The new national seismic hazard maps for design of buildings and infrastructures in Indonesia

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Indonesia is one of the most seismically active countries in the world, and its large, vulnerable population makes reliable seismic hazard assessment an urgent priority. Historical earthquake events with Magnitude Mw > 4.5 occurring in and around Indonesia from 1900 to August 2016 are merged from many sources and presented in Figure 1. In 2015, Team for Updating of Seismic Hazard Maps of Indonesia 2017 was established by the Government of Indonesia. The team consists of experts from Institut Teknologi Bandung (ITB), the Ministry of Public Works, Indonesian Institute of Sciences (LIPI), Meteorological, Climatological and Geophysical Agency (BMKG), Center of Volcanology and Geological Hazard Mitigation (PVMBG), Geospatial Information Agency (BIG), and professional associations such as Indonesian Society for Geotechnical Engineering (HATTI) and Indonesian Disaster Expert Association (IABI). Result of the updating work is documented in “Earthquake source and hazard map of Indonesia 2017” (2017) by M. Irsyam, S. Widiyantoro, D.H. Natawidjaja, I. Meilano, A. Rudyanto, S. Hidayati, W. Triyoso, N.R. Hanifa, D. Djarwadi, L. Faizal, and Sunarjito (editors), published by Indonesian National center for earthquake Studies, Research and Development Agency of Ministry of Public Work and Housing. ISBN 978-602-5489-01-3.

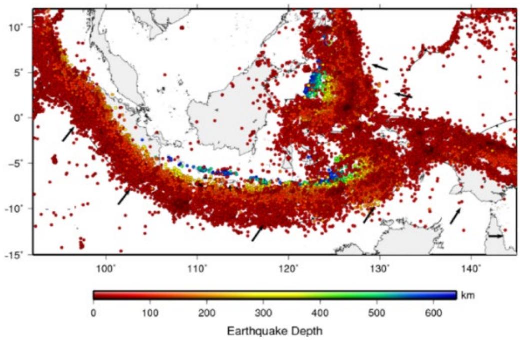

Fig. 1. Earthquake epicenters in and around Indonesia with Mw > 4.5 from 1900 to August 2016 (Irsyam, et al., 2017).

The team was assigned to update and enhance the previous national seismic hazard maps that was published in 2010. Enhancements are conducted by using more complete and accurate information of sources, more up to date ground motion prediction equations (GMPE), more detail model for background seismicity, and more variation in hazard calculation. Latest important information regarding earthquake sources is incorporated for updating seismic hazard maps such as results of recent active-fault studies utilizing trenching, carbon dating, epicenter relocation, strain analysis (GPS) as well as availability of basic data including the SRTM-30, IFSAR, LiDAr and other data that is just recently available.

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. Geometry of subduction Megathrust and Benioff zone models were derived from recent 3-D tomography model. 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. Background seismicity was utilized to account for random earthquakes on unmapped faults and smaller earthquakes on mapped faults.

Fault sources represent individual faults for which data are sufficient to determine maximum earthquake magnitudes distributions and slip rate estimates. Input parameters for fault source model include: (1) source location (trace coordinates); (2) orientation (strike, dip angle, and maximum depth); (3) style of faulting; (4) maximum earthquake magnitude distribution; and (5) slip rate distributions and associated earthquake recurrence intervals. The earthquake source parameters including tectonic feature and sense of faulting, slip-rate, dip, top and bottom elevation, length and maximum magnitude used in this work are described in detail by Irsyam et al. (2017). In total, the working group on geology has identified and characterized 295 faults, a dramatic increase from the 85 active faults used in the development of the 2010 hazard maps. Although this was a vast improvement over the active fault information available for the 2010 version of the map, there are still many active faults that require detailed mapping and further research, both those that have been identified but poorly characterized and others that may not be known at all. Many of the active fault parameters that were used in the present hazard map have significant uncertainties that can only be reduced through more intensive and detailed geodetic and paleo-seismological studies.

There are two models of magnitude–frequency relation usually used in seismic hazard assessment. The first model is exponential model; this model base on the temporal distribution of earthquakes is assumed to follow frequency-magnitude relationship proposed by Gutenberg-Richter (G-R). The second model is characteristic model. The characteristic recurrence frequency distribution reconciles the exponential rate of small- and moderate-magnitude earthquakes with the larger characteristic earthquakes on individual faults. The activities of background source zones were modeled by fitting a Gutenberg-Richter (GR) truncated exponential curve to the historical seismicity data. For fault source and interpolate / megathrust subduction source were modeled by mean of fault slip-rate in conjunction with the pure characteristic magnitude model. For moderate earthquakes, magnitude distributions were modeled by fitting a GR truncated exponential curves to the historical seismicity data.

