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RESEARCH ARTICLE

Seismic Vulnerability of Semarang, Indonesia for Shallow Crustal Fault Earthquake

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Abstract. In 2017, the National Centre for Earthquake Studies of Indonesia released the distribution of 25 shallow crustal fault lines throughout the island of Java in Indonesia and four of them (Semarang, Demak, Rawapening and Weleri fault lines) are located around the city of Semarang. The presence of four shallow crustal fault earthquake sources, has led to the need to understand the potential earthquake hazards of Semarang through the development of earthquake-microzoning maps. Earthquake-microzoning maps of Semarang should be developed with reference to the Indonesian earthquake hazard maps and based on the deterministic and probabilistic seismic hazard approaches. Through the development of earthquake-microzoning maps, it is possible to estimate the areas with the highest and lowest surface-shaking (peak ground acceleration). The earthquake-microzoning maps based on the Semarang and Demak fault earthquake scenarios provide a preliminary indication that buildings constructed using the Indonesian Seismic Code (SNI 1726:2002) will experience stronger surface-shaking if the earthquake magnitude from both sources is at least M5.5. The results of the analysis for the creation of earthquake-microzoning maps based on the Rawapening and Weleri fault earthquake scenarios provide a preliminary indication that buildings constructed using SNI 1726:2002 are expected to experience slightly weaker ground-shaking if the earthquake magnitude from both sources reaches a maximum of M6.5. All buildings constructed in this area using SNI 1726:2012 and SNI 1726:2019 are expected to experience weaker surface-shaking due to the four earthquake source scenarios with a maximum magnitude of M6.5.

1. Introduction

Indonesia is an area with very high seismic activity. This makes the Indonesian archipelago very vulnerable to earthquake disasters. The high seismic activity in the Indonesian region is due to the meeting and collision of three large plates: the Eurasia, Indo-Australian and Pacific plates. As a consequence of the collisions and active movement of several plates, earthquake source lines are scattered throughout the Indonesian archipelago. In general, earthquake sources scattered in the Indonesian archipelago are grouped into subduction and shallow crustal fault sources.

In 2017, the National Centre for Earthquake Studies (PuSGeN) released the distribution of 25 shallow crustal fault lines throughout the island of Java in Indonesia. Four fault lines (Semarang, Demak, Rawapening and Weleri fault lines) are located around the city of Semarang. Figure 1 shows the four shallow crustal fault lines located around the research area. Among the four fault lines, the Semarang fault is an active fault that passes through the city of Semarang.

The presence of four shallow crustal fault earthquake sources, has led to the need for a greater understanding of the potential earthquake hazards of Semarang through the development of earthquake-microzoning maps. Earthquake-microzoning maps of Semarang have been developed with reference to the Indonesian earthquake hazard maps and based on the deterministic seismic hazard analysis (DSHA) and probabilistic seismic hazard analysis (PSHA) approaches (Indonesian standard design for building, SNI 1726:2012 and SNI 1726:2019).

SNI 1726:2002 considers subduction earthquake sources as the only earthquake sources that affect the entire territory of Indonesia. The earthquake map presented in SNI 1726:2002 uses a 500-year return period. Since SNI 1726:2002 only includes subduction earthquake sources, it is necessary to evaluate the vulnerability level of the city of Semarang to potential earthquake-shaking due to shallow faults. This is especially true for buildings constructed before 2012, which were designed and built based on SNI 1726:2002.

The national earthquake hazard maps developed by PuSGeN in 2017 were created for the entire Indonesian archipelago. However, the earthquake maps created in 2017 are very difficult to use to estimate ground-shaking (i.e., peak ground acceleration [PGA]) caused by earthquake event scenarios. For example, the 2017 earthquake maps are

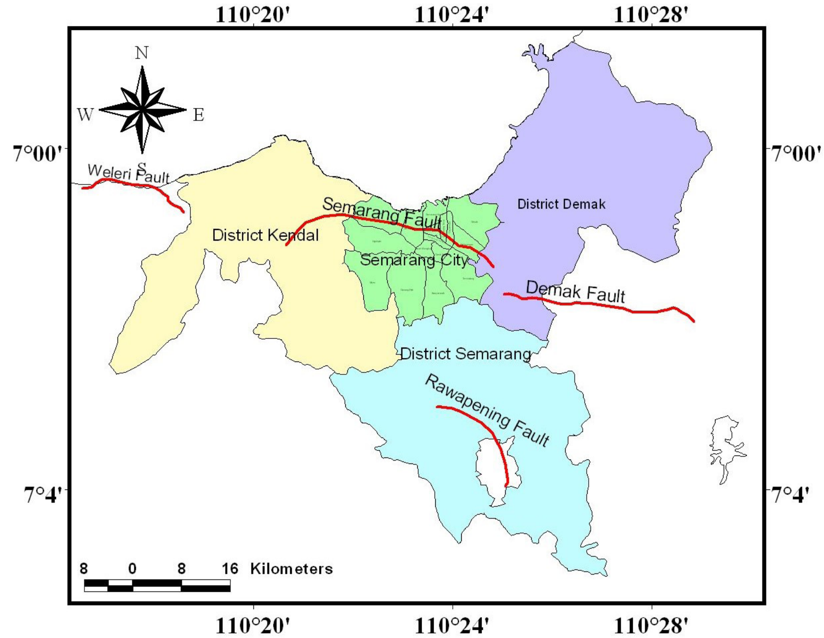


Figure 1. Fault lines around the city of Semarang

difficult to use to estimate the ground-shaking that the city of Semarang would experience from a nearby shallow crustal fault earthquake scenario. It is necessary to develop earthquake hazard maps for smaller areas (cities or regencies) that are located close to the earthquake's source. Maps developed for smaller areas are also known as earthquake-microzoning maps. The development of earthquake-microzoning maps can be conducted using two approaches: DSHA and PSHA.

Research in earthquake-microzoning has been conducted in Indonesia. Irsyam et al. (2015) presented the results of research on the earthquake-microzoning hazard risk due to subduction and shallow fault sources. They determined the risk of ground-shaking in bedrock in the event of an earthquake originating from subduction. Examples of earthquake events due to shallow faults were also simulated in this research. The simulation of the earthquake risk due to shallow faults is due to the fact that the city of Jakarta is not located near a shallow fault line. The estimated ground-shaking was calculated based on standard penetration test (N30) observation data and shear-wave velocity (Vs30) values from microtremor testing. Earthquake-prone areas can be predicted based on the Vs30 values. The higher the Vs30 value in an area, the smaller the level of ground-shaking caused by an earthquake. Firmansyah et al. (2019) presented multi-hazard research in the city of Bukittinggi considering earthquakes, landslides, fire and flooding. The results show areas at high risk due to all four hazards. This research also investigated disaster mitigation to reduce risks, considering hazard, vulnerability and resilience factors.

Pranata and Triyono (2021) presented the results of earthquake-microzoning research in the Jakarta area. They presented Vs30 map of the city of Jakarta based on seismometer investigations. Estimates of earthquake-prone areas are predicted based on the Vs30 values. Maze et al. (2021) conducted earthquake-microzoning research in the city of Bengkulu. This research was conducted using seismometer and cone penetration test (CPT) data. Seismometer investigation was used to predict the soil layer from the bedrock elevation up to the surface elevation. The soil layer was predicted based on the results of horizontal to vertical spectral ratio (HVSR) analysis. The CPT study was used to predict the physical properties of the soil layers. The vulnerability level of the area to earthquake hazards was predicted based on the Vs30 values and the physical properties of the subsoil. This research was conducted only to obtain the Vs30 maps. Seismic-microzoning research for Bandung was conducted by Ridwan et al. (2024). This research only produced a Vs30 distribution map, and it was conducted based on field observations using array seismometer equipment.

