Proposed long period transition map for new Indonesia earthquake resistant building code based on Indonesia seismic hazard map 2010

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Abstract. The new method for determining ground-motion parameters in the next edition of the Indonesian Earthquake Resistant Building Code SNI 03-1726-X, which will be issued in this year, has significant changes than the old code. The major changes in SNI 03-1726-X are using Risk-Targeted Maximum Considered Earthquake (MCER) Spectral Response Acceleration maps. These maps developed by Team for Revision of Seismic Hazard Maps of Indonesia were based on probabilistic approach for 2% probability of exceedance 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. For building design, it has been decided that ASCE 7-10 will be adopted for coming code SNI 03-1725-X. The design philosophy adopted from ASCE 07-10 standard contains a significant addition consisting of a constant-displacement segment of the design response spectrum. This paper presents the proposed parameter TL developed by the author and Disaster Mitigation Research Center ITB (Pusat Penelitian Mitigasi Bencana ITB) to provide more realistic estimates of the ground motions at periods T > 4 sec by consisting a constant-displacement segment.

Key words: long period transition map, seismic hazard, deaggregation, 3D seismic sources, indonesia building code.

Introduction

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-X 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.

The new method for determining ground-motion parameters in SNI 03-1726-X has significant changes than the old code. The code has been revised to incorporate maps of a new parameter, TL, the period on the design response spectrum separating the constant-velocity and constant-displacement segments. This paper, in conjunction with Team for Revision of Seismic Hazard Maps of Indonesia, intends to proposed parameter TL to provide more realistic estimates of the ground motions at periods T > 4 sec by consisting a constant-displacement segment.

Method of using Indonesia Seismic Hazard Maps 2010

If we refer to ASCE 07-10, The M_{CER} ground motion in SNI 03-1726-X will be characterized by two parameters, S_{MS} and S_{M1}, which represented the constant short-period spectral acceleration and the 1-sec spectral acceleration, respectively. Both S_{MS} and S_{M1} include the effects of the local site geology through site amplification coefficients, F_a and F_v, which were multiplied by the ground motions for Site Class B, S_S and S_1, to obtain S_{MS} and S_{M1} (i.e., $S_{MS} = F_a.S_S$ and $S_{M1} = F_v.S_1$). The design ground-motion parameters were:

$$S_{DS} = (2/3)\ S_{MS}$$
$$S_{D1} = (2/3)\ S_{M1}$$

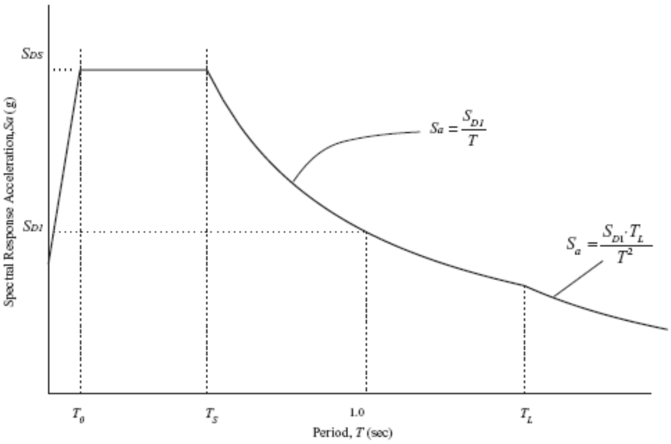

Figure 1. Design response spectrum based on ASCE 07-10.

From the figure 1, there is one parameter needed to the develop design response spectrum. The parameter T_L was introduced to provide more realistic estimates of the ground motions at periods T > 4 sec that would affect the design of tall buildings.

