Development of Seismic Risk Maps of Jakarta City

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Development of Seismic Risk Microzonation Maps of Jakarta City

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ABSTRACT: Development of seismic risk microzonation study is required for disaster preparedness, risk and hazard mitigation decisions for the Government of Jakarta. The study includes estimation of seismic hazard, site characterization, site specific response analysis and risk assessment. Seismic hazard is performed based on deterministic and probabilistic approaches considering seismic sources influencing Jakarta. Geotechnical parameters are interpreted from previous and recent measurements and depth of engineering bedrock is estimated based on microtremor array measurement. Identification of local site effects is conducted by carrying out one-dimensional ground response analysis considering the behavior of soil non-linearity. The result of the hazard microzonation study includes the distribution of site response such as spectral acceleration and amplification ratio. The results are then combined with building fragility that is determined based on the FEMA 154. Two building fragility curves are formulated corresponding to existing building type in Jakarta which are the confined masonry and in-filled frame structures.

1 INTRODUCTION

Several damaging earthquakes in the last decades in Indonesia have alerted the Government of Republic of Indonesia to mitigate future damages due to earthquake. Figure 1 show several massive earthquakes in the last decade, for example, Aceh 2004, within 150 kilometers of Aceh Province that followed by a massive tsunami, 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 billion of dollars for rehabilitation and reconstruction.

In 2011, the Coordinating Ministry for People’s Welfare appointed a national team to develop seismic risk microzonation maps for Jakarta city in order to enhance disaster preparedness, risk reduction and hazard mitigation. The team members consist of experts from national agencies and university research center including: Research Center for Disaster Mitigation of ITB, Government of Jakarta; Ministry of Public Works; Bureau of Meteorology, Climatology and Geophysics; National Disaster Management Agency; Ministry of Energy and Mineral Resources; Ministry of Research and Technology; Agency for Assessment and Application of Technology; and National Agency for Surveying & Mapping. The team members also collaborate with experts from Australian National University through AIFDR.

Jakarta is located in the North of Java Island with total land area approximately 664 km$^2$ with total population, from national census in 2010, approximately 10 million people with density about 15 thousand people for every km$^2$ area. It makes that seismic microzonation study is crucial to be completed immediately. The Indonesia seismic hazard maps published by the Ministry of Public Works in 2010 show that Jakarta is subjected to about 0.3 - 0.4 g ground acceleration at bedrock for the hazard level 2% probability of exceedance in 50 years. Seismic microzonation study is generally recognized as one
of effective method to perform seismic hazard assessment and risk evaluation which is defined as the zonation with respect to ground motion characteristics taking into account source and site conditions (ISSMGE/TC4, 1999). This paper presents several aspects in seismic microzonation in Jakarta city including the seismotectonic condition, geological condition, site amplification and risk evaluation by taking into account the building fragility. The microzonation level is graded based on the scale of investigation and method of ground motion assessment. Based on the technical committee on earthquake geotechnical engineering, TC4 of the International Society of Soil Mechanics and Geotechnical Engineering (1999), the seismic microzonation process methodology and level of study of Jakarta city is performed according to ISSMGE/TC4, 1999.

Seismic microzonation study in Jakarta requires rigorous input parameters regarding the seismic hazard in Jakarta, depth of engineering bed-rock, geotechnical condition and parameters, ground water level, ground response analysis and quantification of building vulnerability. It means that the seismic microzonation process are divided into 4 steps:

a. Evaluation of the input motion at bedrock or outcrop.

b. Site Specific Response Analysis

c. Seismic hazard microzonation

d. Seismic risk microzonation by taking into account the building fragility.

2 SEISMIC SOURCES INFLUENCING JAKARTA CITY

As mentioned previously by Irsyam et al., (1999 and 2011), Indonesia is located in a tectonically very active area at the point of convergence of three major plates and nine smaller plates as developed by Bird (2003). The Eurasian, Pacific and Australian-Indian plates, along with some smaller plates (i.e. Philippine Sea plate), are all actively moving toward each other in the Southeast Asia region creating a complex network of plate boundaries.

The earthquake data recorded by numerous national and international institutions show that the total number of earthquake occurring in Indonesia region between 1900 – 2000 with a magnitude Ms > 5.0 is approximately more than 8000 occurrences, where 5 percent of occurrences occurred in or near Java Island. Western Indonesia, where Jakarta is located, tectonically consists of the Sunda Shelf which includes the islands of Sumatra, Java, Bali, Borneo, and the southwestern part of Sulawesi (Hamilton, 1979).