The results of the earthquake-microzoning research described above are mostly based on the observation of Vs30 values. The potential earthquake hazard due to shallow crustal fault earthquake sources located on land was not considered. The Yogyakarta earthquake in 2006, the Pidie Jaya Aceh earthquake in 2016 and the Palu earthquake in 2018 are examples that indicate the need to conduct earthquake-microzoning research for earthquake event scenarios caused by shallow fault earthquake sources. The earthquake-microzoning research conducted in this study is focused on the impact of earthquake scenarios caused by four shallow fault sources located around the city of Semarang. The surface ground acceleration (peak ground acceleration (PGA_M) values calculated according to SNI 1726:2002 up to 2019 and used in building design are compared with the results of surface PGA (PGAS) calculations based on earthquake event scenarios (DSHA). The PGAS values were calculated based on four earthquake source scenarios with magnitudes of M5 to M6.5.

Examples of PGA_M calculation results in the city of Yogyakarta based on SNI 1726:2002 range from 0.12 g to 0.2 g. Acceleration time histories recorded at YOGI station in Yogyakarta, shows that the PGAS value ranges from 0.32 g to 0.34 g (Elnashai et al., 2007). The PGAS value due to the earthquake in 2006 was one and a half times greater than the PGA_M values used in buildings design based on SNI 1726:2002.

The information needed for the earthquake-microzoning map of Semarang includes the geological, geophysical and geotechnical conditions of the region. Data on the geological conditions in this study were obtained from the geological map of Magelang and Semarang Sheets issued in 1996. Figure 2 shows the geological map of Semarang and the position of the Semarang fault line. Figure 2 shows that the northern part of Semarang consists of a fairly extensive layer of alluvium and is estimated to cover one-third of the study area. Soft soil (Qa/Alluvium) is located in the northern part of the city. Sedimentary rock formations are located in the central and southern parts of the city. Several formations, such as the Damar Formation (Qtd), Kaligetas Formation (Qpkg), Kalibening Formation (Tmpk), Kerek Formation (Tmk), Kaligesik Volcano Formation (Qpk), Gajah Mungkur Volcano Formation (Qhg), Andesite (Tma), Kemalon Volcano Rocks (Qks), and Jongkong Formation (Qpj) are scattered around the central and southern parts of the city (Thanden et al., 1996].

Following the results of seismometer tests conducted in Semarang, the Vs30 map was developed. The Vs30 value was calculated at 241 seismometer points. Figure 3a shows the Vs30 map of Semarang. Figure 3a shows that the northern area of Semarang has a maximum Vs30 value of 200 m/s. Vs30 values between 200 m/s and 350 m/s are spread over most of the central and southern parts of the city. A small portion of the southern part of the city of Semarang has Vs30 values between 400 m/s and 450 m/s.

Figure 3b shows the distribution map of N30 values analyzed at 210 drilling points. The distribution of N30 values is almost the same as the Vs30 distribution, with N30 values less than 20 distributed in the northern part of the city. Areas with N30 values between 20 and 50 are scattered in the central and southern parts of the city. Small areas with N30 values between 50 and 60 are scattered in the southern part of the study area.

2. Methods

The calculation of the PGA value of Semarang was carried out using two approaches, DSHA and PSHA. The DSHA approach was carried out by considering earthquake event scenarios due to the shallow crustal fault with magnitudes of M5 to M6.5. The calculation of the PGA with PSHA or a

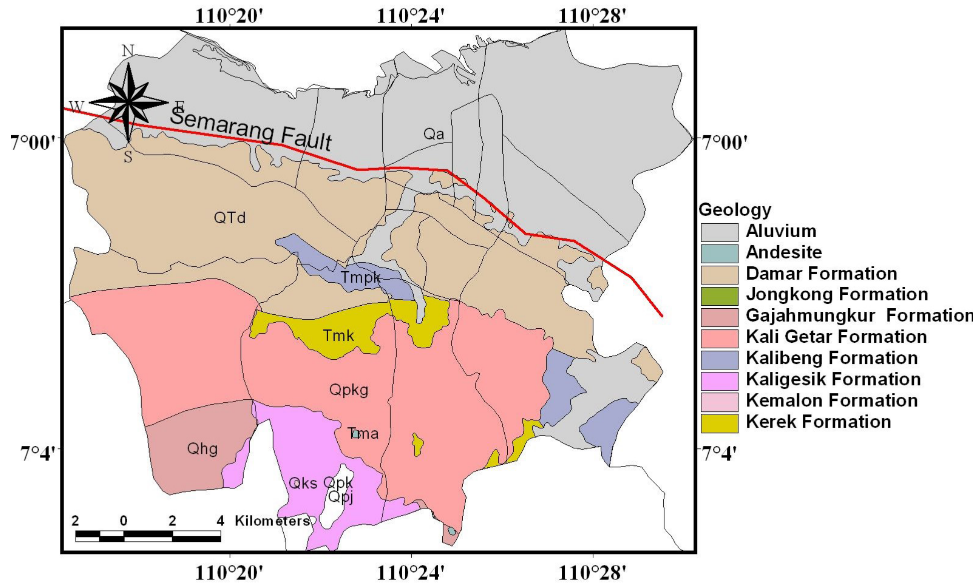
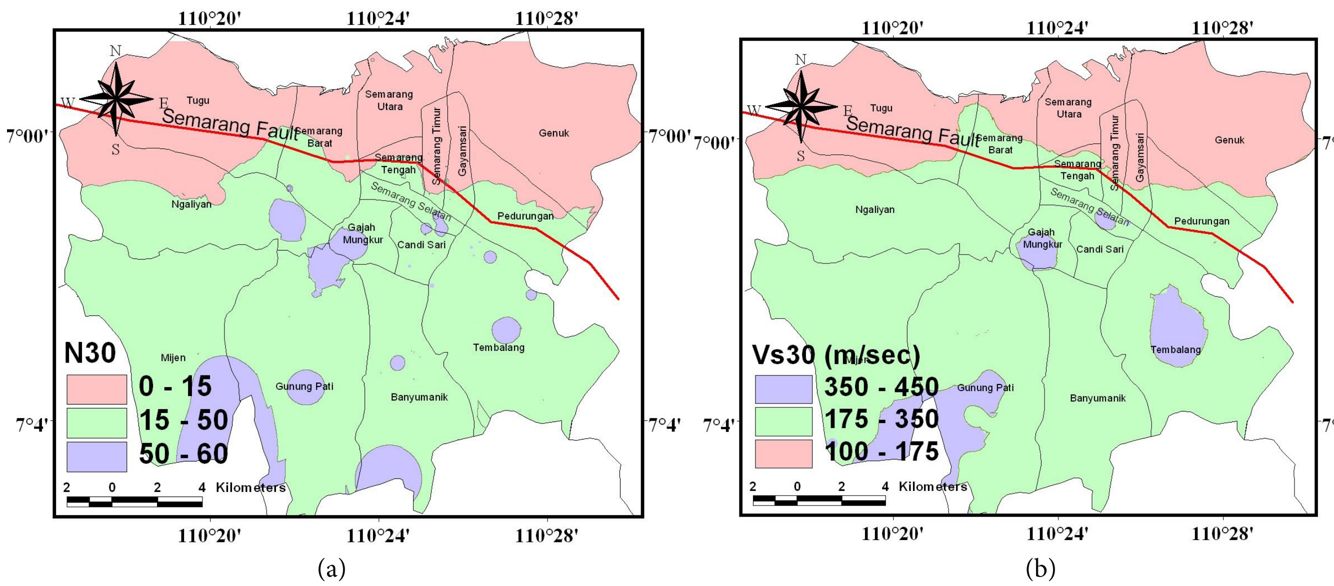


Figure 2. Geological map of Semarang and the Semarang fault line



(a) (b)