The method to calculate T_L was explained detail at Crouse CB., et al. (2006). The first step consisted of establishing a correlation between earthquake magnitude and TL. This correlation was established by (1) determining the corner period between intermediate and long period motions based on seismic source theory (Brune, 1970, 1971), and (2) examining the response spectra of (i) strong motion accelerograms recorded during moderate and large magnitude, shallow crustal earthquakes, and (ii) ground motions simulated from models of large subduction-zone earthquakes (Gregor et al., 2002). This corner period, Tc, marks the transition between the constant displacement and constant velocity segments of the Fourier spectrum representing a theoretical fault-rupture displacement history. Tc, which was considered an approximation for TL, was related by coauthor Silva to moment magnitude, M, through the formula, log Tc = -1.25 + 0.3 M. This formula was selected from several available formulas based on comparisons of Tc predicted by this equation and TL estimated from strong motion accelerograms with reliable long period content.

Table 1. Moment magnitude versus corner period (Crouse C.B, et. al)

M	T_c (sec)
6.0 – 6.5	4
6.5 – 7.0	6
7.0 – 7.5	8
7.5 – 8.0	12
8.0 – 8.5	16
8.5 – 9.0	20

To determine the T_L values for Indonesia, the author and Disaster Mitigation Research Center ITB (Pusat Penelitian Mitigasi Bencana ITB), follow method proposed by Crouse CB., et.al, constructed maps of the modal magnitudes (M_d) in half-unit increments. The maps were prepared from a deaggregation of the 2% in 50-years hazard for S_a (T = 2 sec), the 5% damped response spectral acceleration at an oscillator period of 2 sec. The M_d that was computed represented the magnitude interval that had the largest contribution to the 2 percent in 50-yr hazard for S_a.

The M_d maps were judged to be an acceptable approximation to values of M_d that would be obtained if the deaggregation could have been computed at the longer periods of interest. These M_d maps were color-coded to more easily permit the eventual construction of the T_L maps. Generally, the T_L maps corresponded to the M_d maps, but some smoothing of the boundaries separating T_L regions was necessary to make them more legible.

PSHA and Deaggreagation PSHA

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

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

where v_i is annual rate of earthquakes (with magnitude higher than some threshold value of M_{oi}) in source I, and fMi (m) and fRi|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.

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/s^2). 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 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.

Earthquake catalog, Seismosectonic Model, Recurrence relations, and Ground motion Prediction Equation

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 90°E to 145°E longitudes and 15°S to 15°N 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.

Results and Discussion

The analysis result showed that the maps of long period transition are associated the highest contribution, for the areas near the fault, magnitude of fault control (lower corner period). In areas far from the fault, the magnitude from the subduction control (higher corner period) and for areas far from faults and subduction, gridded seismicity model control (middle value corner period).

