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RECENT EFFORTS TO MITIGATE THE IMPACTS OF EARTHQUAKE HAZARD IN INDONESIA FROM GEOTECHNICAL ENGINEERING PERSPECTIVE

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INTRODUCTION

Indonesia has been well known as one of the most seismically active countries in the world since it is located on the boundaries of three major plates; Asian, India-Australia, and Pacific plates. The India-Australia plate converges northeastward about 50 to 70 mm/year to the Asian Plate along the Sunda trench (Bock et al, 2003). This tectonically dynamic environment puts most parts of Indonesia prone to earthquake and their secondary hazards such as tsunami, landslides, liquefaction, flood and fire. Considerable numbers of active faults are also identified on offshore and onshore of Indonesia such as Great Sumateran fault, Palu-Koro fault, Molucca fault, Sorong fault and many others.

Lessons learned from several great earthquakes repeatedly occurred in Indonesia since the 2004 Aceh earthquake have increased the awareness to public and government regarding the impacts of seismic hazard on their structures such as buildings, bridges, dams, and any other critical facilities. Based on Irsyam et al (2013a), the estimated total losses due to the earthquake from 2004 to 2010 vary from US$39 million to US$4,745 million. In addition, almost 200,000 were killed due to the earthquakes activities. Over the last decade, many research agencies, universities, including professional associations have significantly increased the efforts to improve the understanding of earthquake phenomena and the predictive capabilities of earthquake science and to mitigate the impacts of future earthquakes in Indonesia.

The recent efforts in Indonesia to mitigate the impacts of earthquake hazard from geotechnical engineering perspective which involving the Indonesian Society for Geotechnical Engineering (ISGE) and the Research Center for Disaster Mitigation (RCDM) of Institute of Technology Bandung (ITB) include several activities as follows:

- Updating of seismic hazard maps of Indonesia 2010 and 2016
- Revision and continuous updating of building and infrastructure codes
- Development of microzonation maps for big cities in Indonesia
- Development of academic draft of National Earthquake Master Plan
- Development of national code for geotechnics and earthquake
- Preparation for establishment of the National Center for Earthquake Studies

UPDATING OF SEISMIC HAZARD MAPS OF INDONESIA 2010 AND 2016

The need to revise and to update the Indonesian Seismic Hazard Map 2002 was driven by several great earthquake occurrences in Indonesia such as the 2004 Aceh Earthquake (M_w9.0-9.3) which was followed by tsunami, the 2005 Nias Earthquake (M_w 8.7), and the 2009 Padang Earthquake (M_W 7.6). In 2009, Ministry of Public Works has assigned eleven (11) researches as a Team for Revision of Seismic Hazard Maps of Indonesia (TRSHMI 2010) to revise the 2002 map. The team consists of several institutions in Indonesia such as: ITB; Institute of Road Engineering Agency for Research and Development and Center for Research and Development of Housing and Settlements of the Ministry of Public Works; Indonesian Institute of Sciences (LIPI); Meteorological, Climatological and Geophysical Agency (BMKG), and Geological Research and Development Center (GSC). The team also collaborated with the United Stated Geological Survey (USGS) and the Australia-Indonesia Facility for Disaster Reduction (AIFDR). Several issues such as recent seismic activities, latest research works regarding fault characteristics in Indonesia, improvements of the method in seismic hazard analysis and latest provisions in International Building Code (ASCE 2010) have been considered in the development of the national hazard maps 2010.

Following TRSHMI 2010 (Irsyam et al., 2010, 2013a and 2013b), seismic sources were classified into three types of source models; fault zone, subduction zone, and background seismicity. Classification was conducted based on seismogenic conditions, focal mechanisms and earthquake catalogs. The seismogenic conditions included geometry and geomorphological of tectonic plate such as faults and subduction zones. Fault sources were modeled as a plane in 3-D space for calculation of distance from a site to a certain point at the plane. Subduction zone model were derived from tomography model conducted by Widiyantoro (2009), historical earthquake catalogs and seismotectonic conditions. Background seismicity was utilized to account for random earthquakes on unmapped faults and smaller earthquakes on mapped faults. A type of background seismicity was gridded models based on spatially smoothed earthquake rates (Frankel, 1995).