Figure 3. Vs30 distribution map (a), and N30 distribution map (b).

combination of the DSHA and PSHA approaches was carried out with reference to the Indonesian earthquake regulations SNI 1726: 2002 (PSHA), SNI 1726: 2012 (PSHA and DSHA) and SNI 1726: 2019 (PSHA and DSHA). Figure 4 shows the methodology for the seismic vulnerability evaluation of the study area. As shown in Figure 4, the basic method to determine the seismic vulnerability of Semarang is to compare the PGA_M values calculated based on the seismic code (SNI 1726) and the PGAS values based on the deterministic calculation of earthquake scenarios. The DSHA and PSHA spectral acceleration calculations for SNI 1726:2012 were conducted using seven different attenuation functions, from Abrahamson and Silva (2008), Boore and Atkinson (2008), Campbell and Bozorgnia (2008), Chiou and Youngs (2008), Idriss (2008), Youngs et.al. (1997) and Zhao et. al. (2006). However, the DSHA and PSHA spectral acceleration calculations for SNI 1726:2019 were conducted using an attenuation function developed by five different research teams: Abrahamson et al. (2014), Boore et al. (2014), Campbell and Bozorgnia (2014), Chiou and Youngs (2014) and Idriss (2014).

The calculation of the PGAS values requires geological, geophysical and geotechnical data from the research area. Geological data are needed to determine the distribution of the rock lithology and the position of alluvium deposits in the observation area. Geological data are also needed to determine the earthquake source mechanisms; this data include the fault rupture width and the average depth of the rupture. Geotechnical data are required for the calculation of N30, which is the average N-SPT (Standard Penetration Test) value to a depth of 30 m below the ground surface. The geophysical information required for surface PGA calculation is Vs30 values, the average Vs (shear wave velocity obtained from seismometer investigation) values to a depth of 30 m. The second piece of information that can be obtained from seismometer investigation is the approximate bedrock elevation, which is the elevation of the rock layer with a minimum Vs value of 760 m/s.

This research does not present a map of the distribution of the population, type and condition of buildings scattered throughout the city of Semarang and potentially affected by an earthquake event. This study only presents a description of the predicted ground-shaking (PGAS) due to earthquake event scenarios and compares it with the PGA_M values used in earthquake-resistant building planning. This study only presents the distribution of areas affected by a single earthquake event.

Earthquake Source Distance Calculation

The distance of the earthquake source to the observation point is an indispensable parameter in DSHA and PSHA earthquake hazard analysis. The observation points used in the calculation of the earthquake source distance are drilling points and seismometer testing points (Partono et al., 2016, 2021, 2023). To facilitate the calculation of the distance from the observation point to the earthquake source, software has been developed using the VB6 (Visual Basic 6) programming language (Partono et al., 2021).

Soil Boring and Seismometer Investigations

Standard penetration investigations to obtain the N-SPT values of Semarang have been conducted at 210 boring points with a minimum depth of 30 m and a maximum depth of 60

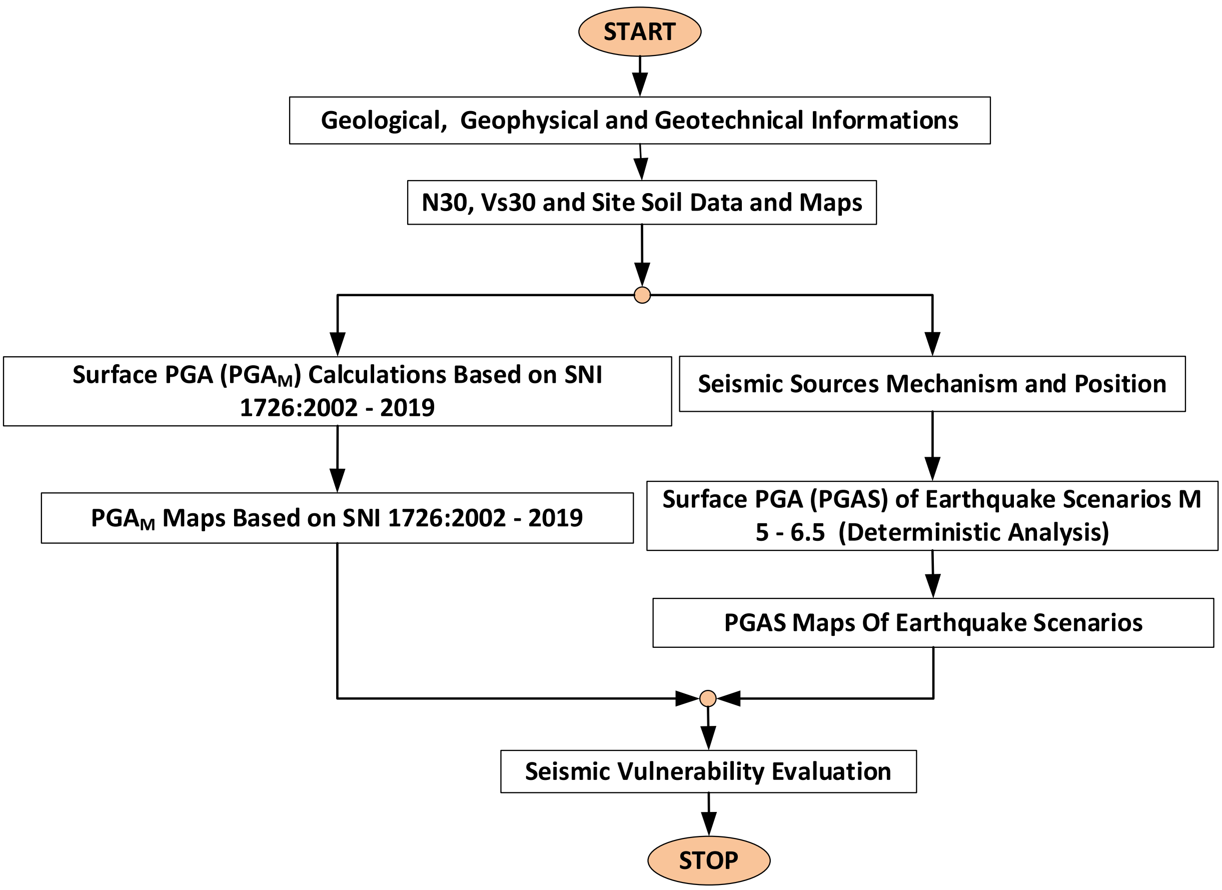


Figure 4. Seismic vulnerability of the city of Semarang

m. The maximum N-SPT value found in this investigation is 60. The locations of soil borings conducted in this area can be seen in Figure 5a. Figure 5a shows that the drilling locations are not evenly distributed throughout the Semarang area. This is because most of the boring observation points were obtained following the soil investigation used for building foundation design.

One of the objectives of earthquake hazard analysis is to estimate the value of the PGA in bedrock (SB). To calculate the PGA in bedrock, earthquake source scenario data and attenuation functions are required. The attenuation function (i.e., the ground motion prediction equation [GMPE]) is an empirical equation that can be used to estimate the level of ground-shaking caused by an earthquake scenario. The seismic parameters needed for the PGA calculation values are the magnitude, the distance from the earthquake source to the observation location and the seismic mechanism of the earthquake source. An important parameter that is also required in the calculation of the PGA is the VS30 value. Figure 5b shows 241 seismometer testing points and ten seismometer-array investigation positions. The purpose of seismometer array testing is to verify the results of single-seismometer testing and estimate the elevation of bedrock with a minimum Vs value of 760 m/s.

