Riset Geologi dan Pertambangan
(Geology and Mining Research)

RESEARCH ARTICLE

OPEN ACCESS

Riset Geologi dan Pertambangan (2025) Vol. 35, No. 1, 11–24
DOI: 10.55981/risetgeotam.2025.1331

Keywords:
Peak Ground Acceleration
Spectral Acceleration
Amplification Factor

Corresponding author:
Lindung Zalbuin Mase
lmase@unib.ac.id

Article history:
Received: 14 October 2024
Revised: 05 December 2024
Accepted: 15 December 2024

Author Contributions:
Conceptualization: ZF, LZM, RM
Data curation: ZF, LZM, RM
Formal analysis: ZF, LZM, KA
Funding acquisition: RM, HD
Investigation: LZM, RM
Methodology: ZF, LZM
Supervision: LZM, KA
Visualization: ZF, LZM, KA, RM, HD
Writing – original draft: ZF, LZM
Writing – review & editing: ZF, RM, KA, LZM, HD

Citation:
Fahrezi, Z., Misliniyati, R., Amri. K., Mase, L. Z., and Hardiansyah, H., 2025. Earthquake Hazard Evaluation Study on the Central Area of Selebar District, Bengkulu City based on Seismic Response Analysis, *Riset Geologi dan Pertambangan 35(1)* 11–24, doi: 10.55981/risetgeotam.2025.1331

Earthquake Hazard Evaluation Study on the Central Area of Selebar District, Bengkulu City, based on Seismic Response Analysis

Zhehan Fahrezi[1], Rena Misliniyati[1], Khairul Amri[1], Lindung Zalbuin Mase[1], Hardiansyah[1]

[1]Department of Civil Engineering, Faculty of Engineering, University of Bengkulu, Bengkulu 38371, Indonesia

Abstract

The Selebar District, a developing area in Bengkulu City, has been the site of at least two significant earthquakes with a magnitude of M_w 7.0 in the past two decades. This study, which presents a seismic hazard assessment for the central area of the Selebar District, is of paramount importance. The study commences with field investigations at three strategically chosen points in the central area of Selebar District, Bengkulu City, including the airport, educational center, and toll road. The analysis, which involves the propagation of seismic waves, aims to comprehend the seismic behavior during an earthquake. The potential impact of seismic waves on structures and the environment is a serious concern. Seismic response analyses, a critical component of this study, were constructed based on a one-dimensional wave propagation model using a non-linear method. These analyses offer valuable insights into the potential impact of seismic waves on structures and the environment, a matter of serious concern. The results of the field investigations were also examined for seismic response analysis. The PGA, spectral response acceleration, and amplification factors are presented in this study and analyzed to determine the seismic hazard. Based on the PGA values, two earthquake sources can cause very high damage to buildings, and one earthquake source has a high potential. The generated spectral acceleration has exceeded the design spectral acceleration, especially at short periods. Therefore, using local spectra in building structure design can be a recommendation for local engineers to consider the impact of earthquakes on the central area of Selebar District, Bengkulu City.

1. Introduction

Bengkulu city is located on the west coast of Sumatra Island. It is the capital city of Bengkulu province, categorized as a developing city in Indonesia (Mase, 2022). Bengkulu City has been reported to be highly vulnerable to earthquakes related to several tectonic activities, such as the Sumatra Subduction, Sumatra Fault, and Mentawai Fault, which surround the area (Mase, 2020). The seismotectonic conditions in Bengkulu City can be seen in Figure 1. In 2000, the M_w 7.9 earthquake occurred in Bengkulu Province, Indonesia. The earthquake caused extensive damage, including the collapse of buildings, loss of life, and injuries. The earthquake also triggered other disaster hazards, such as landslides and liquefaction in the mountainous and coastal areas of Bengkulu. Seven years later, another major earthquake with a magnitude of MW 8.6 hit the area (Mase, 2017a). These earthquakes also resulted in structural damage and other geotechnical phenomena, such as subsidence and liquefaction. On both occasions, Bengkulu City suffered more severe impacts than other cities and regencies in Bengkulu Province, as the energy released by the earthquakes in 2000 and 2007 was enormous (Mase, 2017a).

