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Development of seismic risk microzonation map for Semarang due to Semarang fault earthquake scenarios with maximum magnitude 6.9 Mw

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Abstract. Research on seismic microzonation of Semarang is still ongoing. The first seismic microzonation research for this area was performed on 2015. Seismic microzonation map was developed by implementing deterministic 1-D site response analysis at 190 boring locations. Lasem fault was considered to be the main earthquake source which taken into account for seismic microzonation research of Semarang. The second research for developing seismic microzonation map was performed on 2016. Following the research conducted by Team for Updating Seismic Hazard Maps of Indonesia 2016, Rawapening Fault, Ungaran Fault, Weleri Fault, Demak Fault and Semarang Fault are five new shallow crustal fault earthquake sources identified in this research. This paper presents the development of seismic risk microzonation map caused by Semarang fault earthquake scenarios with maximum 6.9 Mw. Deterministic 1-D site response analysis was performed at 288 boring locations for developing seismic risk microzonation map. This research was performed by implementing response spectral matching and site propagation analysis. Due to inadequate data caused by Semarang fault earthquake, response spectral matching was implemented in this research to obtain modified acceleration time histories. All acceleration time histories were developed from five different earthquakes with magnitude 6.05 – 6.9 Mw and maximum epicentre distance 15 Km.

1 Introduction

Research on seismic microzonation of Semarang is still ongoing. The first research of seismic microzonation for this area was performed on 2015 by [1] and following the work conducted by Team for Revision of Seismic Hazard Maps of Indonesia 2010 (TRSHMI 2010). Seismic microzonation map was developed by implementing deterministic 1-D site response analysis at 190 boring locations. Lasem fault, an active and closest shallow crustal fault, was considered to be the earthquake source scenario conducted for site response analysis. Following the research conducted by Team for Updating of Seismic Hazard Maps of Indonesia (TUSHMI) 2016, five new shallow crustal fault earthquake sources were

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identified (Rawapening Fault, Ungaran Fault, Weleri Fault, Demak Fault and Semarang Fault).

This paper presents the development of seismic risk microzonation map based on the surface spectra acceleration values (PGA, Spectra 0.2s and Spectral 1s) calculated using 1-D site response analysis. All surface spectra acceleration were developed due to Semarang fault (reverse fault mechanism) earthquake scenarios with maximum magnitude 6.9 Mw and maximum epicentre distance 15 Km. Surface PGA, spectral 0.2 s and spectral 1s were calculated at 288 boring locations. Fig. 1(a) shows the position of Semarang and Lasem fault traces and the position of all 288 boring locations against Semarang fault trace.

This research was performed by conducting five important steps: 1) geological, geophysical and soil investigations and analysis for developing soil profile and bedrock elevation 2) collecting acceleration time histories data from worldwide historical earthquake records due to reverse fault mechanism earthquakes with magnitude 6 - 7 Mw and maximum distance 15 km, 3) developing modified acceleration time histories by conducting response spectral matching analysis, 4) conducting shear wave propagation analysis using modified time histories and calculated using 1-D site response analysis for obtaining surface acceleration time histories and surface response spectra and 5) developing seismic risk microzonation maps.

2 Experiment details

2.1 Geological and geotechnical investigations

Depth of engineering bedrock and soil properties profiles from top until bedrock elevation are two important informations for performing site response analysis. Prediction of bedrock elevation for the study area was performed using single station feedback Microtremor [1]. The prediction of bedrock elevation was implemented by conducting three component ambient vibrations investigation at 218 locations [1 and 2]. Top soil properties investigations were conducted at 288 boring locations with minimal 30 meters depth. Fig. 1(b) shows the distribution of bedrock elevation for the whole area of the city.

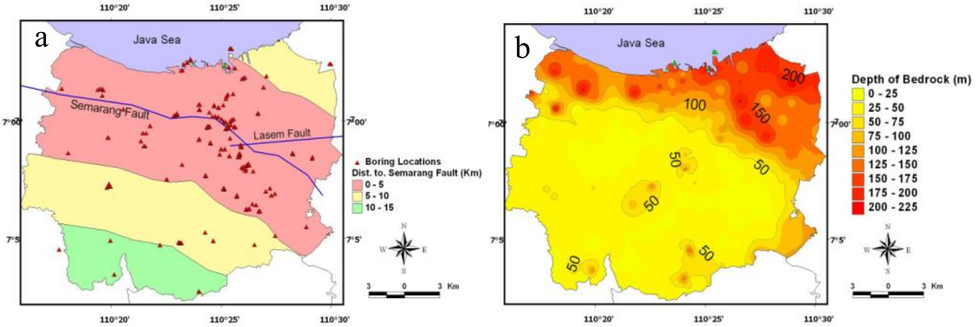

Fig. 1. Semarang fault and Lasem fault trace and boring locations (a) and contour map of bedrock elevation (b).