Earthquake Source Distance Calculation

The distance from the observation points to the earthquake source was determined based on the position of 241 seismometer testing points. Based on the calculation of the distance of each seismometer testing point, a map of the distribution of the distance to the four shallow fault earthquake sources was developed. Figures 6a and 6b show the distance distribution contours of the Semarang fault line and the Demak fault line. Figures 6c and 6d show the distance distribution contours of the Rawapening fault line and the Weleri fault line. The four fault distance maps were calculated at 241 seismometer testing positions. From the four figures, it can be seen that the Semarang fault earthquake source is the closest to the entire Semarang area, followed by the Demak fault, Rawapening fault and Weleri fault.

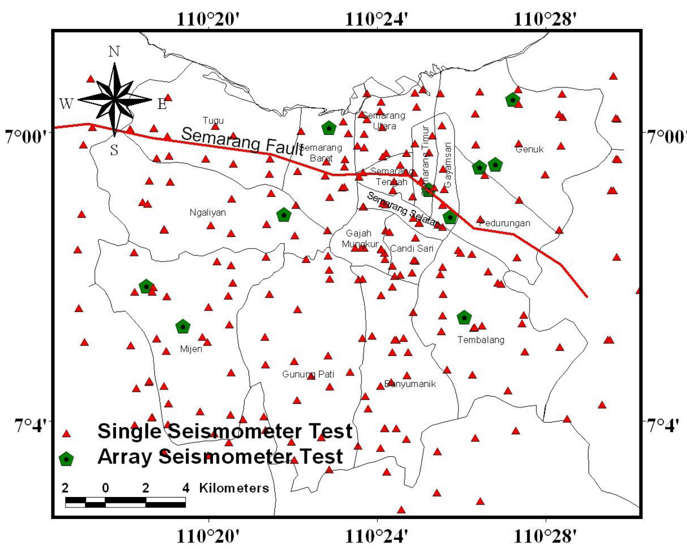
Surface PGA (DSHA) Calculations of Earthquake Scenarios

The DSHA of the earthquake scenarios of the study area was conducted using the attenuation function (GMPE) from the 2014 NGA West-2 Model. The calculation of the PGA requires the distance from the observation point to the earthquake source, the value of Vs30 and earthquake source mechanism data such as the slip rate, Ztor and Rx or Rjb. Five GMPEs that are often used in DSHA are those developed by PEER NGA-West2. The GMPEs of Abrahamson et al. (2014), Boore et al. (2014), Campbell and Bozorgnia (2014), Chiou and Youngs (2014), Idriss (2014) and Gregor et al. (2012) are used on a limited basis for Vs30 values greater than 450 m/s. For the calculation of the PGA at bedrock elevation, Vs30 = 760 m/s was applied to all GMPEs. The results of VS30 calculations at 241 seismometer test points showed Vs30 values less than 450m/s for GMPEs other than those of Abrahamson et al. (2014), Boore et al. (2014), Campbell and Bozorgnia (2014) and Chiou and Youngs (2014). Figure 6 shows the results of acceleration spectra calculation using four GMPEs with Vs30 taken as 760 m/s, and with magnitudes of M5, M5.5, M6 and M6.5. The four acceleration spectra at 0 s shown in Figure 7 represent the average PGA values taken from the four GMPE models. Figure 8 shows three examples of the surface spectral acceleration of the Semarang fault earthquake scenario with a magnitude of M5, Rjb (seismic source distance) = 5-15 km and Vs30 = 100-400 m/s.

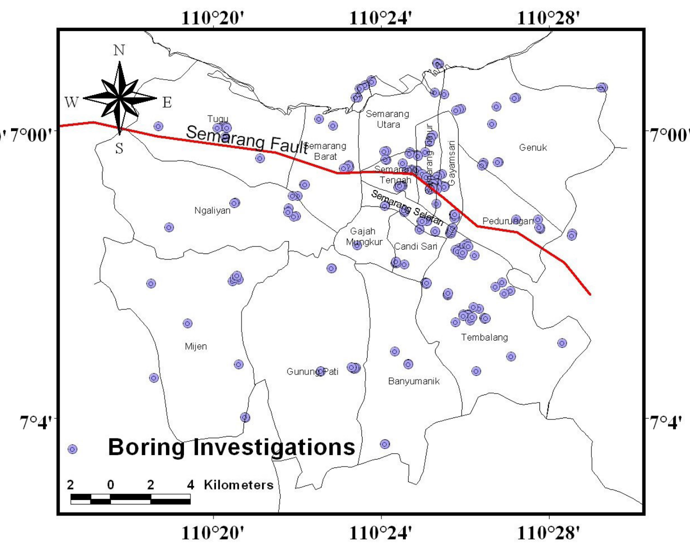
As shown in Figure 7a the PGA values (bedrock) of the Semarang fault earthquake for magnitudes of M5, M5.5, M6 and M6.5 are 0.14157 g, 0.20134 g, 0.25959 g and 0,32397 g, respectively. Figure 8a shows that the corresponding surface PGA values calculated at four different Vs30 values of 100 m/s, 200 m/s, 300 m/s and 400 m/s are 0.1527 g, 0.15449 g, 0.14370 g and 0.13327 g, respectively.

Surface PGA (PGA_M) SNI 1726 Calculations

The creation of the SNI 1726:2002 surface PGA (PGA_M) map aims to evaluate existing buildings that were designed using SNI 1726:2002. The selection of SNI 1726:2002 is based on the experience of the Yogya earthquake in 2006. Many



(a)



(b)

Figure 5. Soil boring investigation (a) and seismometer investigation (b) positions