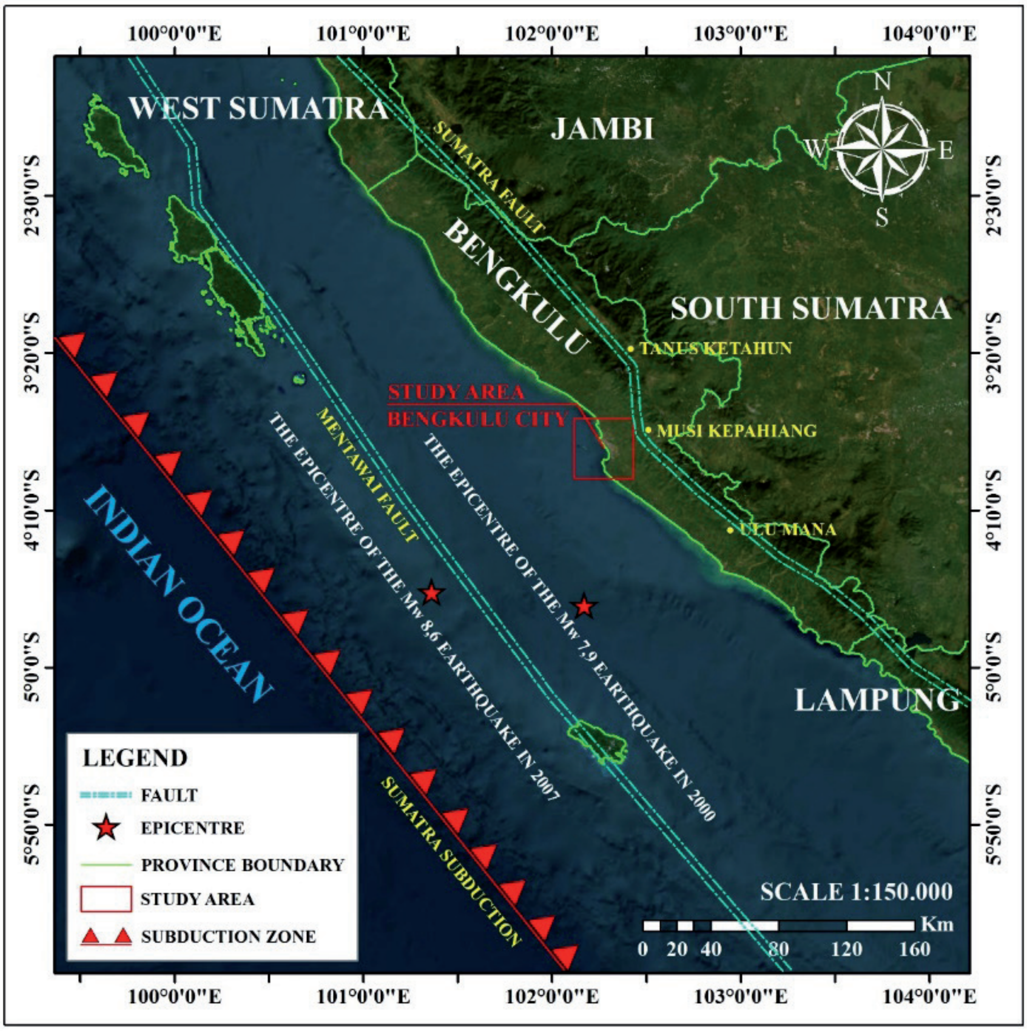


Figure 1. Seismotectonic conditions in Bengkulu City.

Selebar is one of the districts in Bengkulu City with an area of 43.35 km2 and a population of 79,498. This developing area is planned as a sub-city service II with functions as a district government center, public services, trade and service centers, industrial centers, health and sports centers, and national-scale transportation nodes. Farid and Mase (2020) said the Selebar district will be used as a trade area, settlement, green open space, and industrial area. Critical facilities in the Selebar district include Fatmawati Soekarno Airport, Fatmawati Soekarno State Islamic University, Bengkulu-Taba Penanjung toll road, and government and private office buildings.