2.2 Time histories data collection and response spectral matching analysis

Due to inadequate and limited records of Semarang fault earthquake, historical earthquake records with magnitude from 6 to 7 Mw and maximum distance 15 km were collected for reverse mechanism shallow crustal fault. Five selected earthquakes (Iwate Japan 2008, Chuetsu-oki Japan 2007, Chi-Chi Taiwan 1999, Northridge 01 California 1994, Northridge

02 California 1994) were used in this research for site response analysis and developing seismic risk map of the study area. All acceleration time histories data were collected from PEER NGA-West 2 Databases. Table 1 shows all acceleration time histories from 5 different earthquake events used in this study.

Table 1. Earthquake sources data used in this study.

Event	Station	Magnitude (Mw)	Epicentre Distance (km)
Northridge-02 (1994)	Arleta - Nordhoff Fire Sta	6.05	1.48
	Newhall - Fire Sta	6.05	7.36
	LA - Century City CC North	6.05	18.34
Chi-Chi, Taiwan-03 (1999)	TCU084	6.2	3.68
	TCU089	6.2	5.93
	TCU076	6.2	13.04
Northridge-01 (1994)	Arleta - Nordhoff Fire Sta	6.69	3.3
	Beverly Hills - 14145 Mulhol	6.69	9.44
	LA - Brentwood VA Hospital	6.69	12.92
Chuetsu - oki, Japan (2007)	Nagaoka	6.8	3.97
	Kashiwazaki City Takayanagicho	6.8	10.38
	Yan Sakuramachi City Watershed	6.8	12.98
Iwate, Japan (2008)	IWTH24	6.9	3.1
	IWT011	6.9	8.41
	Kurihara City	6.9	12.83

All acceleration time histories used in this study need to be matched with the target spectrum of Semarang fault earthquake scenario. The target response spectrum were developed using deterministic analysis and conducting three different attenuation functions proposed by [3, 4 and 5]. The target spectrum used for spectral matching analysis was predicted at bedrock elevation and following the same method conducted by [6]. All target spectrums were calculated for reverse mechanism shallow crustal fault earthquake sources.

Response spectral matching analysis was conducted following the same method proposed by [6] for producing modified (matched) acceleration time histories. The matched acceleration time histories were predicted using two components acceleration time histories (East-West/EW and North-South/NS directions). Initial time histories must have similar shape with matched time histories (time histories calculated from response spectral matching). Fig. 2(a) shows an example result of spectral matching calculated for Iwate Japan earthquake 6.9 Mw with epicentre distance 3.1 Km (EW direction). Fig.2(b) shows initial and matched time histories for EW direction acceleration time histories due to Iwate earthquake with magnitude 6.9 Mw and epicentre distance 3.1 Km.

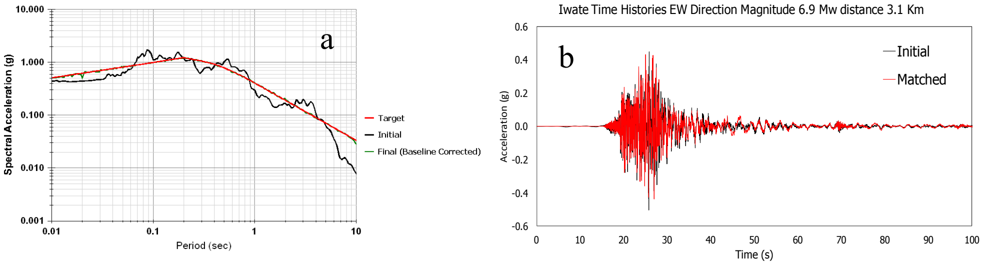

Fig. 2. Response spectral matching analysis (a) and two time histories (initial and matched) (b) for Iwate earthquake 6.9 Mw and distance 3.1 Km East/West (EW) directrion.