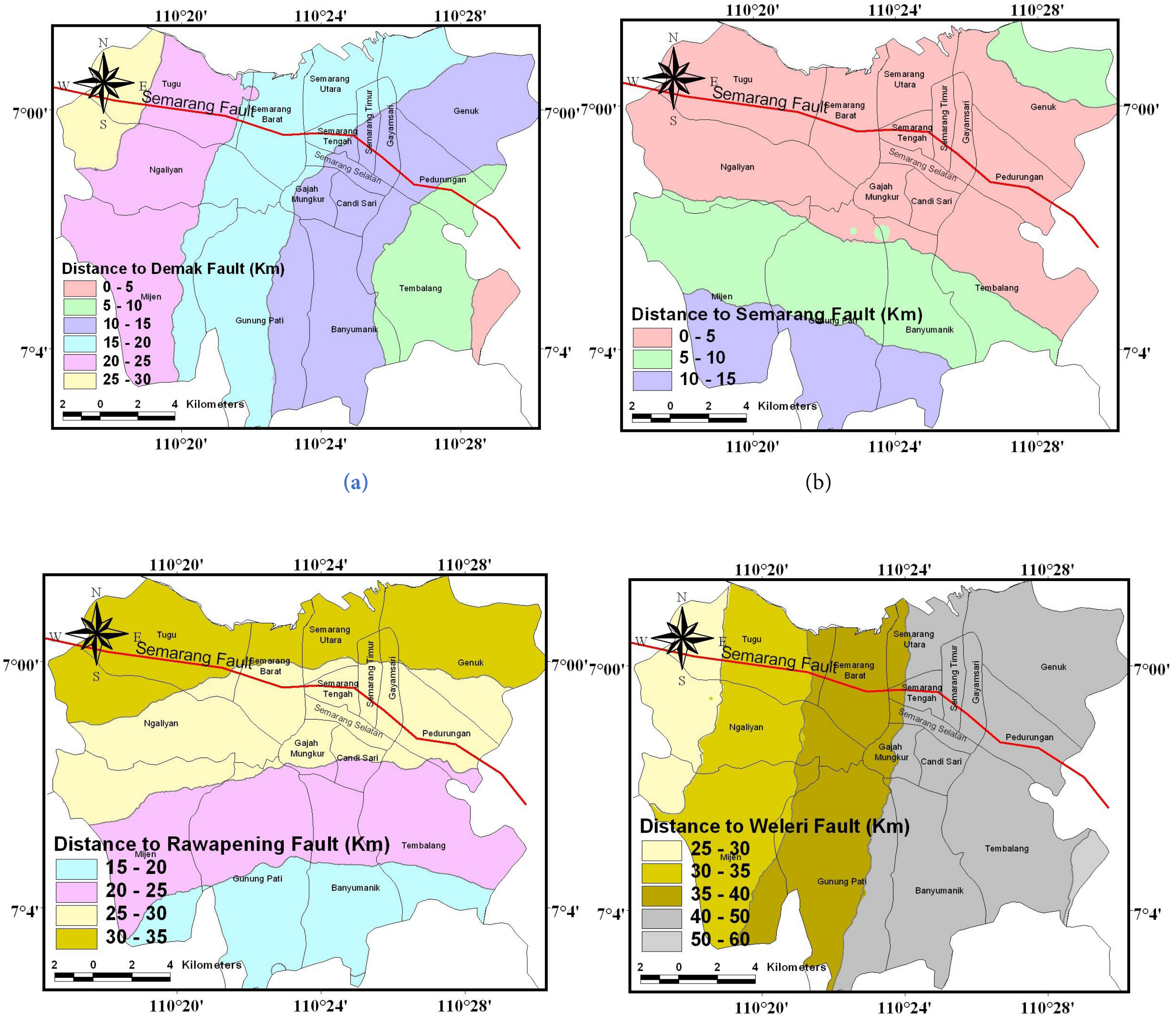


Figure 6. Earthquake source distance distribution maps of Semarang (a), Demak (b), Rawapening (c) and Weleri (d) fault lines.

Table 1. PGAS of Semarang fault earthquake scenario magnitude M5

Rjb	Vs30 = 100 m/s	Vs30 = 200 m/s	Vs30 = 300 m/s	Vs30 = 400 m/s
5 km	0.15721 g	0.15449 g	0.14370 g	0.13327 g
10 km	0.09961 g	0.08777 g	0.07611 g	0.06819 g
15 km	0.07560 g	0.05608 g	0.04711 g	0.04156 g

buildings built based on SNI 1726:2002 or previous regulations were unable to withstand surface ground-shaking due to a shallow fault earthquake with a magnitude of M6.3 (Elnashai et al., 2007). Figure 9a shows the distribution of PGA_M values calculated at 241 seismometer observation points based on the SNI 1726:2002 code.

The calculation of PGA_M is also carried out based on the earthquake regulations SNI 1726:2012 and SNI 1726:2019. The calculation of the PGA_M values of SNI 1726:2002, 2012 and 2019 at each investigation point was carried out by multiplying the PGA value at bedrock elevation with the amplification factor or site factor F_{PGA}. Equation 1 shows the PGA_M calculations methods based on the SNI 1726 code. PGA_M, F_{PGA} and PGA in Equation 1 represent the surface PGA, PGA amplification factor and PGA at bedrock elevation, respectively. Figure 9b shows the distribution of PGA_M based on the SNI 1726:2012 code. Figure 9c shows the distribution of PGA_M calculated based on the SNI 1726:2019 code.

$$PGA_M = F_{PGA} * PGA \quad (1)$$

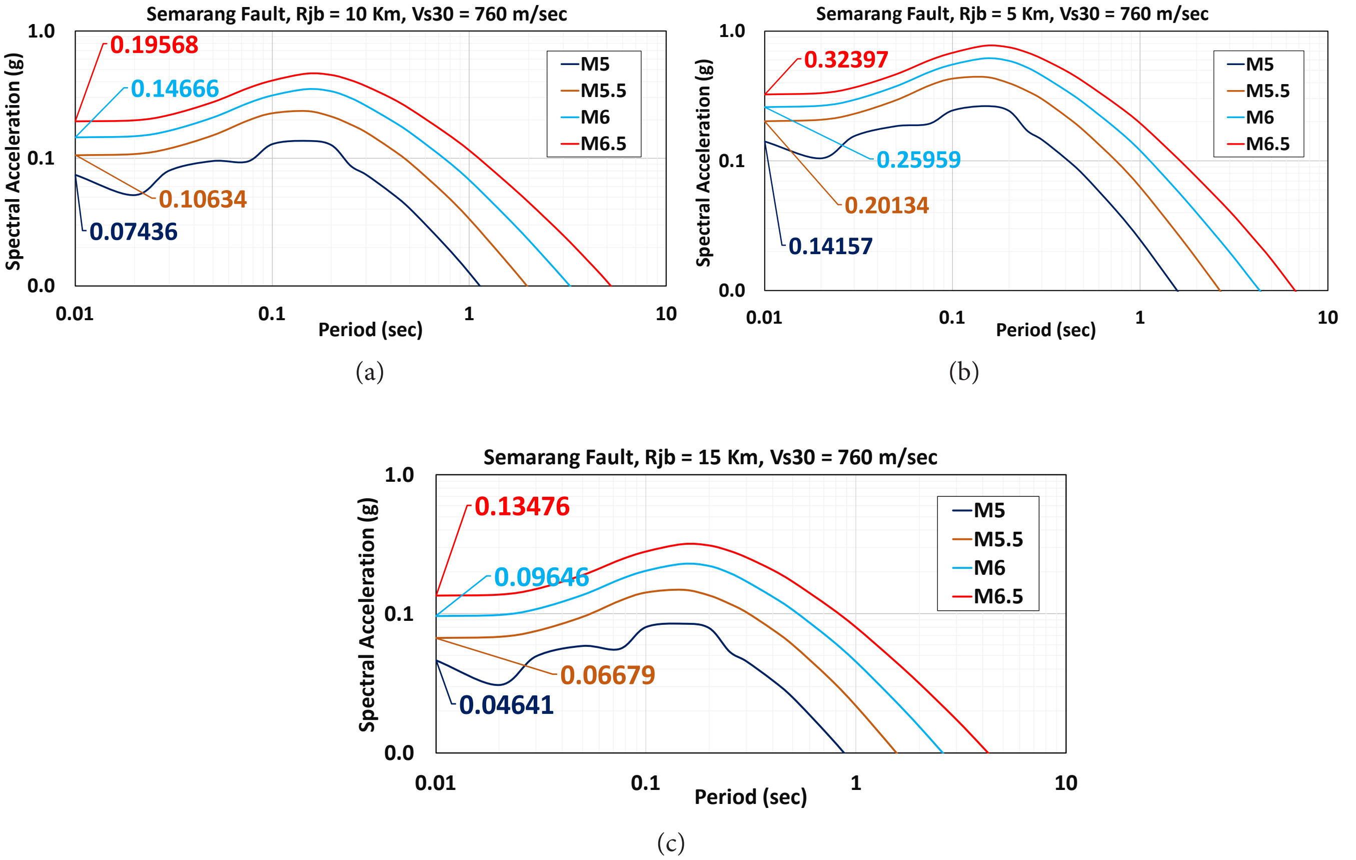


Figure 7. Spectral acceleration calculation of four GMPEs due to the Semarang fault earthquake scenarios at Rjb = 5 km (a), Rjb = 10 km (b) and Rjb = 15 km (c).