The earthquakes that occurred in the past triggered massive structural damage, indicating an urgent need to evaluate the seismic design codes in Indonesia. In addition, earthquakes can trigger liquefaction (Mase et al., 2021). In Indonesia, seismic resistance design should be prioritised before construction (Mase and Keawsawasvong, 2022). In response to these earthquake events, the Indonesian government revised the previous seismic design code (SNI 03-1726-2012) into a new code (SNI 03-1726-2019). This updated seismic design code, incorporating the latest research and best practices in earthquake engineering, is now a reference for construction design for local engineers in Indonesia. The SNI 03-1726-2019 is particularly relevant to this study as it forms the basis for the seismic response analyses presented here. It should be considered a design practice for buildings across Indonesia, underlining this research's immediate relevance and importance. The seismic response analyses in this study are conducted by the guidelines and parameters set by the SNI 03-1726-2019, ensuring the reliability and applicability of the findings to real-world construction practices.

In this study, seismic response analyses due to earthquakes are presented. This research aims to test the reliability of the updated seismic design code (SNI 03-1726-2019) against earthquakes in the central area of Selebar, Bengkulu City. The central location is economically and socially significant, including airports, universities, toll roads, and office districts. Ground motion is propagated from the bedrock surface through the subsoil. The ground motion is transferred to spectral acceleration curves at the ground surface, which are then compared with the updated seismic design code. In addition, the amplification factors between the propagated ground motion, the propagated input wave motion, and the analyzed surface waves are presented. In general, this research is expected to provide a better understanding of seismic response analysis in the Selebar district of Bengkulu City and advise local engineers in considering spectral acceleration design for construction in the Selebar district of Bengkulu City. These considerations offer potential benefits and improvements in earthquake-resistant construction practices, instilling a sense of hope and optimism in the face of seismic hazards.

2. Geological Condition of Bengkulu City

The geological condition of Bengkulu City can be seen in Figure 2. In general, Bengkulu City is composed of several geological formations. The most dominant geological formation in Bengkulu City is alluvium terraces (Qat). This formation is generally found along the coast of Bengkulu City. It is important to note that alluvium terraces are susceptible to liquefaction during earthquakes, which can significantly increase the seismic hazard in these areas. This formation is composed of sand, silt, clay, and gravel. In addition, a small amount of Reef Limestone (Ql) formation is also found along the coastline of Bengkulu City. Alluvium (Qa) is generally found in the central part of Bengkulu City. These formations comprise boulders, gravel, sand, silt, mud, and clay. The northern and eastern parts of Bengkulu City are composed of swamp deposits (Qs) of sand, silt, clay, and peat. Andesite (Tpan) and bintunan formations (QTb) are also found in Bengkulu City. A polymictic conglomerate and igneous rocks dominate these formations (Farid and Mase, 2020). Understanding the composition and characteristics of these geological formations is crucial for assessing the seismic hazard and designing earthquake-resistant structures in Bengkulu City.

