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The 3rd International Conference of European Asian Civil Engineering Forum
Yogyakarta, INDONESIA, 20 - 22 September 2011
Designing and Constructing in Sustainability

Keynote Speakers

- Ir. Agus Widjanarko, MIP (German Alumni- University of Stuttgart), Secretary General of Public Works Ministry of the Republic of Indonesia
- Dr. Norbert Baas, His Excellency, the Ambassador of Republic Federal of Germany

Invited Speakers

The Development of Nanotechnology for Construction Materials
Prof. Dr.-Ing. habil. Michael Schmidt (University of Kassel)

Real-Time Rainfall and Flood Forecasting in Ta Tapao River Basin, Thailand
Prof. Tawatchai Tingsanchali, D.Eng. (Nakhon Pathom Rajabhat University)

Designing the Future
Klaus Thorsten, M.Sc. on behalf of Prof. Dr.-Ing. habil. Werner Sobek(University of Stuttgart, GERMANY)

New Structural Systems Employing Innovative Structural Materials
Keiji Ando (The Japan Iron and Steel Foundation, Japan)

Optimisation of Sustainable Geotechnical Structures in Urban Civil Engineering
Prof. Dr.-Ing. habil. Christian Moormann (University of Stuttgart)

The Development of Construction Safety Management Systems
Prof. Chan Weng Tat (National University of Singapore)

Construction Management Research and Education Activities Moving Up Asian Universities Collaboration
Prof. Shunji Kusayanagi (Kochi University of Technology, Thailand))

BM - Building Materials Engineering (Nanotechnology)

The Use of Local Materials in the Flexible Pavement Structure Towards the Sustainable Pavement Materials in Indonesia
Bambang S. Subagio

CM - Construction Management and Project Management

GT - Geotechnical Engineering

IS - Infrastructure (environmental, coastal, transportation, water) Engineering

SC - Structural and Construction Engineering

PEAK BASE ACCELERATION OF SEMARANG CITY WITH THREE DIMENSIONAL SEISMIC SOURCE MODEL

(GT-006)

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ABSTRACT

This study presents seismic hazard analysis that aims to estimate peak ground acceleration of Semarang for 500 – year return period earthquake that is to validate the Indonesia seismic rules. The seismic hazard analysis is based on geology and history condition by probabilistic seismic hazard analysis (PSHA) method using EZ FRISK program that models fault sources in three dimensional representations. The seismic sources considered are the acknowledged earthquake potential to a depth of 200 km within radius of 500 km from Semarang. This study utilizes a logic tree to cover uncertainties within one method of earthquake assessment. Seismic parameters are calculated by the method of Kijko & Sellevoll and Weichert. Three attenuation models are chosen for determination of the ground motion. The attenuation model of Youngs is selected to represent the subduction environment of Java and attenuation models of Boore et al. and Sadigh et al. are selected to represent shallow crustal fault surrounding Semarang. The result of the analysis shows that the peak base acceleration of Semarang is 0.17 g for 500 – year return period. The value is still on the range of that of Indonesia seismic rule.

Keywords: Ground motion, peak base acceleration, probabilistic seismic hazard analysis, three dimensional seismic source.

1. INTRODUCTION

According to its seismo-tectonical condition, Indonesia is a country that is much suffered from earthquakes. The records of earthquakes hitting this country in last 15 years have been representing how much it is risky to damage due to earthquake. A large number of devastating quakes have striken, such as the Aceh earthquake that triggered the catastrophic tsunami, Padang earthquake, and Yogyakarta one. For this reason, the analysis of seismic hazard must be inserted in a building design.

This seismic hazard analysis was conducted using Probabilistic Seismic Hazard Analysis (PSHA) method since this was quite flexible to estimate ground motion probability in earthquake prone areas having seismic sources that clearly or not measured (Frankel, A, 1998). The result of PSHA was a seismic hazard curve that displayed a probability of exceedence as a function of ground motion. The first estimation of seismic hazard using this method was conducted by Cornell (1968). In addition, the building codes dominantly occupied by American had been using seismic zone maps based on PSHA in which represented the seismic hazard (Leyendecker et al., 1995). Several recent researches also exhibited to use PSHA and it was believed that the method was still used in the future.