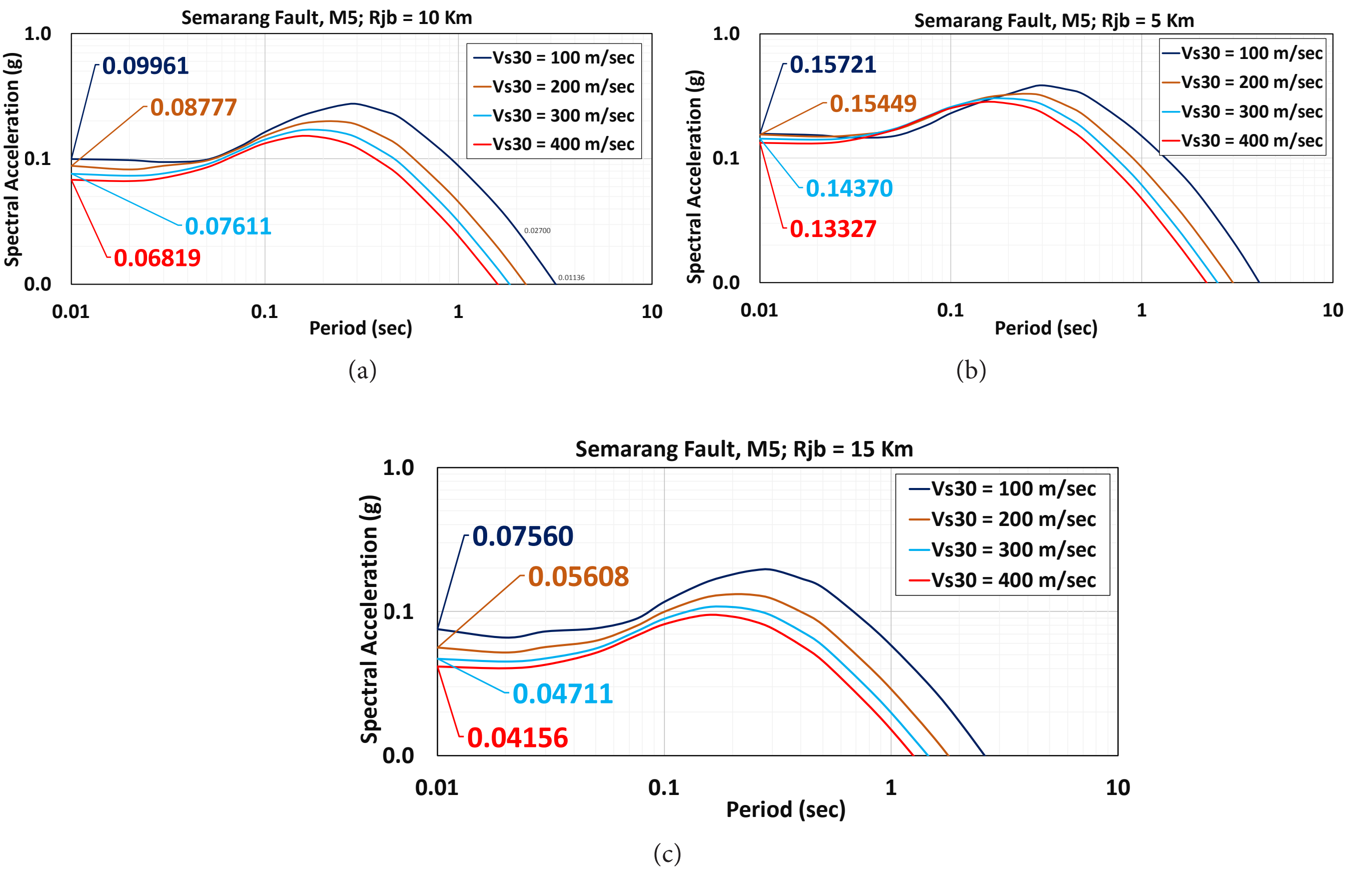


Figure 8. Surface spectral acceleration calculation of four GMPE due to the Semarang fault earthquake scenarios at Rjb = 5 km (a), Rjb = 10 km (b) and Rjb = 15 km (c).

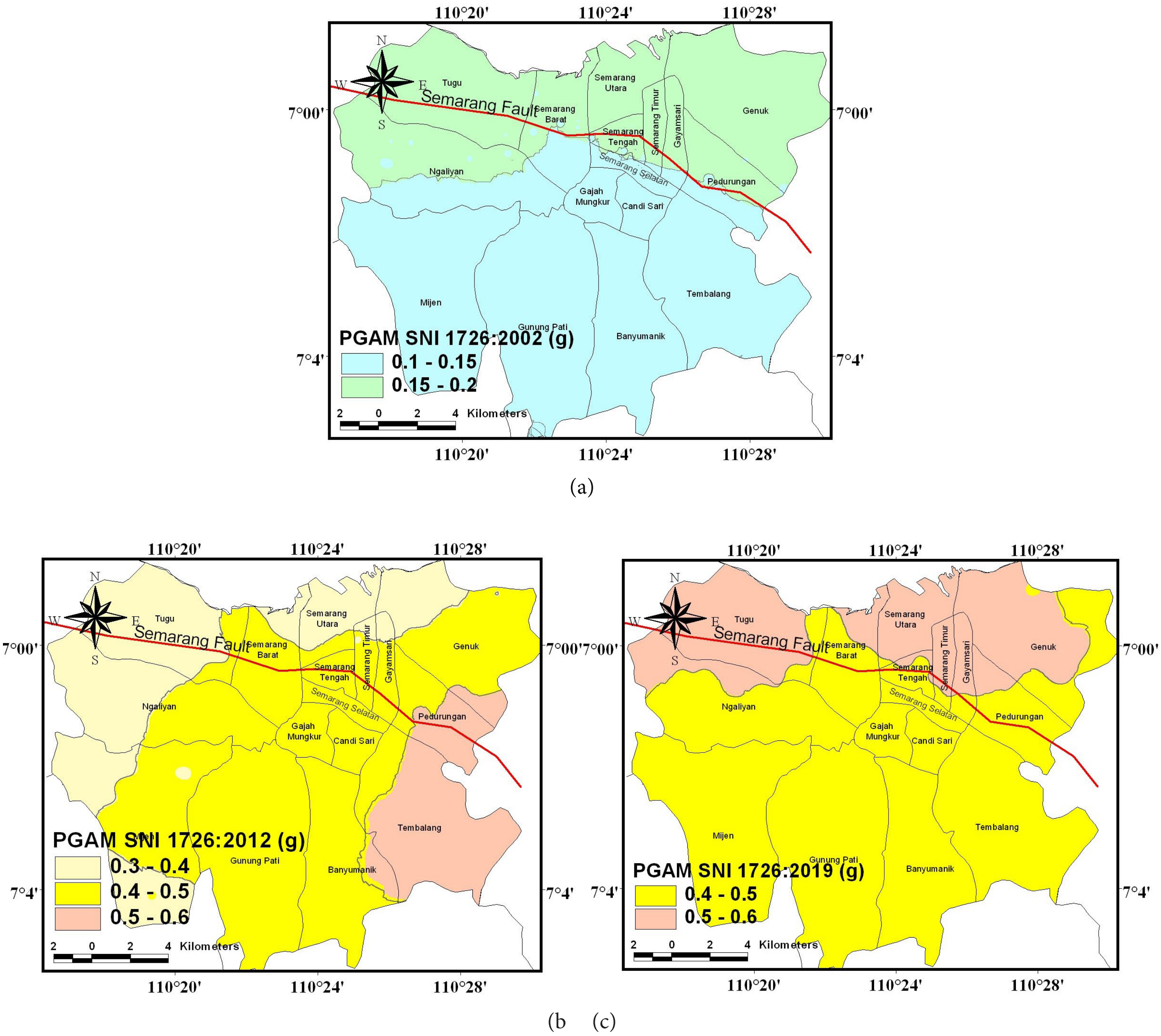


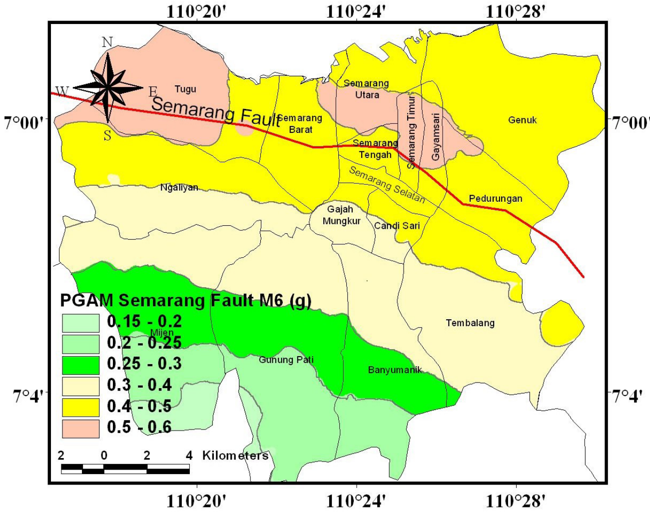
Figure 9. PGA_M distribution maps of SNI 1726:2002 (a), SNI 1726:2012 (b) and SNI 1726:2019 (c).