The fault model and subduction model utilized by TRSHMI 2010 is shown in Figure 1. The hazard maps have been officially published and signed by the Minister of Public Work of Indonesia in 2010 and implemented in a newly revised national code for earthquake resistance building design SNI 1726-2012.

TRSHMI 2010 has also proposed recommendation to the government. The recommendations include: conduct periodic updating of seismic hazard maps and related national codes every three to five years; conduct micro seismicity investigation of active faults that have not been well identified and well quantified, especially near big cities such as Jakarta, Surabaya, Semarang; accelerate the installation of strong-motion accelerometer networks in Indonesia in order to develop database of time histories and attenuation functions; and perform seismic microzonation studies for big cities in Indonesia.

In order to follow up the recommendation from TRSHMI 2010, in 2015 The National Agency for Disaster Management (BNPB) started coordinating several institutions in Indonesia to update the national seismic hazard maps 2010. The team consists of experts from ITB, BMKG, Center of Volcanology and Geological Hazard Mitigation (PVMBG), Ministry of Public Works, LIPI, Geospatial Information Agency (BIG), Agency for the Assessment and Application of Technology (BPPT), and professional associations such as IABI. The team is divided into several working groups, such as geology, geodesy, seismology, ground motion prediction equations, and Seismic Hazard Analysis. Important information is considered for updating seismic hazard maps such as significant results of recent active-fault studies utilizing trenching and carbon dating as well as availability of basic data including the SRTM-30, IFSAR, LiDAr and other data that is just recently available. It can be expected that this new information will result in more accurate tectonic model and their seismic parameters, such as maximum magnitudes and slip-rates. This updating work is currently on going and it is expected to be completed before end of 2016.

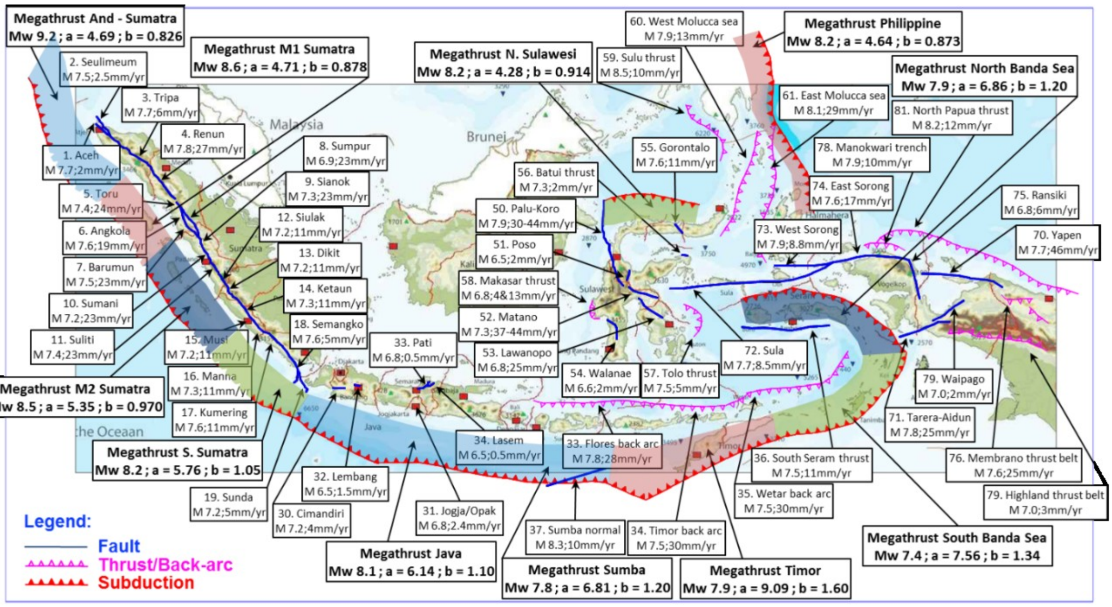

Fig. 1 Earthquake sources and their parameters used by TRSHMI 2010 (Irsyam et al., 2010, and 2013a)

