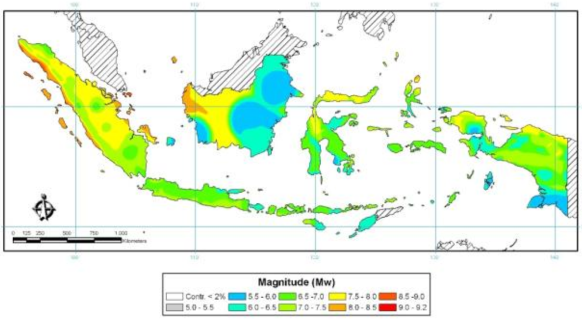

Figure 1 Mean magnitude map of 0.2 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

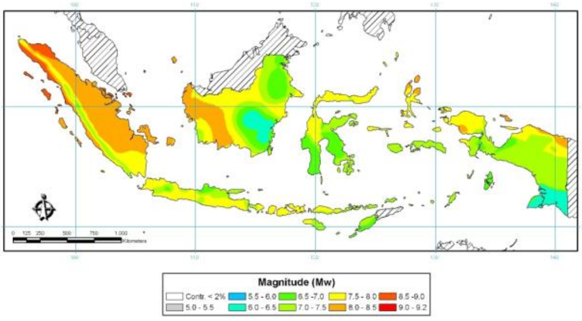

Figure 2 Mean magnitude map of 1.0 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

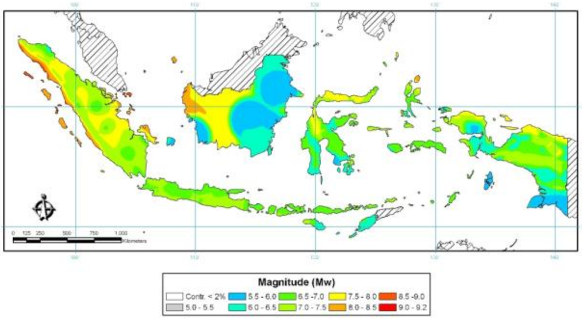

Figure 3 Mean magnitude map of peak ground acceleration at bedrock for 2% probability of exceedance in 50 years

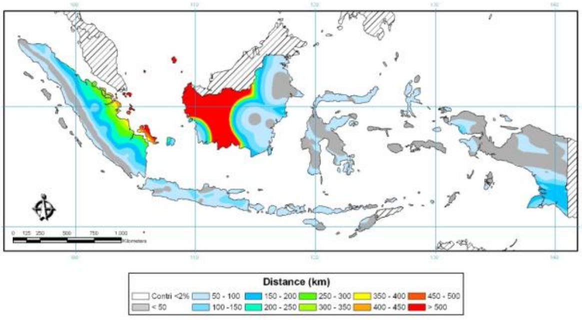

Figure 4 Mean distance map of 0.2 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

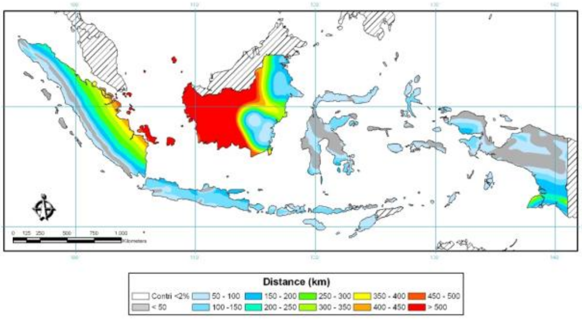

Figure 5 Mean distance map of 1.0 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

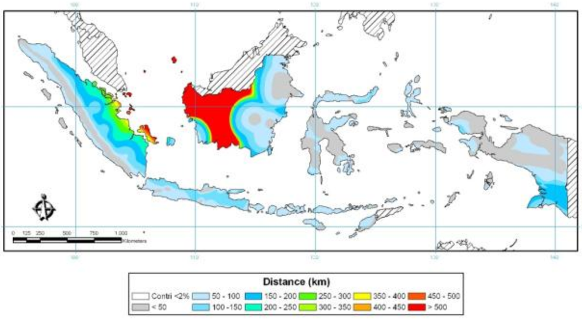

Figure 6 Mean distance map of peak ground acceleration at bedrock for 2% probability of exceedance in 50 years

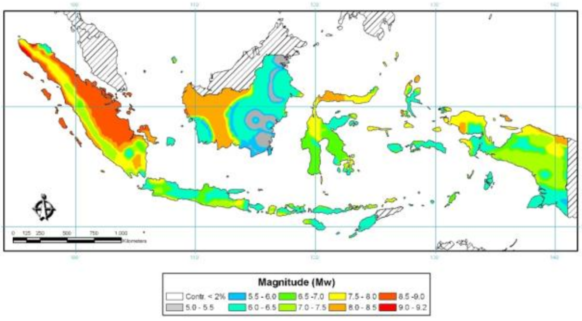

Figure 7 Modal magnitude map of 0.2 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