Figure 1: Seismic activity and seismotectonic condition in Sumatra and Java Island, Indonesia for the last few decades. (Modified from USGS)
The active tectonics of western Indonesia is dominated by convergence of the Australia plate with Sumatra and Java. Along Sumatra the direction of convergence is highly oblique to the trench strike, and is partitioned into nearly arc-perpendicular thrusting at the trench and arc-parallel, right lateral slip at the Sumatran fault (Bock et al., 2003).

Seismotectonic map showing the faults locations, geological setting and historical earthquakes influencing Jakarta is shown in Figure 2. Seismotectonic study has been collected in a circular area for detail with having radius of about 250 km around Jakarta. The seismotectonic map for Jakarta city contains several major fault lines in western Java with historical maximum magnitudes (Moment Magnitude, $M_w$) ranging from 6.5 – 7.6, and subduction zone either megathrust or deep intraslab subduction (Benioff) sources in sea with historical maximum $M_w$ ranging from 7.8 to 9.0. The source models were derived based upon seismogenic conditions, focal mechanisms and earthquake catalogs. This seismogenic conditions include geometry and geomorphological of tectonic plate such as faults and subduction zones.

The Sunda Strait segment is located in the transitional zone between the Sumatera and Java segments of the Sunda Arc subduction zone. The angle of the subducted plate is depicted by vertical section shown in Figure 3. The dip angle of the megathrust represents important input for PSHA. Therefore, dip angles were investigated further by using carefully relocated events of Engdahl et al. (2007) using a 3D velocity and a double-difference (DD) technique (Pesicek et al., 2010). Figure 4 shows the dip angles of megathrust zone and can be depicted well.

In this study, several fault lines sources in Sumatra and Java Island are included. The 1900-km long Sumatran fault zone (SFZ) traverses the back-bone of Sumatra, within or near the active volcanic arc (Katili and Hehuwat, 1967; Sieh and Natawidjaja, 2000). Other fault sources that are also considered include the East Lampung fault (Semangko) and the Sunda Strait fault line.

In Java Island, the nearest fault sources which have been proven as active shallow crustal faults are the Cimandiri and Lembang faults. The Cimandiri fault is considered as an active fault based on micro earthquake monitoring and geomorphic expression instead of the slip rate calculation (Kertapati, 1984). Table 1 summarizes the activity both for the fault and subduction zone influencing Jakarta city.

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![Seismotectonic map of Sumatra and Java Island](image_url)
Seismic hazard analysis is conducted using similar procedures used by the Team for Revision of Seismic Hazard Maps distribution from 1964 and 2007. Both probabilistic and deterministic approaches are used. Seismic hazard analysis is performed based on earthquake catalog, geological, and seismological information of active faults. The analysis includes truncated exponential model, pure characteristic model, and combined models. Earthquake source parameters are derived based upon earthquake catalog, geological, and seismological information of active faults.

### Table 1. Identified active seismic sources within 250 km radius from Jakarta city

<table>
<thead>
<tr>
<th>Sources</th>
<th>Name</th>
<th>Mechanism</th>
<th>$M_{\text{max}}$</th>
<th>Length (km)</th>
<th>Activity (mm/yr)</th>
<th>GR Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault</td>
<td>Cimandiri</td>
<td>Strike-slip</td>
<td>7.2</td>
<td>62.2</td>
<td>4</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Lembang</td>
<td>Strike-slip</td>
<td>6.6</td>
<td>34.4</td>
<td>1.5</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Semangko</td>
<td>Strike-slip</td>
<td>7.2</td>
<td>65</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Sunda</td>
<td>Strike-slip</td>
<td>7.6</td>
<td>150</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Kumering</td>
<td>Strike-slip</td>
<td>7.6</td>
<td>150</td>
<td>11.0</td>
<td>--</td>
</tr>
<tr>
<td>Subduction</td>
<td>South Sumatra Megathrust</td>
<td>Reverse</td>
<td>9.0</td>
<td>--</td>
<td>5.76</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Java Megathrust</td>
<td>Reverse</td>
<td>9.0</td>
<td>--</td>
<td>6.14</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Figure 4. Vertical sections across the Sunda strait through the global data set by Enghdahl et al., 2007 (EHB) and relocated events using a double-difference (DD) method and 3D velocity model. (Pesicek et al., 2010, Widiyantoro et al., 2011)
3.1 Probabilistic Seismic Hazard Analysis (PSHA)

Three seismic source models are utilized in this analysis; fault zone, subduction zone, and gridded seismicity for shallow background and deep intraslab. The source models were selected using seismogenic conditions, focal mechanisms and earthquake catalogs. This seismogenic conditions include geometry and geomorphological of tectonic plate such as faults and subduction zones.