REVISION AND CONTINUOUS UPDATING OF BUILDING AND INFRASTRUCTURE CODES

The Ministry of Public Works has practically implemented SNI 1726-2012 to replace SNI 03-1726-2002 as a national code for earthquake resistance building design since 2014. The new code for buildings follows the concept of Maximum Considered Earthquake Geometric Mean (MCE_G) and Risk-Adjusted Maximum Considered Earthquake (MCE_R) used by ASCE 7-10. For the purpose of geotechnical calculation, it combines both the results from probabilistic seismic hazard analysis for 2% probability of exceedance in 50 years (2,500 years earthquake) and deterministic seismic hazard analysis for area located near active fault. Both approaches were utilized according to the procedure proposed by Leyendecker et al. (2000) and the result of combining both probabilistic and deterministic analyses is called MCE_G.

In order to evaluate the seimic hazard for low and high risk structure (e.g. building), the spectral acceleration maps are required. The 0.2s and 1.0s spectral acceleration maps have been developed by taking into account the probability of collapse for a structure. Probability of collapse of a structure is influenced by the structural capacity that has uncertainty including as site-to-site variability in the shape of hazard curve, material properties, nonstructural components, etc that will result in a lack of uniformity in structural capacity (Luco, 2006). For the new national code, probability of collapse of a structure is targeted to be equal to 1% in 50 years according to ASCE 7-10. Figure 2 and 3 show the maps of Risk-Adjusted Maximum Considered Earthquake (MCE_R) at 0.2s and 1.0s spectral response acceleration in SNI 1726-2012.

Updating of national standards for design of infrastructure is also conducted for bridges, dams, harbours, tunnels, and others special structures. It seems that each type of infrastructure code will utilize hazard maps having different return period of earthquake. For design of bridge, updating of the code is already completed. The standard RSNI2 2833:201X that follows AASHTO LRFD Bridge Design Specification, 5th Edition, 2012 utilize return period of earthquake equals to approximately 1000 years that corresponds to 7% probability of exceedance in 75 years. Based on the new code, three maps of spectral response accelerations are required to develop the design response spectra, i.e. spectral acceleration at 0.0s, 0.2s, and 1.0s. The hazard maps for T=0.2s for site class S_B can be seen in Figure 4.The code is already in the Indonesian Standardization Body and expected to be launched by the end of 2016.