3. Results and Discussion

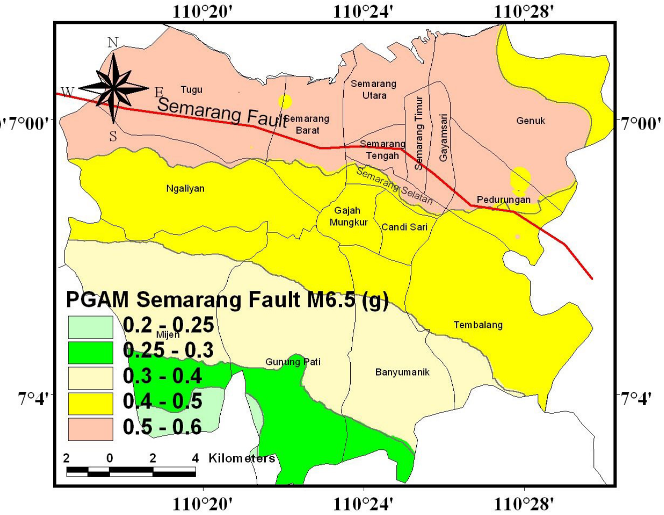
The calculation of the PGAS values due to shallow crustal fault earthquake scenarios was carried out from a magnitude of M5 up to a maximum magnitude of M6.5. The calculation of four earthquake magnitude scenarios for M5, M5.5, M6 and M6.5 was conducted at 241 seismometer testing points. The calculation was performed by inputting the Vs30 value obtained from the seismometer investigation results and the distance of the earthquake source (Rjb) from each seismometer observation point to each fault earthquake source line.

Figure 10a shows the PGAS distribution due to the Semarang fault earthquake scenario with a magnitude of M6.5. In the M6.5 earthquake scenario, the city is expected to suffer surface-shaking ranging from 0.2 g to 0.6g. The maximum PGAS values are distributed in the northern part of the city and north of the Semarang fault line. PGAS maps were also generated for three Semarang fault earthquake scenarios with magnitudes of M6, M5.5 and M5. Figures 10b, 10c and 10d show the surface PGA distribution maps for three earthquake scenarios: M6, M5.5 and M5. Semarang will experience a PGAS of 0.15 g to 0.6 g due to an M6 earthquake. As a result of the M5.5 earthquake scenario, Semarang will experience surface-shaking between 0.1 g and 0.5 g. Meanwhile, due to an earthquake with a magnitude of M5, the city is expected to suffer surface-shaking from 0.05–0.4 g.

Based on the results of the PGAS calculations of the four magnitude scenarios, it can be seen that the strongest distribution of surface-shaking will occur in the northern area of the city. The weakest surface-shaking will occur in the southern part of the city. This is quite relevant because the southern part of Semarang is located at the greatest distance from the earthquake source, with a Vs30 value greater than that of the northern part of the city. Areas with a distance of less than 5 km to the Semarang fault line are expected to experience ground-shaking (PGAS) greater than 0.2g. This surface-shaking value is greater than the estimated shaking according to SNI 1726:2002. In contrast to the calculation results according to SNI 1726:2002, all buildings constructed according to SNI 1726:2012 and SNI 1726:2019 are expected to experience weaker surface-shaking the Semarang fault earthquake scenarios with a maximum magnitude of M6.5.



(a)



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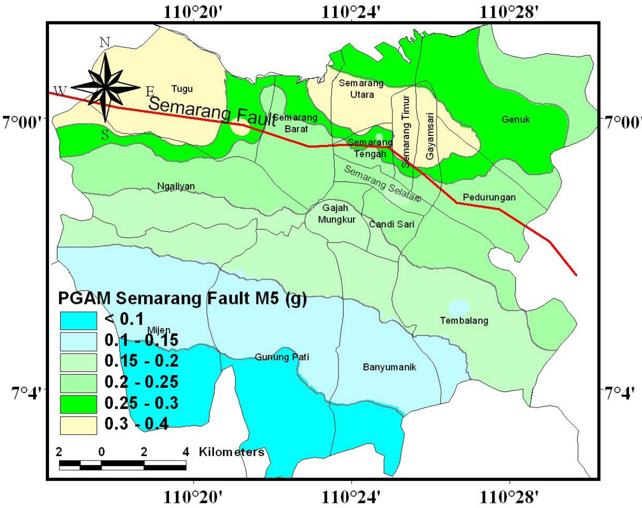

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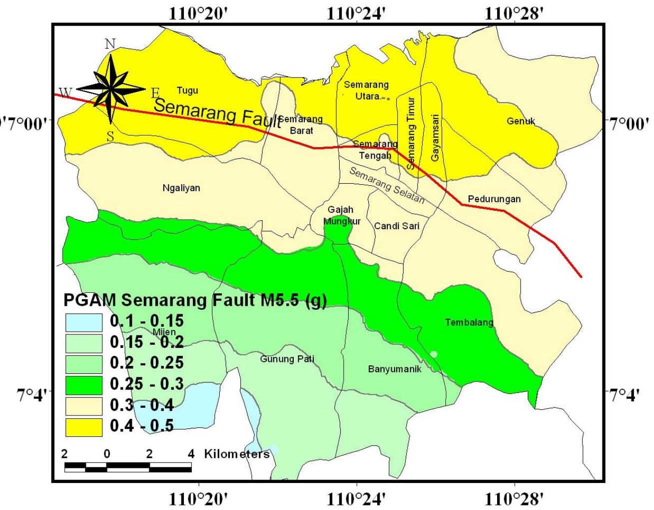
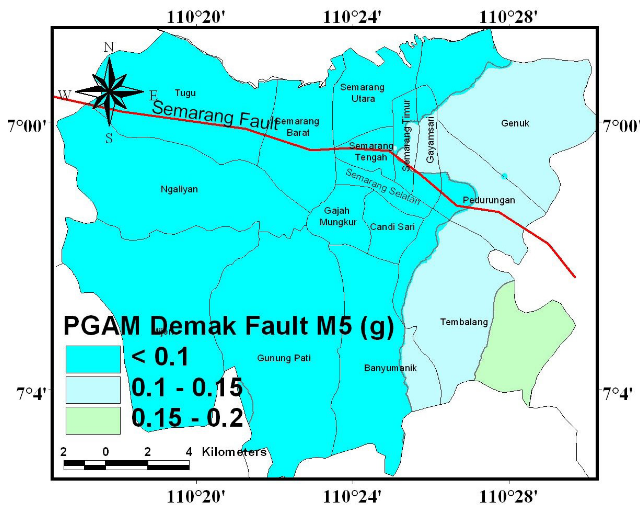
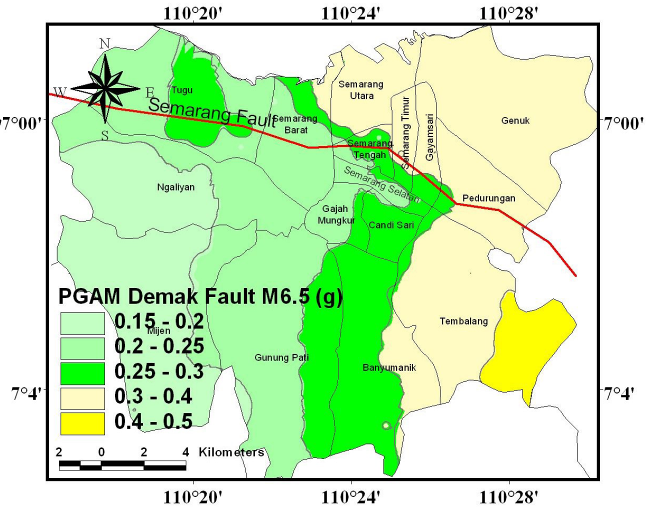


(d)

Figure 10. PGAS distribution map of Semarang fault earthquakes at M6.5 (a), M6 (b), M5.5 (c) and M5 (d).