The modeling of the subduction sources is conducted based on well-identified seismotectonic data such as location of subduction in latitude and longitude coordinates, slope of subduction plane (dip), rate, and b-value from historical earthquake catalogues, and limit depth of subduction zones. The subduction zone that is shallower than 50 km is considered as the Megathrust or interface zone, whereas, the earthquake occurrence deeper than the Megathrust zones is classified as the Benioff zone and considered as deep background sources (Irsyam et al., 2013b).

Fault source is treated as a plane in 3-D space for calculation of distance from a site to a certain point at the plane. Parameters of fault required for input of PSHA include fault traces, focal mechanism, slip-rate, dip, length and width of the fault. Location of each fault was determined based on information obtained from previous publications and relocated epicenters. The information was then used to trace each fault on the Shuttle Radar Topographic Mission (SRTM) that indicates geomorphology. Using this procedure, coordinate and length of each fault can be obtained. Other input data required for analysis was obtained from publications and technical discussions (Irsyam et al., 2010a and Irsyam et al., 2013b).

Gridded (smoothed) seismicity model are utilized to determine the rate of occurrence of small earthquakes on mapped faults and random earthquakes on unmapped faults (Petersen et al., 2008). This model is used to predict the likelihood of bigger earthquake for region in which lack of seismogenic data but has seismic activities report from small to moderate earthquakes.

A truncated-exponential or Gutenberg-Richter (Gutenberg and Richter, 1954) magnitude-frequency distribution between M5.0 and M6.5 is used to model rates for different sizes of earthquakes in every grid. The composite catalog was used as input for background seismicity and it was divided into five depth intervals, i.e. shallow earthquakes (0-50 km), intermediate earthquakes (50–100 km and 100–150 km), and deep earthquakes (150–200 km and 200–300 km) (Irsyam et al., 2010a, Irsyam et al., 2010b, Irsyam et al., 2011, and Irsyam et al., 2013b).

3.2 Attenuation Functions

Based on the previous researchs in the development of Indonesia seismic hazard maps (Irsyam et al 2010a, Irsyam et al, 2011, and Irsyam et al, 2013) a number of attenuation functions from worldwide historical earthquake data record is adopted to estimate the ground shaking in Jakarta city.

Attenuation from Atkinson-Boore intraslab seismicity world data BC-rock condition (Atkinson and Boore, 1995), Geomatrix slab seismicity rock (Youngs et al, 1997), and Atkinson-Boore intraslab (Atkinson and Boore, 2003) were used for Benioff (deep background sources). Attenuation from Chou-Young NGA (Chiou and Youngs, 2008), Boore-Atkinson NGA (Boore and Atkinson, 2008), and Campbell-Bozorgnia NGA (Campbell and Bozorgnia, 2008) were chosen for faults and background sources. Attenuation from Geomatrix subduction (Youngs et al., 1997), Atkinson-Boore BC rock and global Source (Atkinson and Boore, 2003) and Zhao et al., with variable Vs-30 (Zhao et al, 2006) were chosen for Megathrust zone (subduction interface).

3.3 Seismic Hazard Level of Jakarta City

Based on the earthquake sources listed on Table 1 and the attenuation function determined before, the PSHA is carried out to obtain the hazard level for Jakarta. The analysis considers two hazard levels; 10% and 2% probability of exceedance in 50 years. Figure 5 shows the distribution of peak ground acceleration (PGA) for Jakarta city. The value of PGA at bedrock ranges from 0.18 – 0.22 g and from 0.33 – 0.39 g for 10% and 2% probability of exceedance in 50 years.

3.4 De-Aggregation & Time Histories Development

The probabilistic seismic hazard analysis that was mentioned previously allows computation of the mean annual rate of exceedance at particular site location based on the cumulative risk from potential earthquake sources having different magnitude occurring at different source-site distance. The computed rate of exceedance is not associated with any particular earthquake magnitude or source-site distance. In order to estimate the most likely earthquake magnitude and the most likely source-site distance, de-aggregation process is conducted. The process requires that the mean annual rate be expressed as a function of magnitude and distance (the representing/controlling earthquakes). The results of de-aggregation is then used to select ex-
existing ground motion records, which recorded in earthquake of similar magnitude and at similar source-site distance. The de-aggregation results are summarized in Table 2.