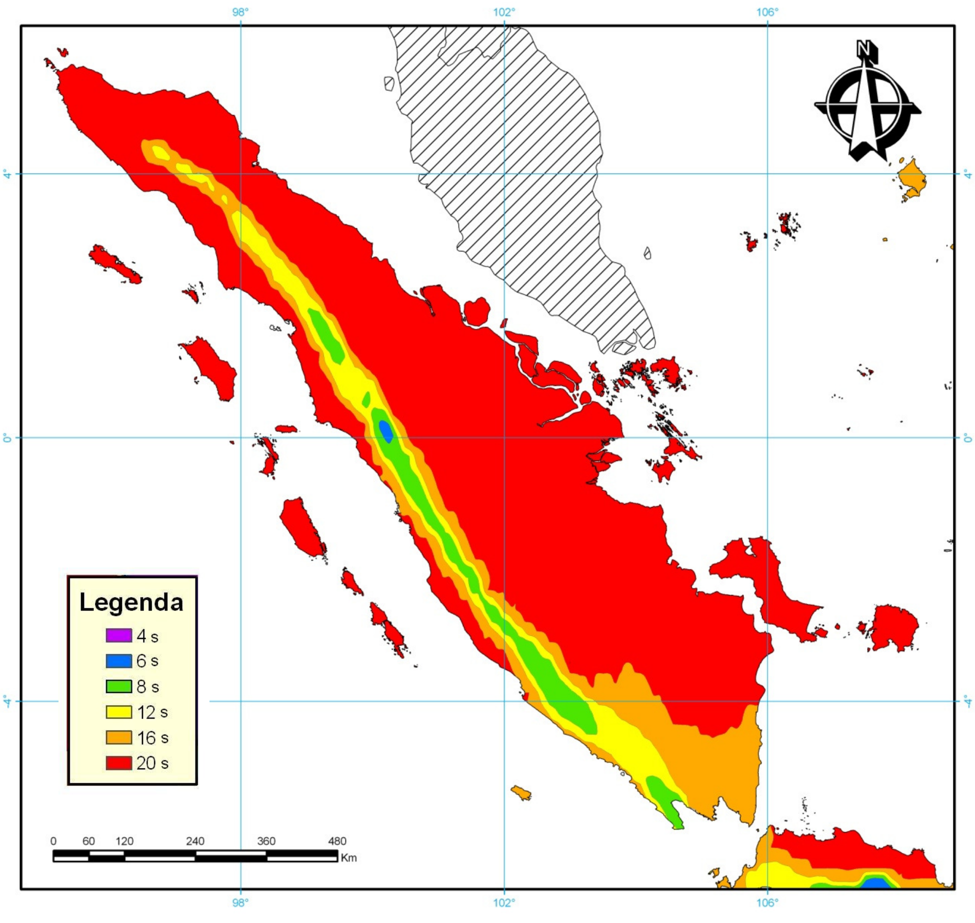

Figure 2. Map of T_L for Sumatera and its surrounding.

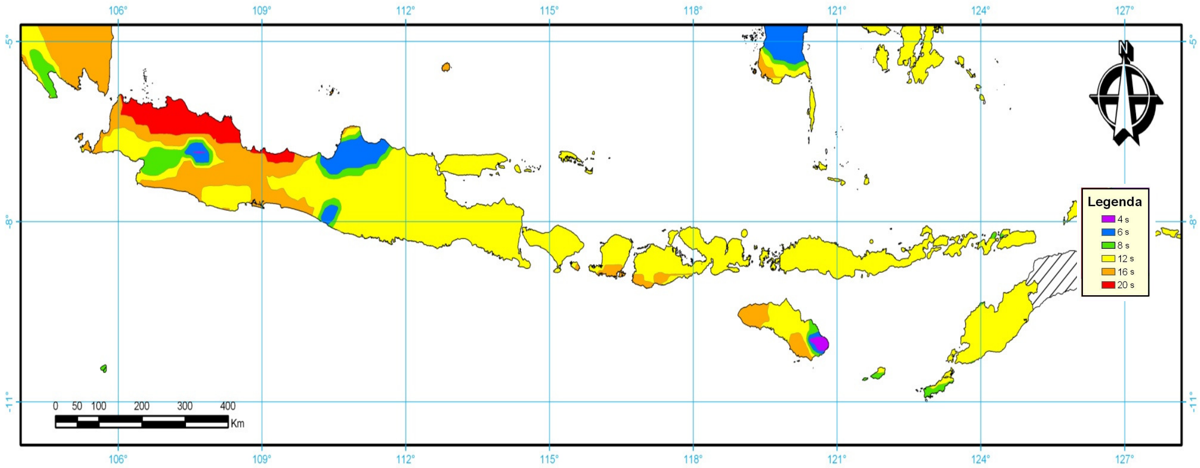

Figure 3. Map of T_L for Java and its surrounding.