In the previous years, the analysis of seismic hazard was used to having two dimensional analysis to design earthquake-resistant buildings. Indonesian seismic codes was still based on the same two dimensional analysis in which this method was done to simplify the desirable calculation in which the effect of seismic source geometrical shape that was real three dimension could be minimized. As to the development of knowledge and technology, a three dimensional analysis of seismic hazard could be easily conducted. Therefore, a three dimensional seismic source model should be considered as the best way to represent the real condition on the field and have an accurate estimation.

The objectives of this research were: 1) to estimate the peak base acceleration (PBA) of Semarang for 200, 500, and 1000 year return period earthquake using a seismic source model in three dimensional representation, attenuation functions, and a suitable logic tree with a help of EZ Frisk version 7.2 program. 2) to develop the response spectra of bed rock of Semarang as a picture of seismic wave in it. 3) to describe an accurate and sophisticated seismic hazard analysis by explaining the calculation with respect to used analysis.

Some restrictions in this research are 1) the seismic sources considered were the acknowledged earthquake potential to a depth of 200 km within radius of 500 km from Semarang. 2) the acceleration was produced by utilizing a logic tree. 3) only accelerations of the year return period earthquake of 200, 500, and 1000 years were estimated.

2. METHODOLOGY

Seismic Data. Seismic data occupied, the hypocenters, were from both Indonesian and International geological boards such as Indonesian Meteological and Geophysical Board (BMG), United Stated Geological Survey (USGS), International Seismological Center (ISC), and Preliminary Determination of Epicenter (PDE). The seismic sources considered were the earthquake potential to a depth of 200 km within radius of 500 km from Semarang from February 1903 to July 2007.

Processing Seismic Data. Based on Firmansjah (1999), the correlation betweeen Ms and mb, and Ms and Mw, for only earthquakes occured in Indonesia, were created.

$$Ms = 1.33\ m_b - 1.98 \quad (2.1)$$

$$Mw = 1.10\ Ms - 0.64 \quad (2.2)$$

Separating between Mainshocks and Aftershocks. Among empirical criteria to identify foreshocks such as Arabasz & Robinson (1976), Gardner & Knopoff (1974), Uhrhammer (1986) dan Firmansjah (1999), in this research the Uhrhammer was occupied.

Completeness of Seismic Data Catalog. According to *Stepp, J.C.* (1972), seismic rate (λ) was defined as the number of earthquakes (N) recorded during a period (T) being devided by the period (T).

$$\lambda = \Sigma N / T \quad (2.3)$$

Standard deviation of rate (σ) was defined as the square root of rate (λ) devided by the period (T).

$$\sigma = (\sqrt{\lambda} / T) \quad (2.4)$$

A seismic rate was assumed to be constant only for long period observation. The period in which rate (σ) was observed started to break and steeper than the previous one denoted seismic data were no longer homogenous.

Characterizing Seismic Data. Identifying and evaluating seismic source were done based on geological and seismological data. Knowledge on the tectonic condition, and the history of geological and seismic data was required to identify seismic sources. In this stage, seismic source zone was created.

To calculate the seismic parameters in the zones needed a prior modelling used to obtain hypocenter distributions in which the dip of each subduction zone observed was estimated. The seismic sources considered are the acknowledged earthquake potential to a depth of 200 km.

When determining a maximum magnitude for each seismic source zone, a maximum magnitude in the areas can be determined geophysically from plate / tectonic structure. A maximum magnitude (Mw) can be a function of seismic moment (Mo), combined with the Kanamori formula (1977).

$$\sigma = (\sqrt{\lambda} / T) \quad (2.4)$$

$$Mw = (\log Mo/1.5) - 10.7 \quad (2.6)$$

While the maximum magnitudes for subduction zone from tectonic structure by Mulyadi, 1999, were used that were Megathrust zone = 8.2 and Benioff zone = 7.2, the ones for strike slip zone by Irsyam, 1999 were used that were Sukabumi fault = 7.6, Bumiayu fault = 6.7, and Yogyakarta fault = 6.3.