The seismic hazard curves for PGA, 0.2 and 1.0 second spectral period are developed and de-aggregated to obtain representing magnitudes and distances for return periods of 500 and 2500 years for Jakarta city. Selection of input motions is conducted based on the magnitude and distance in historic earthquake event and estimated target earthquake of similar magnitude and at similar second spectral period are developed and de-aggregated to obtain representing m

Histories of ground motion from previous historic earthquake event and estimated target spectrum at bedrock using the spectral matching method proposed by Abrahamson (1998).

3.5 Deterministic Seismic Hazard Analysis

In addition to probabilistic approach, deterministic seismic hazard analysis (DSHA) is also performed in the development of seismic microzonation maps of Jakarta. DSHA for Jakarta is carried out first by selecting the matrix combination of magnitude and distance to represent earthquake scenarios due to earthquake sources surrounding Jakarta. The matrix is used as a basis to choose appropriate ground motion from worldwide historical earthquake records.

Each of scenarios for a specific earthquake source with certain magnitude and distance is represented by appropriate time-histories of ground motion records for input motions in shear wave propagation analysis. Historical earthquake records with magnitude ranging from 5.0 to 7.0 and distance from 20 km to 60 km are collected for crustal fault. The scenarios for subduction sources including deep intraslab utilize various historical earthquake with magnitude ranging from 7.0 – 9.0 and distance ranging from 150 – 450 km. Site response analysis using 1-D shear wave propagation procedure is then conducted once the input motions corresponding to a specific earthquake scenario are selected.

4 GEOLOGICAL & GEOTECHNICAL CONDITION OF JAKARTA CITY

Based on the geological map of Jakarta and Seribu Islands Quadrangle, Java (Turkandi et al., 1992), the Great Jakarta city area are founded on Quaternary sediments which are consists of river to coastal alluvium deposits, beach ridge sediments, alluvium fan deposits and volcanic tuff. These sediments occupy the whole of thick sedimentary basin knowing as the Ciputat Sub-Basin (Fachri et al., 2002), which bordered by Tinggian Tangerang to the west, Tinggian Rengasdengklok to the east and the Bogor Antiklinorium zone to the south.

The sediment thickness in this area may locally reach more than 500 m and unconformably overlying the older Tertiary sediment formation, such as Serpong Formation, Genteng Formation, Kaliwangu Formation, Subang Formation, Parigi Formation, Bojongmanik Formation and Jatiluhur Formation as shown in Figure 6.

4.1 Identification of Engineering Bedrock of Jakarta

The depth of engineering bedrock is one of required parameters used to perform the site response analysis. Because of the location of bedrock of Jakarta is not well identified until now, therefore,
Table 2. De-aggregation results of Jakarta city for various return period

<table>
<thead>
<tr>
<th>Return Period</th>
<th>Period</th>
<th>Megathrust Magnitude</th>
<th>Distance (km)</th>
<th>Shallow crustal Magnitude</th>
<th>Distance (km)</th>
<th>Benioff Magnitude</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sec</td>
<td>(M\text{w})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>0.2 s</td>
<td>8.07</td>
<td>113.04</td>
<td>5.90</td>
<td>55.23</td>
<td>6.78</td>
<td>120.88</td>
</tr>
<tr>
<td></td>
<td>1.0 s</td>
<td>8.05</td>
<td>191.44</td>
<td>5.94</td>
<td>58.07</td>
<td>6.71</td>
<td>122.79</td>
</tr>
<tr>
<td>2500</td>
<td>0.2 s</td>
<td>8.09</td>
<td>189.51</td>
<td>5.97</td>
<td>47.38</td>
<td>6.91</td>
<td>117.07</td>
</tr>
<tr>
<td></td>
<td>1.0 s</td>
<td>8.11</td>
<td>199.80</td>
<td>6.41</td>
<td>49.56</td>
<td>7.16</td>
<td>117.38</td>
</tr>
</tbody>
</table>

Figure 6. Geological map of the Greater Jakarta Area and surrounding Area (After Fachri et al., 2002)

An investigation of bedrock depth is urgently required. Microtremors array survey has become an effective method to estimate engineering bedrock based on S-wave velocity structures because it is very simple in the field operation and without active sources. Analysis of dispersion curve of microtremors can be performed by Spatial Auto-Correlation (SPAC) method which was developed by Aki (1957) and expanded by Okada (1998) on the circular array with distance r between two stations. The microtremor study is expected to provide the estimation of depth at which the material is measured its shear wave velocity.