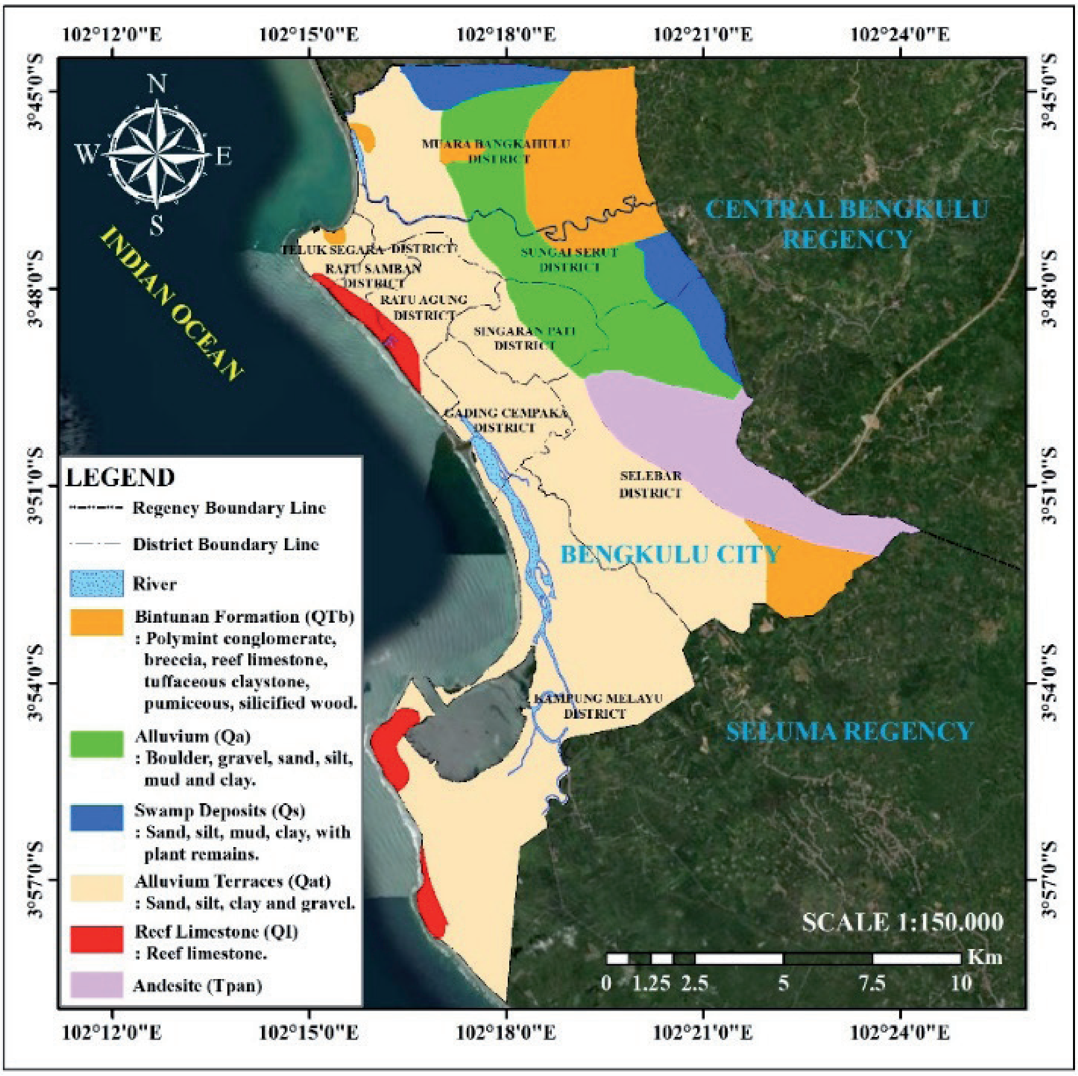


Figure 2. Geological Condition of Bengkulu City (Modified after Farid and Mase, 2020).

Based on the geological conditions of Bengkulu City, the Selebar district of Bengkulu City has considerable earthquake potential. The Selebar area, with its diverse geological formations: Qat, Tpan, Qa, and Qs, each with a different response to seismic waves, is at risk. Therefore, conducting a seismic response analysis is essential in evaluating the earthquake hazard in the Selebar district, Bengkulu City. The potential impact of this hazard on the district cannot be overstated, making this study a critical step in understanding and mitigating the seismic risk.

3. Methods

Study Area

The research was conducted at three points in District Selebar, Bengkulu City. Each selected point represents a place with essential facilities in the Selebar district of Bengkulu City, such as the airport, TOL Road, university, government, and offices. SL-1 is located at Fatmawati Soekarno Airport, SL-2 is on the Bengkulu-Taba Penanjung toll road, and SL-3 is at Fatmawati Soekarno State Islamic University. The research locations can be seen in Figure 3.

Figure 3. Research Location.

Data

The research commenced with meticulous field investigations using microtremor at a chosen research location. The results were then rigorously processed to comprehensively describe each layer's soil layers, VS (shear wave velocity), and VP (pressure wave velocity). The soil data, a product of this thorough process, can be seen in Figure 4.