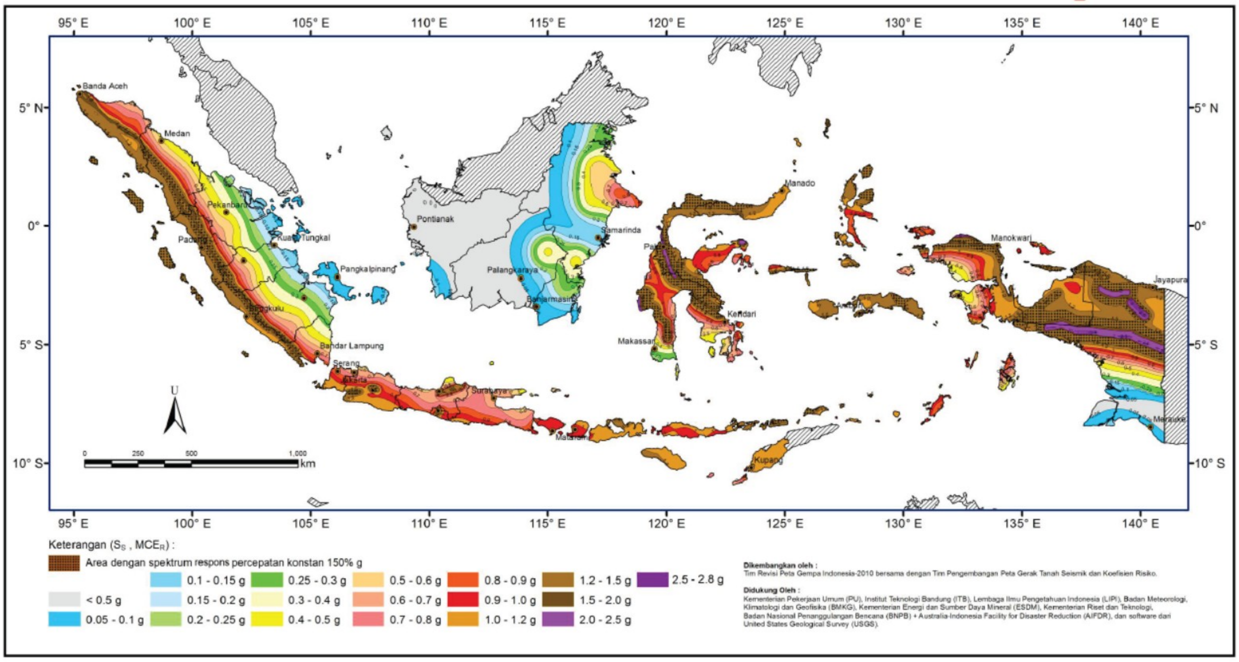

Fig. 22 Map of Risk-Targeted Maximum Consider Earthquake (MCE_R) at bedrock (SB) of Indonesia at 0.2s spectral response acceleration in SNI 1726-2012 for building design

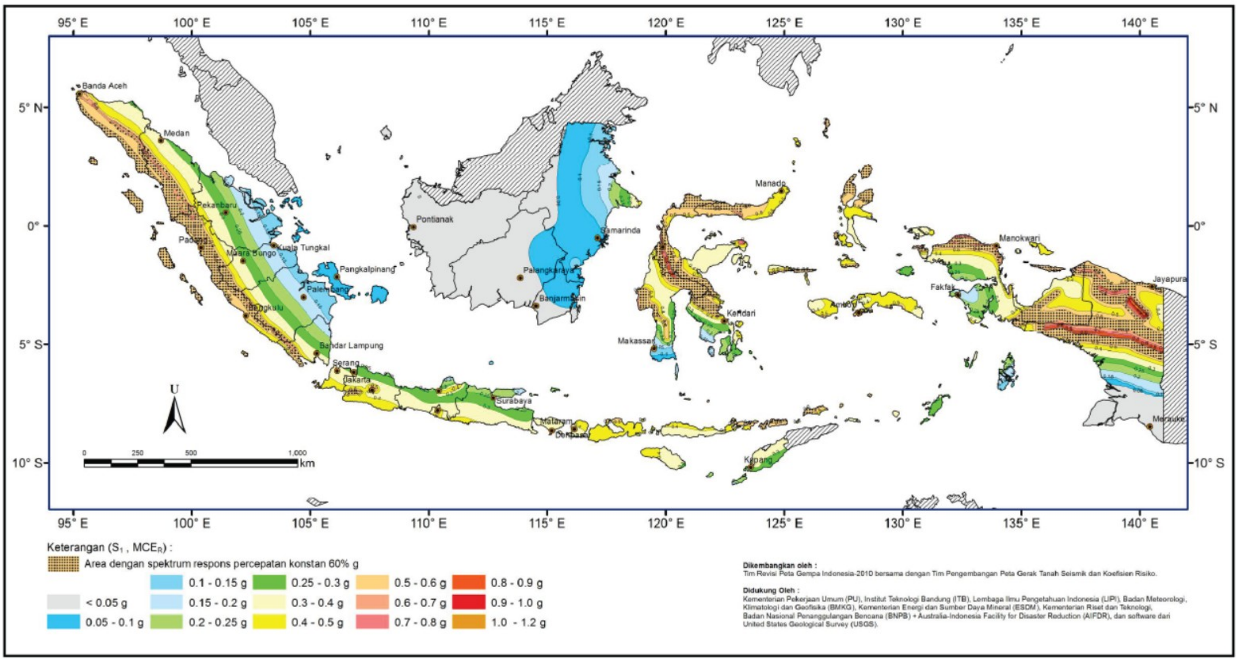

Fig. 3 Map of Risk-Targeted Maximum Consider Earthquake (MCE_R) at bedrock (SB) of Indonesia at 1.0s spectral response acceleration in SNI 1726-2012 for building design