Ridwan et al. (2013) applied microtremors array to obtain the 1D and 2D S-wave velocity profiles in some locations in Jakarta. Estimation of the bedrock depth in Jakarta is based on S-wave velocity parameters. The spatial autocorrelation method was used to estimate dispersion curves, while S-wave velocity structure is derived by genetic algorithm. The result of 2D construction of S-wave velocity structure shows stratigraphy cross section that consists of four layers, where the bedrock depths in northern Jakarta can be depicted in the range from 518 m to 542 m and in the southern part is in the range from 359 m to 398 m (Ridwan et al, 2014). Figure 7 show the location of instrumentation in Jakarta city and the contour map showing the depth of recorded shear wave velocity greater than 750 m/s.

Referring to the Geological condition in Jakarta where layers thickness increases to the North, hence, microtremors survey was designed in one line from the South to the North across Jakarta. The triangular arrays configuration was used for each sites by using 4 instrument and the time duration for microtremors data record was 1 - 2 hours for each array. 1D S-wave velocity profile resulted by individual inversion was used to construct 2D profile after conducted second inversion. The results of microtremors array analysis shows that the subsurface models for Jakarta consist of four layers where engineering bedrock can be estimated at the forth layers (359 - 608 m depth) as shown in Figure 8.
Figure 7. Microtremor measurement to identify engineering bedrock in Jakarta (Ridwan et al, 2013); (a) Location of Instrumentation.; (b) Contour map of depth of engineering bedrock (Vs > 750 m/s) identified by microtremor array.

Figure 8. Shear wave velocity profile across Jakarta from the North to the South that shows the estimated engineering bedrock. (Ridwan et al, 2013)

4.2 Soil Condition of Jakarta City

Site characterization is carried out by interpreting the results of field measurements including in-situ testing such as standard penetration test (SPT), Dutch cone penetration test (DCPT), shear wave velocity measurement using seismic downhole test and laboratory tests. Field and laboratory data are obtained by collection of previous soil investigation results conducted previously by various consultants and by performing new additional soil investigation conducted by the Government of Jakarta. Figure 9
shows the distribution of borehole points in all part of Jakarta city used for the development of seismic microzonation maps.

Further study to identify the dynamic soil properties is also conducted to encounter limited data of shear wave velocity profiles in Jakarta. An empirical correlation between N-SPT with shear wave velocity has been developed based on 42 borehole points from 22 different location in Jakarta. The borehole data is collected from high rise building projects spread across the city and the data is plotted in Figure 10.

Figure 10 indicates that the correlation between N-SPT with shear wave velocity is quite scatter. It shows that the tendency of plotted data is eligible as a basis to develop the empirical equation to estimate shear wave velocity value. The shear wave velocity profile in other borehole is estimated based on this empirical equation shown in Figure 10. Based on the result developed by Yunita (2013), the result show that the equation proposed by Imai and Tonouchi (1982) is the closest relationship for shear wave velocity estimation based on N-SPT value for Jakarta city.

Site classification study for Jakarta is performed based on the N-SPT according to the NEHRP site classification standard as shown in Figure 11. The study show that most of location in Jakarta city is classified as the soft soil site (SE) and medium soil (SD) with N-SPT value less than 15 and ranging from 15 to 30 respectively.

In this study, the seismic risk is considered only for building, neglecting the impact on people. With this definition, the seismic risk is obtained by the convolution of seismic hazard and building vulnerability only. Building vulnerability is considered for different building typologies and is represented using fragility curves.

Fragility curves have been derived for two types of low rise buildings that dominate the residential building population in Jakarta, i.e. confined masonry and in-filled frame structures in this study. The fragility curves are derived based on FEMA 154 procedures for different levels of damage (i.e. Slight, Moderate, Extensive and Complete Damages) and the ground motion severity in these curves are expressed in terms of Peak Surface Acceleration (PSA) shown in Figure 12. The fragility curves allow the estimation of the probability of reaching or exceeding certain levels of damage (P(x≥X) for a given PSA. These fragility curves are later applied to each area in Jakarta to determine the vulnerable area at which the building type distribution is known. Building types distribution in the area considered is obtained through building survey.
The results of the seismic microzonation study of Jakarta city include: probabilistic and deterministic peak acceleration, amplification factors, spectral acceleration, and hazard level at ground surface; and risk maps for Jakarta city. The work is still on going and is expected to be completed next year. Tentative results are presented in the following paragraphs.