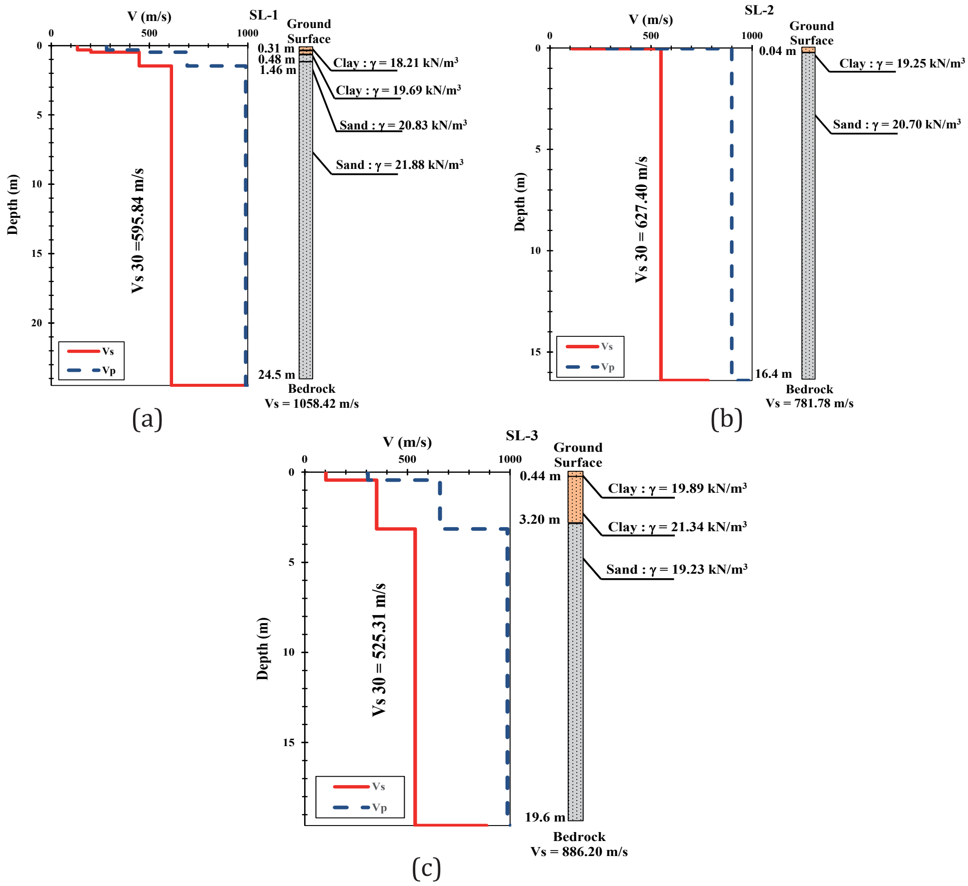
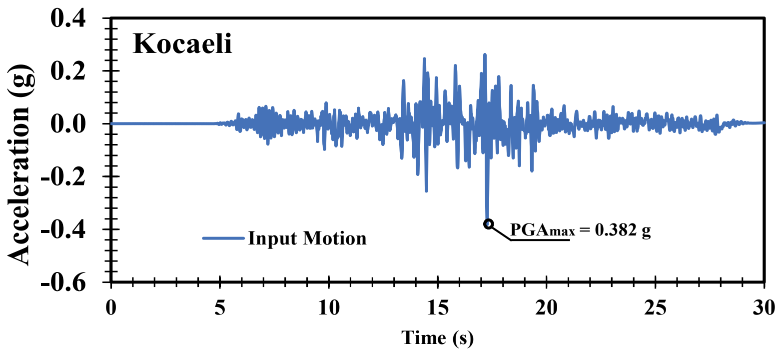


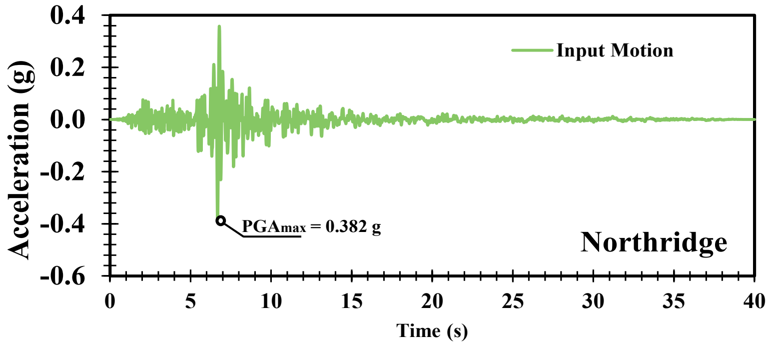
Figure 4. Soil Layer Profile SL-1 (a), SL-2 (b), SL-3 (c).