Seismic Hazard and Rate Recurrence Parameters. Seismic hazard analysis using probabilistic method required a-b parameters to determine the rate recurrence. The two common models in PSHA were Gutenberg-Richter (G-R) (1944) and characteristic earthquake models.

$$\log N(m) = a - bm \quad (2.7)$$

$$\ln N(m) = \alpha - \beta m \quad (2.8)$$

with $\alpha = 2.303a$, $\beta = 2.303b$.

Several methods of G-R model development used to obtain a-b parameters were Least Square (1954), Weichert (1983), dan Kijko & Sellevol (1989).

Attenuation Function. Considering the research that has been done by LAPI-ITB (2000) on attenuation functions with a slight standard error, this research occupied several of them, that was, Youngs (1997) to represent subduction mechanism, Boore et al. (1997) and Sadigh et al. (1997) to represent strike slip (shallow crustal).

Logic Tree. A probabilistic calculation enabled systematic uncertainties of a parameter in seismic hazard model. In many cases, the best method for determining parameters in a model was not absolutely clear. However, using a logic tree could minimize the uncertainties in a model. A logic tree approachness gave a chance to use an alternative model in which each alternative was given a weighted factor. Hence this could be a good model that provide suitable value.

Seismic Hazard Analysis. A method that was sophisticated to analyze seismic hazard using probability concept was probabilistic seismic hazard analysis (PSHA). This method ensured that the uncertainties from magnitudes, locations, and rate of recurrence of earthquakes were explicitly taken into account in seismic hazard evaluation. This analysis was conducted with a help of EZ-FRISK version 7.2 program from Risk Engineering, which represented seismic sources in three dimension. Peak base acceleration (PBA) was the result of this program.

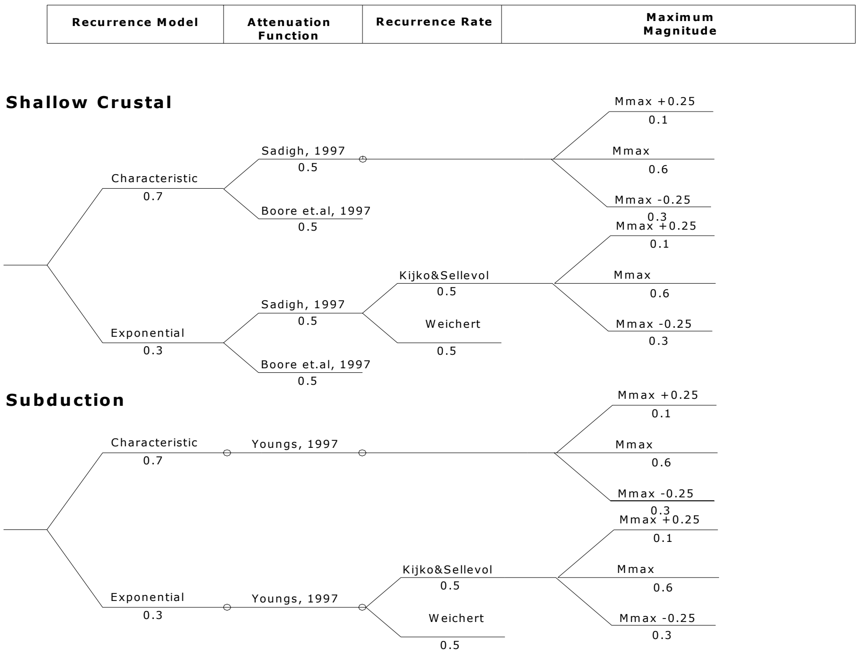

Figure 2.2. Logic Tree for seismic hazard analysis

3. RESULT AND DISCUSSION

Processing seismic data was conducted in a sequence. First, converting the magnitude scale based on the Firmansjah formula (1999), then separating main shocks and aftershocks using empirical criteria from Uhrhammer (1986), and finally estimating the completeness of seismic data based on the Stepp method (1973). The analysis result demonstrated that earthquake data with magnitudes (M) more than 7.0 were completed for last 103 years. However, the magnitudes in the range of 6.0 – 7.0 and the magnitudes in the range of 5.0 - 6.0 were completed only for last 40 years (Figure 3.1).