5 RESULTS & DISCUSSION

The results of the seismic microzonation study of Jakarta city include: probabilistic and deterministic peak acceleration, amplification factors, spectral acceleration, and hazard level at ground surface; and risk maps for Jakarta city. The work is still on going and is expected to be completed next year. Tentative results are presented in the following paragraphs.

5.1 Seismic Hazard Microzonation

Site response analysis is conducted to obtain peak acceleration, amplification factors, spectral acceleration, and hazard level at ground surface due to ground motions at bedrock obtained from probabilistic and deterministic seismic hazard analysis. The site response analysis is performed based on the 1-D non linear wave propagation procedure using the constitutive model proposed by Iwan and Mroz (1967) and by utilizing the free software NERA (Bardet & Tobita, 2001). Figure 13.a and b present the site amplification factor due to ground motions from fault source with magnitude M=6.5 and distance R=20 km and megathrust source with magnitude M=9.0 and distance R=200 km. The maps indicate that the amplification factor ranges from 0.8 to 2.2 and at the center of Jakarta where most of major high rise buildings are located the value varies from 1.2 to 1.6.

Figure 14.a shows peak surface acceleration due to ground motions from fault source with magnitude M=6.5 and distance R=20 km. The peak acceleration at ground surface varies from 0.14 to 0.24 g for fault sources. Figure 14.b present probabilistic peak surface acceleration for 2500 years earthquake occurrence period where the peak acceleration at ground surface ranges from 0.2 to 0.4 g.

5.2 Seismic Risk Microzonation

The seismic risk microzonation maps is developed by combining the seismic hazard with the building fragility. Figures 15-16 show the examples of the maps of seismic risk microzonation, for example, in East Jakarta (Cipayung and Duren Sawit Districts). The seismic scenario used is the deterministic shallow crustal earthquake, with magnitude M=6.5 and distance R=20 km. Due to this earthquake, the PSA in East and North Jakarta is in between 0.12 – 0.26 g. The color scale in Figures 15-16 is different for each risk level it is divided into 5 risk level start from the Very High (Brown), High (Red), Medium (Orange), Low (Yellow) and Very Low (Green).

It can be seen from those figures the different seismic risk levels in Jakarta due to the seismic
scenario applied. These seismic risk maps can be useful instrument for risk reduction or disaster mitigation program in Jakarta. These maps can be used for establishing intervention priorities for population of buildings in certain area in the city, in order to reduce the risk.

6 CONCLUSION

The development of seismic microzonation hazard and risk map have been carried out for Jakarta city as the capital city of Republic Indonesia. The study includes the identification of major seismic sources influencing Jakarta city, probabilistic and deterministic seismic hazard analysis (using worst case earthquake scenario), de-aggregation & probabilistic time histories development, the identification of engineering bedrock by using microtremor array, site characterization and interpolation of soil dynamic properties, ground response analysis and estimation of the soil amplification factor and peak surface acceleration. Moreover, the seismic risk mapping in micro-scale of every part in the Jakarta city (district scale) is developed by identification of building typologies, formulating fragility curves for different building typologies, determination of the vulnerable area for each building type distribution in every district, and calculating the seismic risk. This study then is expected as a basic consideration for disaster preparedness to the government in planning further land planning and development of Jakarta city.

Figure 13. Contour map of deterministic amplification factor for: (a) Scenario-30, fault sources with $M_w=6.5$ and $R=20$ km; (b) Scenario-36, megathrust sources with $M_w=9.0$ and $R=200$ km.

Figure 14. Contour map of: (a) Peak Surface Acceleration (PSA), Scenario-30, fault sources with $M_w=6.5$ and $R=20$ km; (b) Probabilistic Peak Surface Acceleration with 2% probability of exceedance in 50 years.
ACKNOWLEDGEMENT

The authors want to express grateful thanks to Dedy Dharmawansyah and Partogi Simatupang for their supports in this research and also to Department of Industry and Energy - Government of Jakarta; Institut Teknologi Bandung, the Ministry of Public Works; Bureau of Meteorology, Climatology and Geophysics; National Disaster Management Agency; Ministry of Energy and Mineral Resources; Ministry of Research & Technology; and Australian National University through Australia-Indonesia Facility for Disaster Reduction for their supports and assistances during this study.

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Figure 15. Seismic Risk Map in Cipayung District, East Jakarta

Figure 16. Seismic Risk Map in Duren Sawit District, East Jakarta


Ridwan, M (2013) Personal Communication