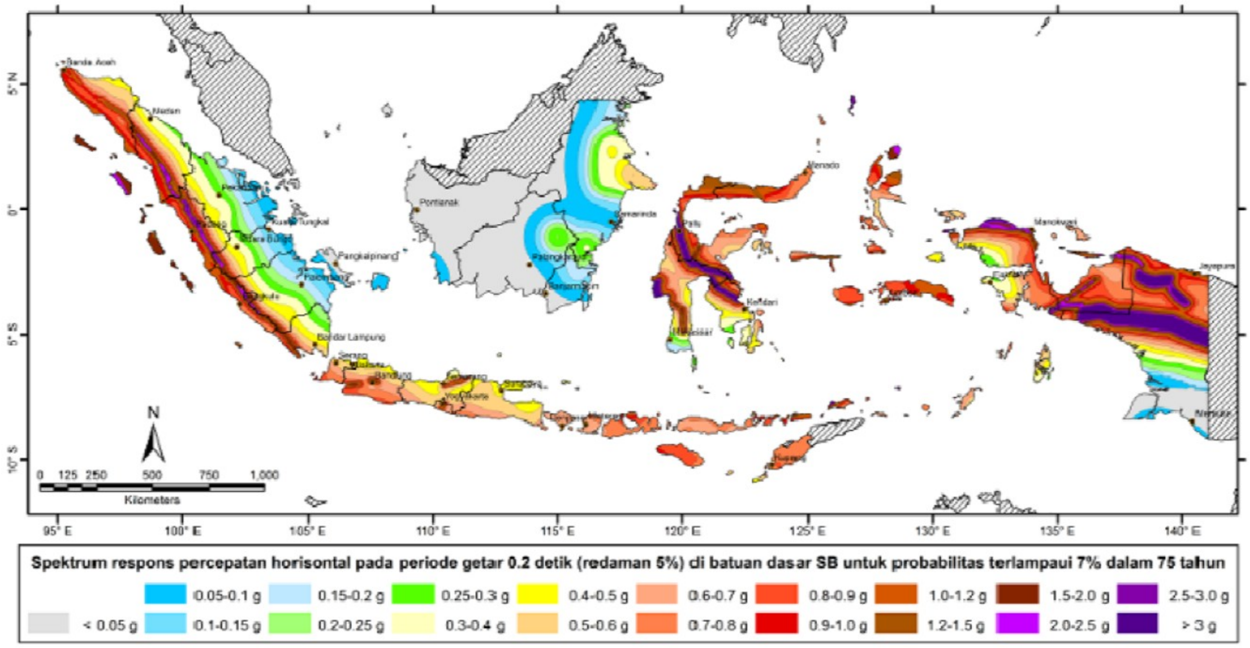

Figure 4. Horizontal response spectra for T=0.2s for Site Class S_B (RSNI2 2833:201X) for bridge design

DEVELOPMENT OF SEISMIC MICROZONATION MAPS FOR BIG CITIES IN INDONESIA

In order to enhance disaster preparedness, risk reduction and hazard mitigation, the Coordinating Ministry for People's Welfare in 2011 started coordinating a national team to develop seismic microzonation maps for selected big cities in Indonesia. The team members consist of experts from national agencies and university research center including: RCDM of ITB, Government of Jakarta; Ministry of Public Works; BMKG; BNPB; PVMBG; BPPT; and BIG. The team members also collaborate with experts from Australian National University through AIFDR.