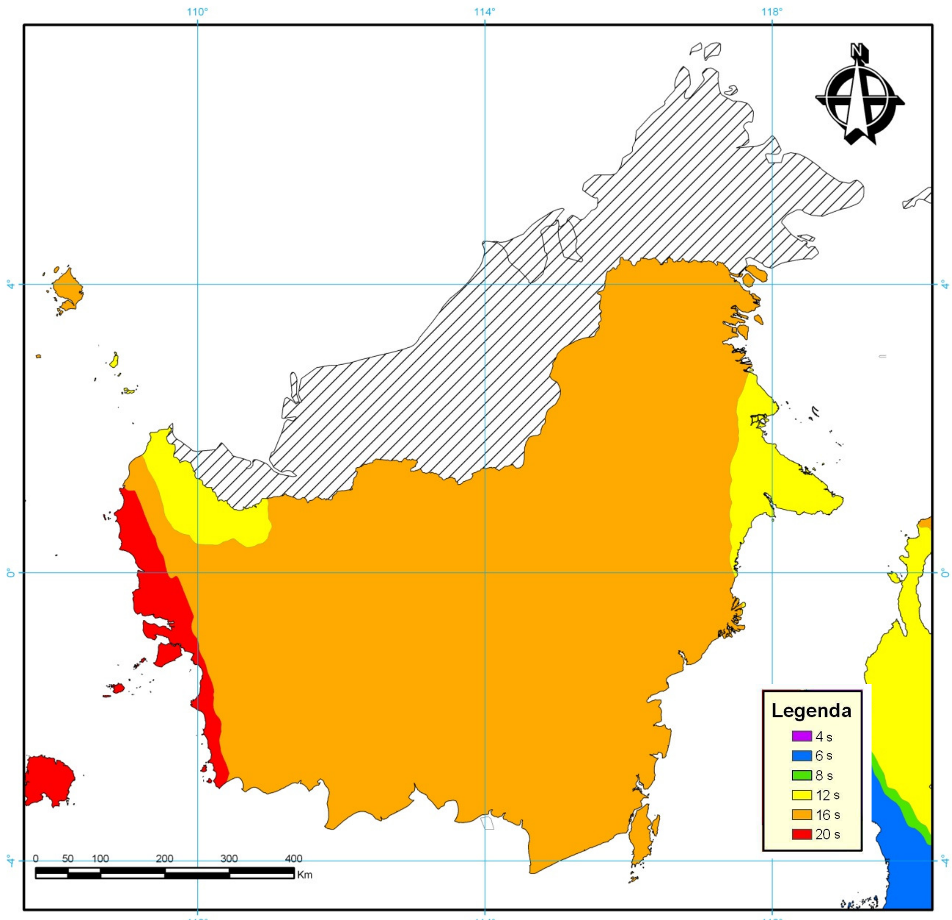

Figure 4. Map of T_L for Borneo and its surrounding.