Based on the previous researches in the development of seismic hazard maps of Indonesia by the authors, a number of attenuation functions from worldwide historical earthquake data record is adopted to estimate the ground shaking for design of buildings and infrastructures in Indonesia. Attenuation from Atkinson-Boore, 2003 (AB Intraslab seismicity Cascadia region BC- rock condition), Youngs et al., 1997 (Geomatrix slab seismicity rock), and Atkinson-Boore, 2003 (AB Intraslab seismicity Cascadia region BC- rock condition) were used for Benioff (deep background sources). Attenuation from Boore-Atkinson NGA, 2008 and Boore-Atkinson NGA West-2 2013; Campbell-Bozorgnia NGA, 2008 and Campbell-Bozorgnia NGA West-2, 2013; Chiou-Young NGA 2008 and Chiou-Young NGA West-2, 2014 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) and Abrahamson et al., 2014 (BC Hydro) were chosen for Megathrust zone (subduction interface).

The Team for Updating of Seismic Hazard Maps of Indonesia 2017 has delivered national maps of peak ground acceleration (PGA) and spectral accelerations for periods of 0.2 and 1.0-second at bedrock from deterministic and probabilistic seismic hazard analyses. The maps include deterministic hazard maps due to subduction and fault zones and probabilistic hazard maps to represent 8 levels of hazard: 20%, 10% and 5% probability of exceedance in 10 years; 7% probability of exceedance in 75 years; 10% and 2% probability of exceedance in 50 years, and 2% and 1% probability of exceedance in 100 years. For earthquake resistance design of bridges, the map of PGA with 7% probability of exceedance in 75 years at bedrock is shown in Figure 2 and spectral hazard maps for 0.2-second in Figure 3.

Following the development of Indonesian seismic hazard maps 2017, the Indonesian building code SNI-1726 is currently being revised for building design. The new building code is partially adopted from risk-based ASCE-7-2016. The codes utilized risk-targeted ground motion (RTGM) of reference base rock (site-class B, SB) spectral acceleration at short and 1-second periods Ss and S1, respectively, defined as risk of 1% probability of building collapse in 50 years.

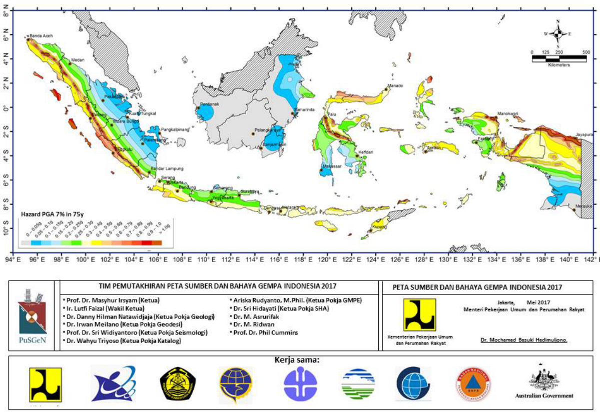

Figure 2. PGA Map at bedrock SB for 7% probability of exceedance in 75 years (Irsyam, et al., 2017)

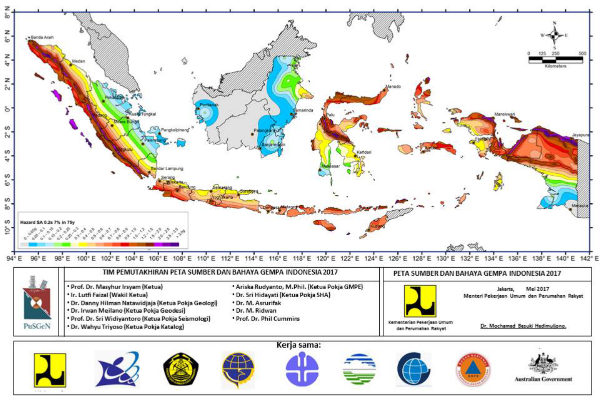

Figure 3. Hazard maps at bedrock SB for 0.2-second spectral accelerations for 7% probability of exceedance in 75 years (Irsyam, et al., 2017)