Currently, Jakarta was selected as prototype for the seismic microzonation work. Seismic risk maps for Jakarta were developed for two hazard levels based on probabilistic approach, i.e. 10% and 2% probability of exceedance in 50 years, and for three scenario earthquakes based on deterministic approach, i.e. subduction Megathrust (M_w=8.7 and R=179 km), subduction Benioff (M_w=7.0 and R=145 km), and shallow crustal (M_w=6.1 and R=51 km).

The work covers estimation of seismic hazard, site characterization, site specific response analysis and risk assessment (Irsyam et at., 2014). Seismic hazard analysis was conducted based on deterministic and probabilistic approachs considering seismic sources influencing Jakarta such as several major fault lines in western Java and subduction zone either Megathrust or deep subduction Benioff sources. Site characterization was 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. Site response analysis were conducted based on the 1-D non linear wave propagation procedure utilizing the free software NERA (Bardet & Tobita, 2001) and by using the constitutive model proposed by

Iwan and Mroz (1967). Peak surface acceleration map of Jakarta due to Megathrust earthquake M=8.7 R=179km is presented in Figure 4.

The seismic risk microzonation maps were then developed by combining the results of site response analysis with building fragility for two types of low rise buildings that dominate the residential building population, i.e. confined masonry and in-filled frame structures. Seismic risk map of Jakarta for residential building due to Megathrust earthquake M=8.7 R=179km is presented in Figure 5.

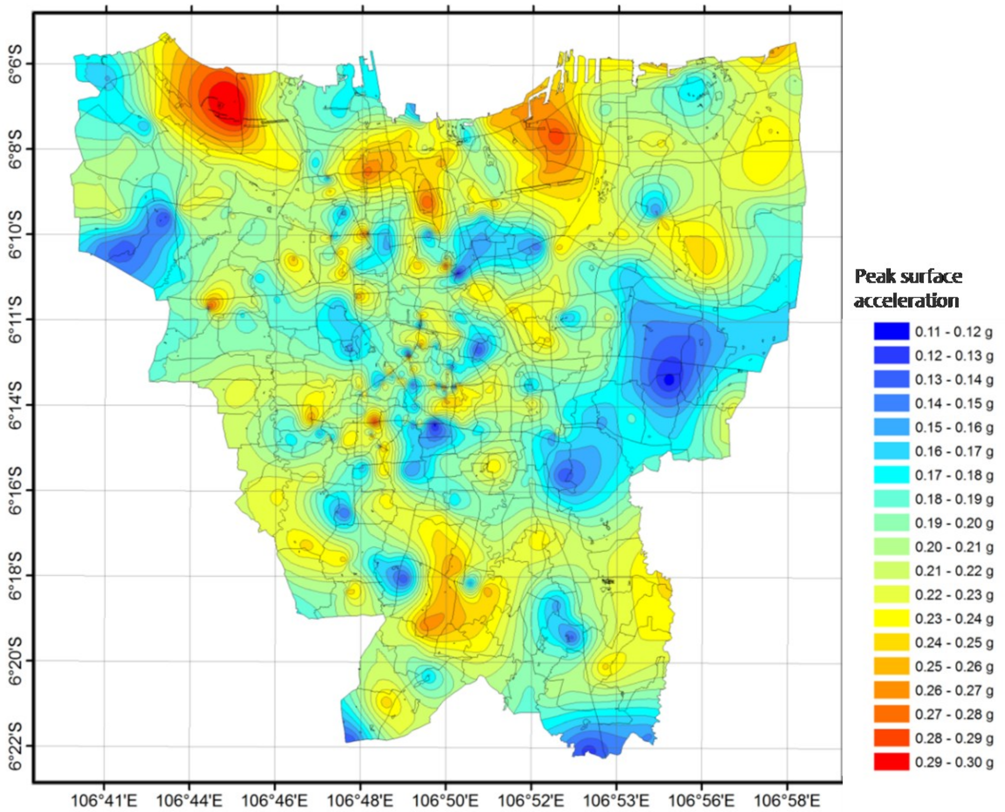

Fig. 4 Peak surface acceleration map of Jakarta due to Megathrust earthquake M=8.7 R=179km (Sakti et al., 2015)