2.3 Site response analysis

Site response analysis was performed at 288 boring positions for obtaining surface acceleration time histories and surface response spectra acceleration. Site response analysis due to a specific earthquake was implemented using a pair of (NS and EW) matched time histories calculated from spectral matching analysis. All 288 soil investigation locations were distributed into three different distance groups (0-5 Km, 5-10 Km and 10-15 Km). Site response analysis for this study was implemented using soil profile model as can be seen on Fig. 3(a). VS1, VS2 and VSn on this figure represents shear wave velocity for soil layer 1, layer 2 and layer n respectively.

Site response analysis was conducted by taking the assumption that all boundaries of soil layer are horizontal and the response of all soil layers for all boring locations are predominantly caused by shear wave propagating vertically from bedrock elevation to surface elevation. In this study the general site response analysis was carry out using equivalent linear approach and conducting the model developed by [7 and 8] and utilizing free software NERA [9].

Surface response spectra was calculated using a method proposed by Goleshorki, R. 2013 [10] using two components surface response spectra (EW and NS) directions. Fig. 3(b) shows an example of two surface response spectra (NS and EW) and total spectra calculated from both NS and EW spectra at Lok33BH1 due to Iwate earthquake scenario with magnitude 6.9 Mw and epicentre distance 3.1 Km. The seismic maps (PGA, Spectral 0.2s and Spectral 1s) were then developed by plotting all 288 surface response spectra calculated from site response analysis. For spectral zoning evaluation all 288 response spectra data were then transferred and distributed into three different zones or categories which represents similar values of corresponding earthquake effect [11].

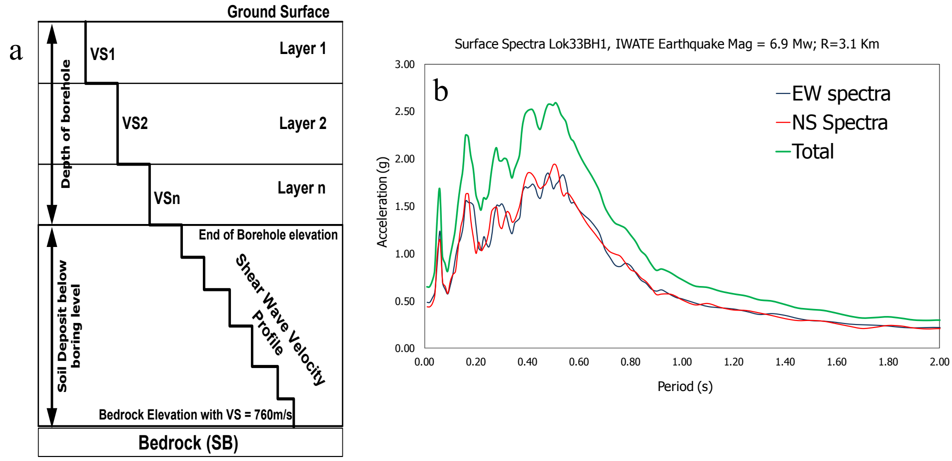

Fig. 3. Soil profile model for site response analysis (a) and example surface response spectra results calculated at Lok33BH1(b).

3 Results and discussions

Based on all surface PGA values calculated at 288 boring locations the distribution of PGA due to earthquake scenario with magnitude 6.9 Mw can be seen on Fig. 4(a). As shown in this figure the highest PGA values are distributed within the closest area to fault trace with values in between 0.7g to 0.9g. The lowest PGA values are distributed in the southern part of the study area in between 0.2g to 0.4g. Fig. 4(b) shows the distribution of surface PGA due to 6.2 Mw earthquake scenarios. Based on those two examples surface PGA map it can be seen that the highest surface PGA values due to Semarang fault earthquake scenarios are distributed at the closest area to fault trace with the value in between 0.7g to 0.9g.