(a)



(b)

Figure 11. PGAS distribution map for Demak fault earthquake magnitudes of M6.5 (a) and M5 (b).

PGAS calculations were also carried out for the Demak fault earthquake scenario, for the same four magnitude scenarios. Figure 11 shows two PGAS distribution maps due to the Demak fault earthquake with magnitudes of M6.5 and M5, respectively. Figure 11 shows that the largest PGAS values are distributed in the eastern part of Semarang. The PGAS caused

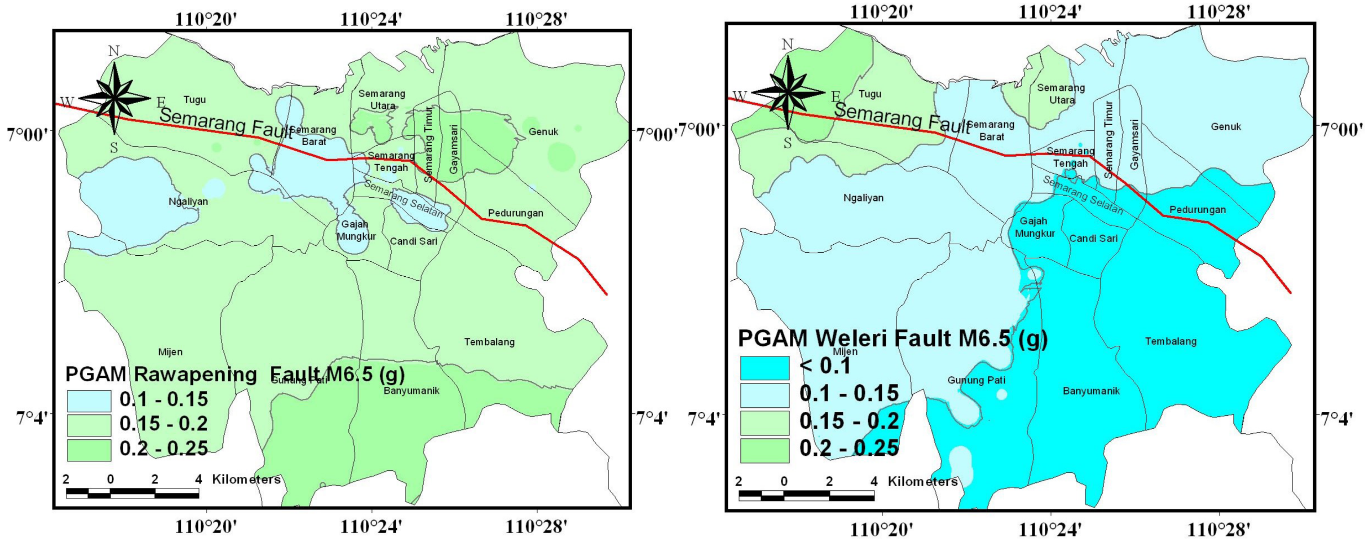


Figure 12. PGAS distribution map of Rawapening (a) and Weleri (b) fault earthquake scenarios with a magnitude of M6.5.

by the M6.5 scenario is expected to cause surface-shaking between 0.1 g and 0.5 g. Meanwhile, if there is an earthquake caused by the Demak fault with a magnitude of M5, the maximum PGAS values is 0.2 g. As a result of the Demak fault earthquake scenario with a maximum magnitude of M5.5, the entire city of Semarang is expected to experience less surface-shaking than predicted by SNI 1726:2012. Based on the PGAS distribution maps of Demak fault earthquake scenarios with magnitudes of M6 or M6.5, all buildings located in the western part of the city and designed following SNI 1726:2012 are predicted to experience weaker surface-shaking.

All buildings constructed according to SNI 1726:2019 are expected to experience weaker surface ground-shaking than the ground-shaking caused by the Demak fault earthquake scenario with a maximum magnitude of M6.5. The opposite condition is predicted for all buildings constructed according to SNI 1726:2002. All buildings constructed according to SNI 1726:2002 are expected to experience greater shaking due to the Demak fault earthquake scenario with a minimum magnitude of M5.5. In the event of an earthquake with a magnitude from M5.5 to M6.5, all buildings in the city are expected to experience surface ground-shaking greater than the estimated shaking according to SNI 1726:2002.

As shown in Figure 6, the distances of the 241 seismometer observation points to the Semarang fault line range from 0 km to 15 km. However, the distances of the 241 seismometer observation points to the Demak fault line range from 5 km to 30 km. The distance of the study area to the Rawapening fault line ranges from 15 km to 35 km. However, the distance from the city to the Weleri fault line ranges from 25 km to 60 km. From the distribution of earthquake source distances, it can be seen that the Rawapening fault is closer to the city of Semarang than the Weleri fault.

Figure 12a shows the PGAS map due to the Rawapening fault earthquake scenario with a magnitude of M6.5. Figure 12b shows the distribution map of the PGAS due to the Weleri fault earthquake scenario with a magnitude of M6.5. According to Figure 12b, the PGAS ranges from 0.05 g to 0.25 g. According to Figure 12a, the PGAS values caused by the Rawapening fault scenario with a magnitude of M6.5 range from 0.1 g to 0.25 g. Based on the results of this calculation, the PGAS values due to the Weleri fault earthquake scenario are smaller than those due to the Rawapening earthquake scenario with the same magnitude value.

According to the analysis of the PGAS calculations due to the Rawapening fault and Weleri fault earthquakes as shown in Figures 12a and 12b, all buildings designed based on SNI 1726:2002 are expected to experience weaker ground-shaking for these two earthquake sources with a maximum magnitude of M6.5. Based on the analysis results according to SNI 1726:2012 and SNI 1726:2019, all buildings constructed according to these two earthquake codes are expected to experience weaker ground-shaking for the two earthquake sources with magnitudes reaching M6.5.

4. Conclusion

According to SNI 1726:2002, the Semarang area is estimated to have a maximum ground-shaking resistance (PGA) of 0.2 g. According to SNI 1726:2012 and SNI 1726:2019, the city of Semarang is estimated to have a maximum ground-shaking resistance (PGA_M) of 0.6 g. The earthquake-microzoning map developed for the Semarang fault and Demak fault earthquake scenarios provides a preliminary indication that buildings constructed using SNI 1726:2002 (built before 2012) will experience stronger shaking if the earthquake magnitude from both sources is at least M5.5. The results of the analysis for the creation of earthquake-microzoning maps for the Rawapening fault and Weleri fault earthquake scenarios provide an initial indication that buildings constructed using SNI 1726:2002 are expected to experience slightly weaker ground-shaking if the earthquake strength from both sources reaches a maximum magnitude of M6.5. All buildings constructed in the Semarang area using SNI 1726:2012 and SNI 1726:2019 are expected to withstand surface-shaking caused by the four earthquake source scenarios with a maximum magnitude of M6.5.

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