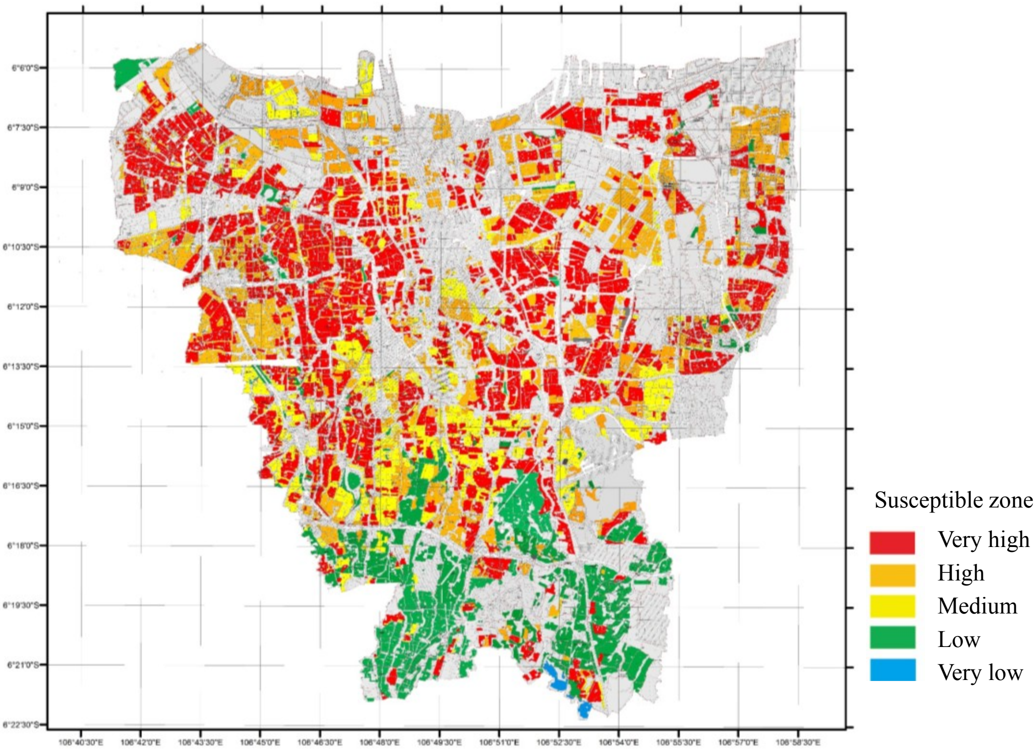

Fig. 5 Seismic risk map of Jakarta for residential building due to megathrust earthquake M=8.7 R=179km (Sakti et al., 2015)

DEVELOPMENT OF ACADEMIC DRAFT OF THE NATIONAL EARTHQUAKE MASTER PLAN

To support disaster risk reduction programs in Indonesia, in 2013 BNPB had selected 12 universities to prepare academic drafts of master plans for 12 hazards. The plans are multiagency programs to reduce the risks of life and property from future hazards in Indonesia. RCDM ITB had been selected by BNPB to lead the establishment of academic draft for Indonesian earthquake master plan. The masterplan is developed with specific purpose to support the earthquake disaster risk reduction. It is particularly used to provide direction / guidance for disaster prevention, mitigation and early warning and to become a planned, integrated and coordinated reference for program of activities, focused priorities and the indicative budget for the ministry/agency and all stakeholders in the response to the earthquake disaster in Indonesia.

The master plan consists of disaster risk reduction program for short, medium and long term based on assessment from several aspects, i.e. basic sciences, engineering and risk analysis, and social and legal aspects. The general purposes of the master plan are: 1) to improve understanding of earthquake processes and impacts, 2) to reduce earthquake impacts on building and infrastructures, and 3) to improve the earthquake resilience of communities nationwide.