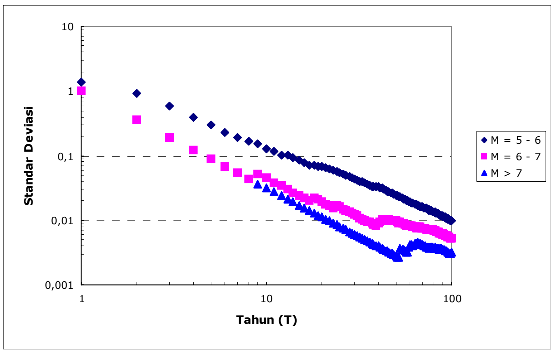

Figure 3.1. Time of completeness of seismic data catalog

The seismic sources considered in this research were the acknowledged earthquakes potential to a depth of 200 km within radius of 500 km from Semarang, and moment magnitudes higher than 5.0 in which consisted of Java's subduction and shallow crustal seismic sources as shown in Figure 3.3. While Java's subduction to a depth of 50 km was modeled as interface or megathrust seismic source (2-1a, 2-2a, 2-3a), subduction in a depth more than 50 km was modeled as intraslab or benioff seismic sources (2-1b, 2-2b, 2-3b). Shallow earthquakes to a depth of 50 km but outside of subduction areas were considered as shallow crustal quakes. These Java's faults such as Sukabumi, Bumiayu, Baribis, Semarang, Lasem, and Yogyakarta faults were rested in an average depth of 25 km. In this study, the seismic source model was based on the Indonesian seismic source map by Firmansyah and Irsyam (1999) and Kertapati (1999) as shown in Figure 3.2

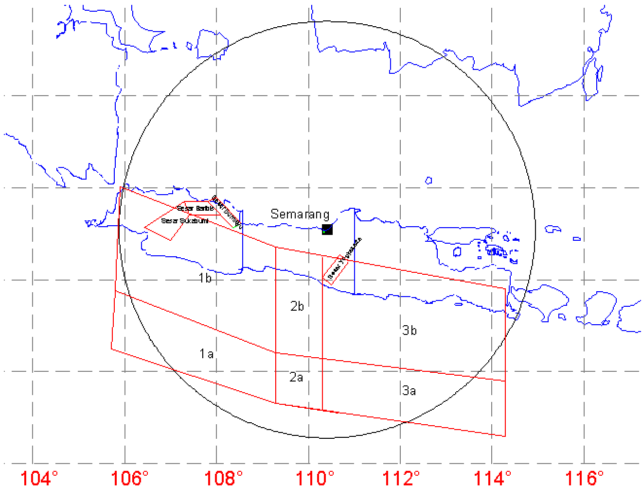

Figure 3.2. Model of seismic source area

The hypocenter profiles in each seismic zone could be seen in Figure 3.3 – 3.5. In these southern – nothern side view, shallow crustal hypocenters have been separated from subduction ones. It could be noticed that the number of quakes in sub zone 2-2 were a bit less than those of other zones. This demonstrated that the seismicity of central Java was lower than that of both western and eastern sides.