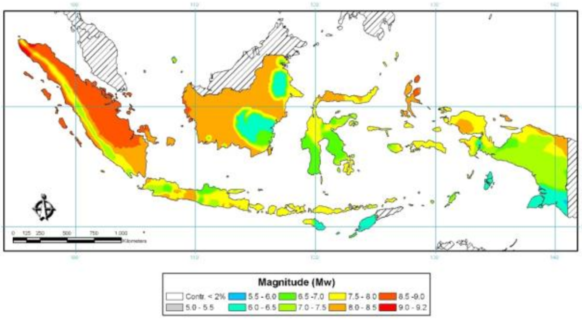

Figure 8 Modal magnitude map of 1.0 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

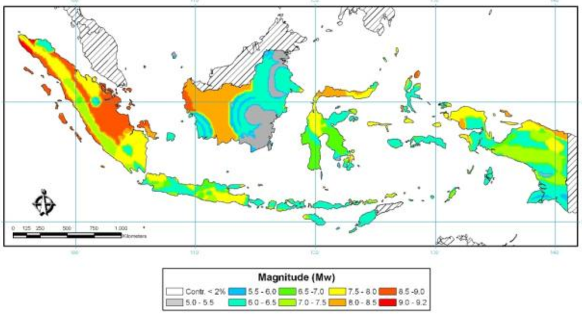

Figure 9 Modal magnitude map of peak ground acceleration at bedrock for 2% probability of exceedance in 50 years

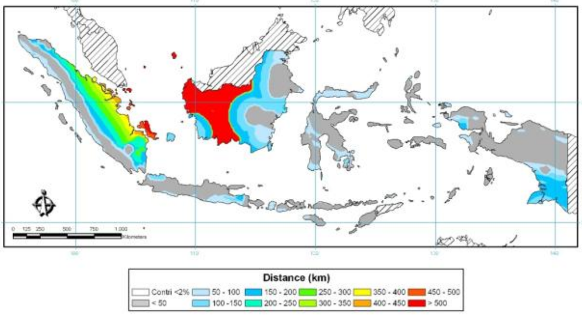

Figure 10 Modal distance map of 0.2 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

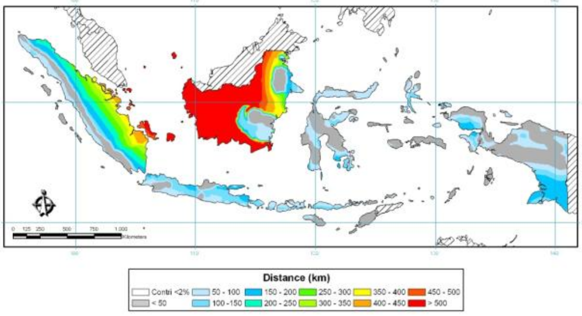

Figure 11 Modal distance map of 1.0 sec. spectral acceleration at bedrock for 2% probability of exceedance in 50 years

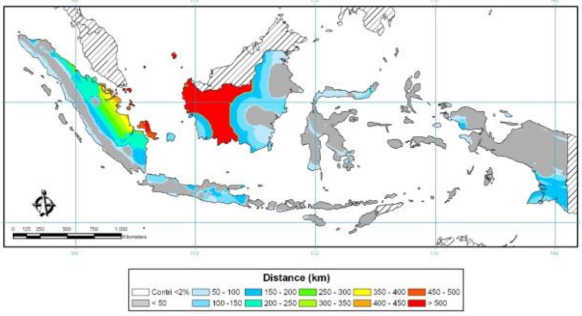

Figure 12 Modal distance map of peak ground acceleration at bedrock for 2% probability of exceedance in 50 years

3. CONCLUSIONS

For most locations, the deaggregation reveal that more than one design earthquake will be required for engineering purposes. The maps of mean and modal of magnitude and distance presented here are intended to convey information about the distribution of probabilistic seismic sources and to provide prescriptions or suggestions for seismic sources to use in building design or retrofit projects. The information of deaggregation analysis can and perhaps should be considered in a complex seismic-resistant design decision-making environment.

Acknowledgements:

The writers wish to his sincerest gratitude to Team for Revision of Seismic Hazard Maps of Indonesia, for allowing writers to incorporate the valuable data when the Team developed new Indonesia Seismic Hazard Maps. The writers are also deeply indebted to USGS (S. D. Harmsen and M. D. Petersen) for providing the writers with technical discussions and the software for PSHA and PSHA Deaggregation. Financial support for the research was provided by Universiti Malaysia Pahang and Institut Teknologi Bandung, Indonesia.

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