Some important proposed recommendations of the master plan can be found in Irsyam et al. (2013c): to study seismic sources which urgently need to be identified (such as activity, the maximum magnitude and slip rate), to update Indonesian seismic hazard maps, to develop microzonation maps for several big cities in Indonesia, to revise and continuous updating of building and infrastructure codes, and to establish earthquake national research center.

DEVELOPMENT OF THE NATIONAL CODE FOR GEOTECHNICS AND EARTHQUAKE

Development of the Indonesia's national code for geotechnics and earthquake has been initiated in 2014 by the Ministry of Public Works. The main purpose of the project is to establish a code as the Indonesian national standard for the design of construction works related to geotechnics and earthquake. The developed code will cover sub structures for buildings, highways, bridges, water resources and settlements. The committee for this work consists of ISGE, Institute of Road Engineering Agency for Research and Development, Research and Development Center for Water Resources, Center for Research and Development of Housing and Settlements, and universities.

The code will provide common structural design rules to be used for design of sub structures including the requirements for field and laboratory tests. There are nine (9) fields that will be covered by the code as follows: 1) Stability of Slope and Embankment, 2) Deep Excavation, 3) Foundation, 4) Tunnel, 5) Seismicity, 6) Geotechnical Investigation, 7) Retaining Structure, 8) Ground Improvement, and 9) Hydraulic failure. All standards in the code are developed by a consensus standards process such as focus group discussion (FGD) organized by ministry of public works and ISGE. Development of the code is currently on going and expected for completion by the end of 2016.

PREPARATION FOR ESTABLISHMENT OF THE NATIONAL CENTER FOR EARTHQUAKE STUDIES

Based upon the academic draft of Indonesia earthquake master plan (Irsyam, et.al, 2013c), a national center for earthquake research is urgently needed to support disaster risk reduction programs in Indonesia. The center is required to enhance the science and practice of earthquake science and engineering and to improve the understanding of the impact of earthquakes on the physical, social, and economic. The center will gather scientists and engineers from different institutions at national level to share and integrate all data, resources, knowledge and new scientific findings in earthquake hazards through collaborative researches.

The establishment of the research center was initiated at the end of 2015 by several Indonesian institutions such as: Ministry of Public Works; ITB; BMKG; LIPI; PVMBG; BIG; BNPB; Ministry of Research, Technology and Higher Education; BPPT; Universities (UNDIP, UGM, and ITS); and profesional associatons (ISGE, IABI, and AFMI).The research center will cover the following tasks such as: conduct basic and applied researches related to earthquake hazard and risk; support and perform the updating of seismic hazard and risk maps periodically and sustainably; develop standards, manual and guidelines related to seismic hazard and risks; and coordinate and synchronize with the ministry/agency and other institutions regarding all the activities related to monitoring systems, measurement, and seismic characteristics analysis for supporting the updating of national hazard maps and earthquake risk. In order to fulfill the tasks, the research center is supported by eight (8) working groups, i.e. geology, geodesy, seismology, ground motion prediction equation (GMPE), seismic hazard analysis, geotechnics, infrastructures and structures, and collateral hazards. It is expected that the national research center to be launched in this year (2016).

CONCLUSIONS

Lessons learned from several great earthquakes repeatedly occurred in Indonesia since the 2004 Aceh earthquake have increased the awareness to public and government regarding seismic activities in Indonesia. Over the last ten years, many research institutions, universities, including association professions such as Indonesian Society for Geotechnical Engineering (ISGE) have significantly increased the efforts to understand earthquake hazards and to mitigate the impact of future large earthquakes in Indonesia. Some of the recent efforts in Indonesia to mitigate the impacts of earthquake hazards were described briefly in this paper. The actions includes updating of the seismic hazard maps of Indonesia 2010 and 2016, revision and continuous updating of building and infrastructure codes, development of microzonation maps for big cities in Indonesia, development of academic draft of Indonesian Earthquake Master Plan, development of a national code for geotechnics and earthquake, and establishment of the national center for earthquake studies.

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