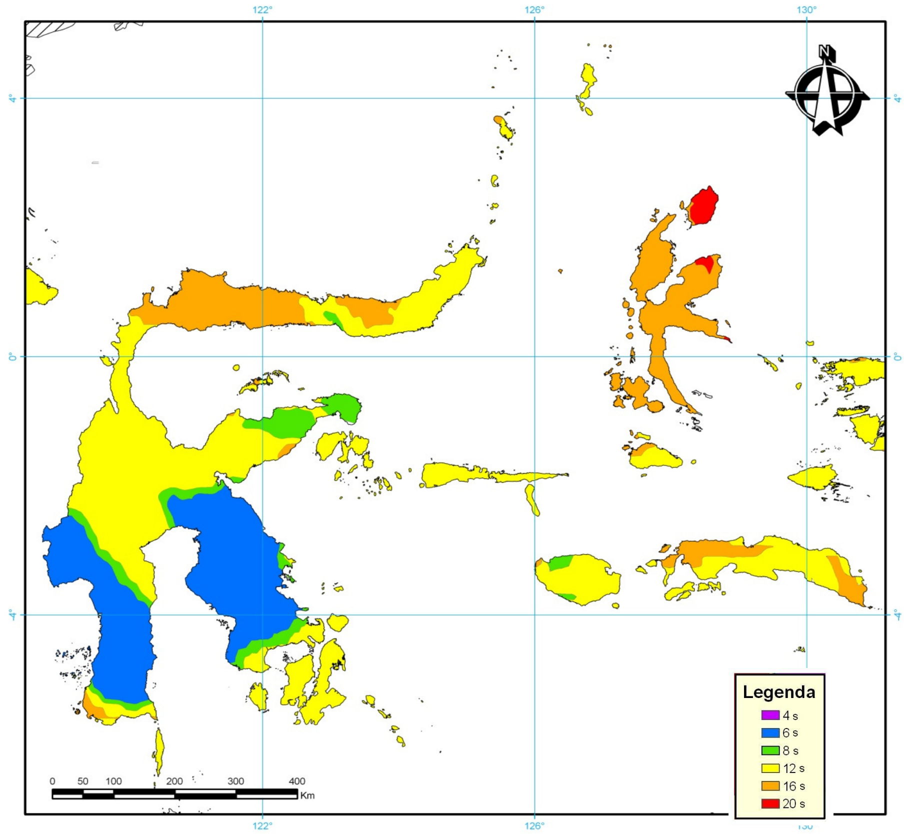

Figure 5. Map of T_L for Sulawesi and Moluccas and its surrounding.

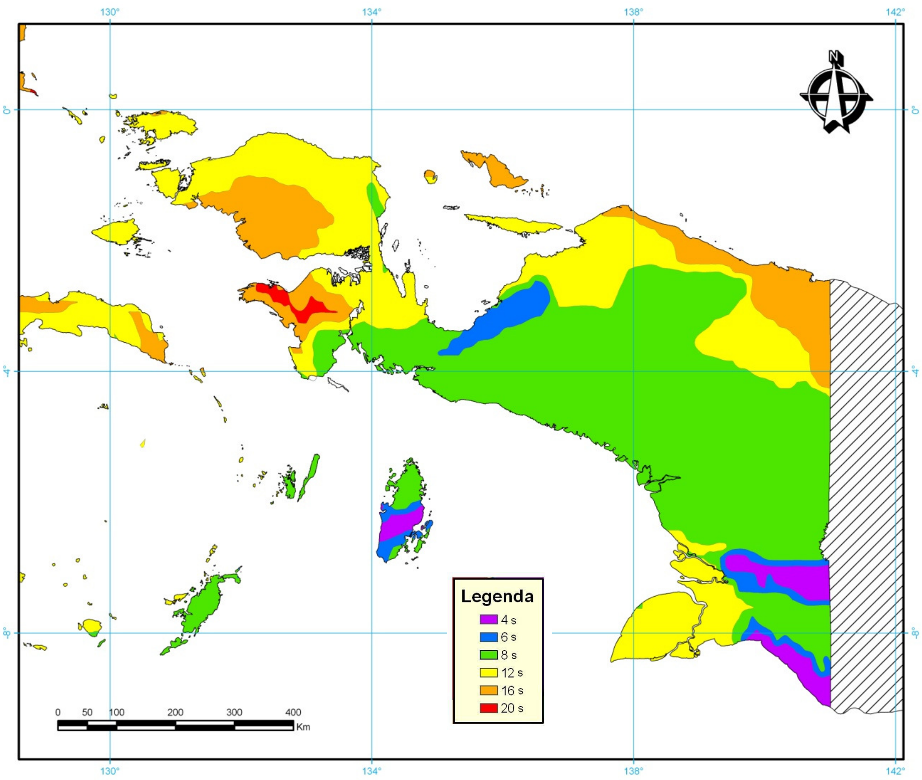

Figure 6 Map of T_L for Papua and its surrounding.

Conclusions

The maps shown represent an incremental improvement to the groundmotion criteria for SNI 03-1726-X. Because a new parameter, T_L, has been introduced, it will likely undergo refinements in subsequent editions and eventually may be replaced by a long period ground-motion parameter derived in the same manner as the S_S and S_1. For most locations, the long period transitions value is dominated by high value that means the spectral acceleration at long period dominated by subduction sources. The information of long period analysis can and perhaps should be considered in a complex seismic-resistant design decision-making environment.

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