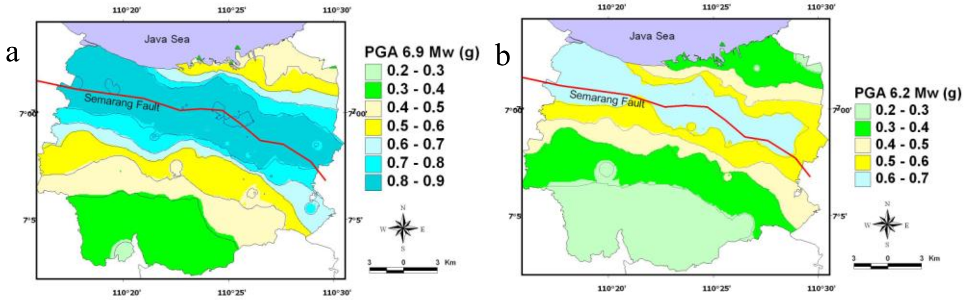

Fig. 4. Surface PGA map due to 6.9 Mw (a) and 6.2 Mw (b) Semarang fault earthquake scenarios.

For evaluating and comparing the distribution of all 288 surface PGA due to Semarang fault earthquake with Peak Surface Acceleration (PSA) values calculated using [12] all surface PGA and PSA values are then distributed in terms of epicentre distance to fault trace. Fig. 5(a) shows the distribution of surface PGA due to 6.2 Mw and 6.9 Mw earthquake scenarios and PSA values (calculated using [12]) in terms of epicentre distance. The surface PGA values due to 6.2 Mw and 6.9 Mw earthquakes are greater than PSA values for all locations with maximum distance 5 Km to fault trace. However the PGA values are smaller than PSA values for all locations located greater than 5 Km to fault trace.

Following the same criteria proposed by [11] risk map of the study area was developed using average value of surface PGA caused by five earthquake scenarios with magnitude 6.05 Mw, 6.2 Mw, 6.69 Mw, 6.8 Mw and 6.9 Mw. Based on the average PGA calculated at 288 locations, the minimum surface PGA is 0.27g and maximum surface PGA is 0.85g. The criteria for developing low, medium and high risk level area were carry out using both minimum and maximum PGA values. The lowest risk level area was identified within the area with PGA values less than 0.46g. The highest risk level area was identified within the area with PGA values greater than 0.74g and the medium risk level area was identified within the area with PGA values in between 0.46g until 0.74g. Fig. 5(b) shows earthquake risk map of Semarang due to Semarang fault earthquake scenarios with magnitude in between 6.05 Mw to 6.9 Mw. Based on risk map as can be seen in Fig. 5(b) the lowest risk level area was identified at the southern part and small area in the north-eastern part of the city. The highest risk level area is identified at the closest distance area to fault trace.

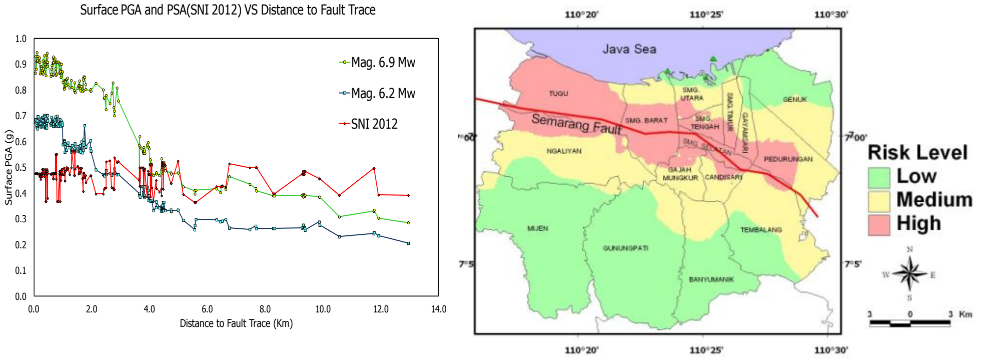

Fig. 5. PSA distribution in terms of epicenter distance calculated using [12] (a) and risk map due to Semarang fault earthquake with magnitude 6.05 Mw to 6.9 Mw (b).

4 Conclusions

Risk microzonation map for Semarang due to Semarang fault earthquake scenarios with maximum magnitude 6.9 Mw has already developed. The risk map was developed using combination of response spectral matching and site response analysis. Response spectral matching analysis was performed due inadequate data related with Semarang fault earthquake events. Site response analysis was performed at 288 boring locations using a pair of (EW and NS) acceleration time histories calculated from spectral matching analysis.

Based on risk map developed from this study it seems that the lowest risk level due Semarang fault earthquake was identified at the southern part and north-eastern part of the city. The highest risk level due to Semarang fault earthquake was identified within the closest area to Semarang fault trace with maximum 5 Km distance from fault trace.

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