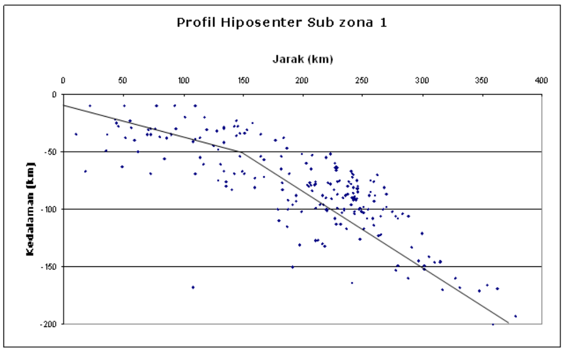

Figure 3.3. Hypocenter profile of sub zone 2-1

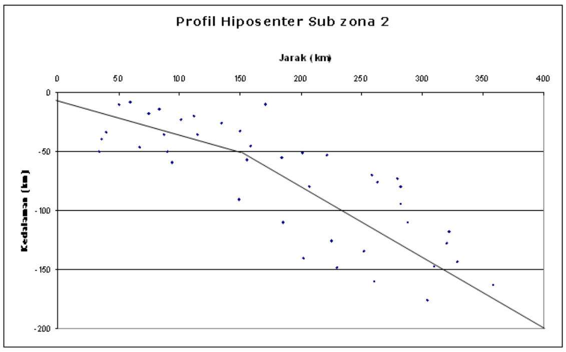

Figure 3.4 Hypocenter profile of sub zone 2-2

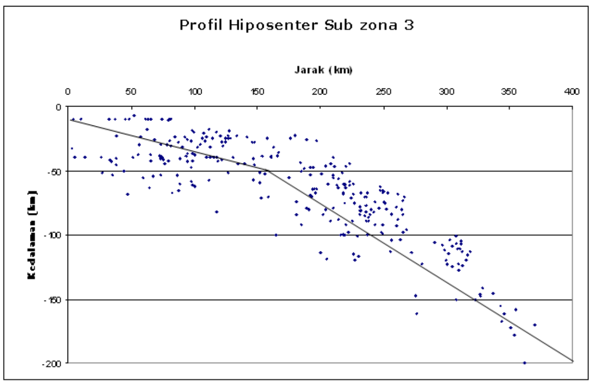

Figure 3.5. Hypocenter profil of sub zone 2-3

The seismic hazard analysis using probabilistic method required a-b parameters to determine seismic rate based on Guyenberg-Richter equation log N(m) = a – b.M. Least square, Weichert (1980), and Kijko & Sellevol (1989) models have been chosen to calcúlate the a-b parameters. Interface seismic sources in Java were united to obtain stable a-b parameters and seismic rates, so did the intraslab and shallow crustal seismic sources. Since epicenter data in Java's fault were not sufficient to obtain stable seismic parameters, the values of a-b parameters for Sukabumi, Lasem, and Yogyakarta faults were estimated by joining all the epicenter data of the faults then they were allocated back to each fault according to number of epicenter contribution. In Baribis, Bumiayu, and Semarang faults it could be found no epicenter there thus a background earthquake as a substitution was occupied in which the rate obtained was from a seismic rate for an area of 10000 km^2. A máximum magnitude 7.0 ± 0.25 was defined, considering the biggest earthquakes that have occured surrounding Semarang was Pati earthquake with Mw 6.8. Seismic parameter values for each seismic zone used in this research could be seen in Tabel 3.1.

Tabel 3.1. Seismic parameters according to Weichert and Kijko & Sellevol method

Zone	Weichert's method					Kijko & Sellevol's method				
	a-value	b-value	Beta	Rate	Allocation	a-value	b-value	Beta	Rate	Allocation
Java Interface:	4.247	0.91	2.095	0.498	1.00	4.606	0.97	2.234	0.570	1.00
1a	3.929	0.91	2.095	0.239	0.481	4.288	0.97	2.234	0.274	0.481
2a	2.834	0.91	2.095	0.019	0.039	3.192	0.97	2.234	0.022	0.039
3a	3.929	0.91	2.095	0.239	0.480	4.287	0.97	2.234	0.274	0.480
Java Interslab:	4.851	0.96	2.211	1.125	1.000	5.153	1.02	2.349	1.130	1.000
1b	4.441	0.96	2.211	0.437	0.389	4.743	1.02	2.349	0.439	0.389
2b	4.074	0.96	2.211	0.188	0.167	4.376	1.02	2.349	0.189	0.167
3b	4.499	0.96	2.211	0.500	0.444	4.801	1.02	2.349	0.502	0.444
Shallow Crustal:	4.550	1.00	2.307	0.355	1.00	4.330	0.99	2.320	0.240	1.00
Sukabumi fault	4.101	1.00	2.307	0.126	0.355	3.881	0.99	2.320	0.085	0.355
Bumiayu fault	4.077	1.00	2.307	0.120	0.337	3.857	0.99	2.320	0.081	0.337
Yogyakarta fault	4.039	1.00	2.307	0.109	0.308	3.819	0.99	2.320	0.074	0.308
Background (Purwana, 2001)	6.14	0.84	1.940	0.047	-	6.6	0.93	2.150	0.048	-

Based on the a-b parameter values, maximum magnitudes from each source, and the logic tree as the inputs of seismic hazard analysis, PBA's and uniform hazard spectra (UHS) curves of Semarang for 200, 500, and 1000 year return period earthquake could be produced (Table 3.2 and Figure 3.6 – 3.9).

Tabel 3.2. Semarang's PBA values for several return periods

Peak Base Acceleration of Semarang (g)		
200 years	500 years	1000 years
0.138	0.170	0.197

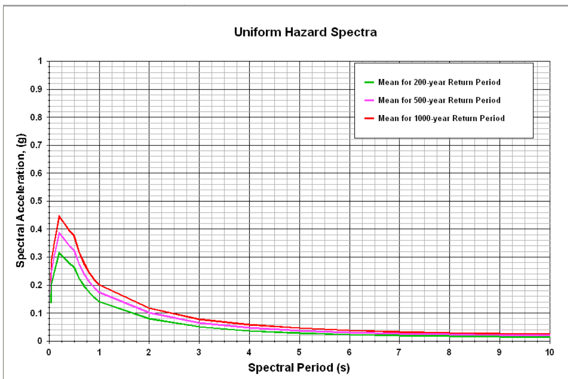

Figure 3.6. Uniform Hazard Spectra (UHS) for several return periods

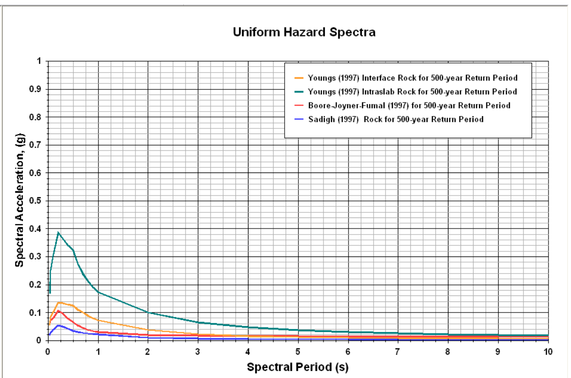

Figure 3.7. Uniform Hazard Spectra 500 years return periods for several attenuation functions

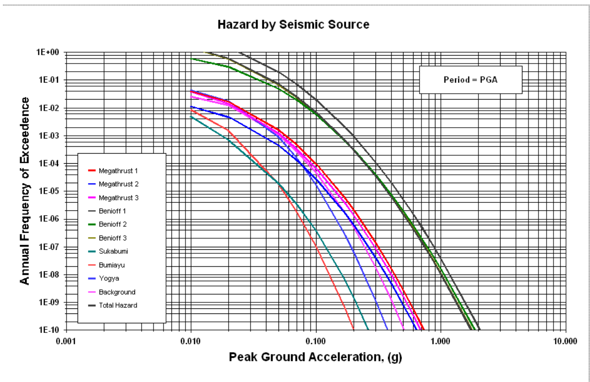

Figure 3.8. Hazard for each seismic source

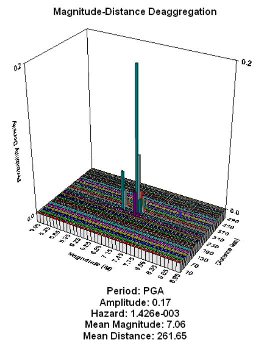

Figure 3.9. Deagregation on T = 0 second

It could be shown from deagregation result that seismic hazard of Semarang was dominated by intraslab seismic source with the mean magnitude and distance were 7.06 and 261 km respectively. Comparing to PBA of other studies in the same city, that were Purwana (2001) 0.14 g, Widhiono (2000) 0.162 g, this study obtained PBA a bit higher than that of them, 0.17 g.

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