V_{S30} can determine soil site class; soils with V_{S30} in the range of 175m/s - 350m/s are classified as medium soils, 350m/s - 750m/s are classified as hard soils (SNI 1726-2019, 2019). Therefore, at points SL-1, SL-2, and SL-3 are classified as hard soil.

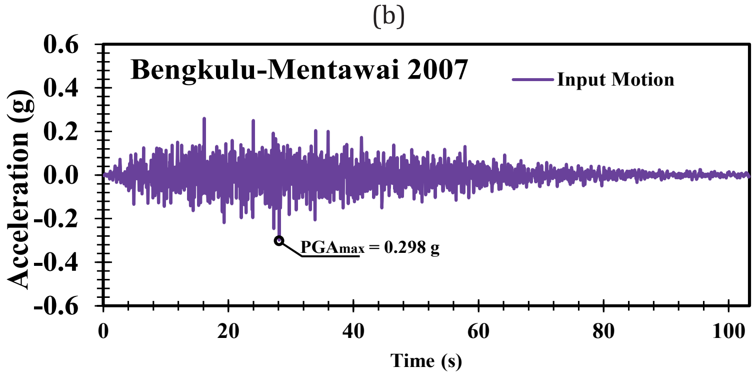
In addition to soil data, the secondary data used in the study were input motions. The input motions used were taken from several sources; this was done to reduce the uncertainty of the location under study. This study used three input waves: Kocaeli, Northridge, and the 2007 Bengkulu-Mentawai earthquake wave obtained from Mase (2017) and Mase (2018). In this study, the reason for selecting three earthquake waves, namely the Kocaeli, Northridge, and Bengkulu-Mentawai 2007 earthquakes, is based on the fact that they are among the major earthquake events that have significant impacts and are recorded in world seismic history. These waves represent various characteristics of large-magnitude earthquakes occurring in regions with different geological conditions, thus providing a comprehensive insight into comparing seismic responses under multiple conditions. The selection of three earthquake waves is also made to reduce the uncertainty related to the types of earthquakes that may occur, so it is necessary to analyze more than one earthquake wave. This selection aims to make the seismic response analyses obtained more representative and to cover various potential earthquakes, resulting in a more comprehensive and accurate evaluation. By analyzing the responses to these three earthquake waves, it is hoped that a better understanding of the effects of earthquake characteristics on building structures and the environment can be gained. The input motions can be seen in Figure 5.



(a)



(b)



(c)

Figure 5. (a) Input Motion Kocaeli, (b) Northridge, (c) Bengkulu-Mentawai 2007.

One-Dimensional Earthquake Wave Propagation Analysis: Non-Linear Method and Modified Mercalli Intensity (MMI).

One-dimensional seismic ground response analysis is conducted to observe soil behavior during earthquakes. Seismic response analysis involves the one-dimensional transmission of seismic waves through horizontal soil layers (Mase and Likitlersuang, 2021). In this study, the non-linear Pressure Dependent Hyperbolic (PDH) model was developed by Hashash et al. (2016). This model emphasizes implementing hyperbolic functions to simulate the nonlinear behavior of soil under dynamic loading. Pender et al. (2016) and Mase et al. (2017) stated that the results of the numerical simulation of this modeling are generally in line with the results of the response analysis on the ground during an earthquake event. This study's one-dimensional seismic wave modeling stages used the finite element method.

The physical and engineering parameters used in the analysis include soil thickness (h), volume weight (γ), and V_S profile. This information can be obtained from field investigations. For dynamic parameters, the shear modulus (G/G_{max}) and damping ratio (ξ) curves are determined based on the soil type. For cohesive soils, the G/G_{max} curves of Vucetic and Dobry (Mase, 2017b) were used with a PI (plasticity index) range of 15-30, which is suitable for the study site (Figure 6), while the G/G_{max} curve of Seed and Idriss (Mase, 2017b) is used for granular soils with average boundaries (Figure 7). The PI value is obtained using the correlation formula V_p.

$$PI=-16{,}491 \ln V_p+121{,}95 \tag{1}$$

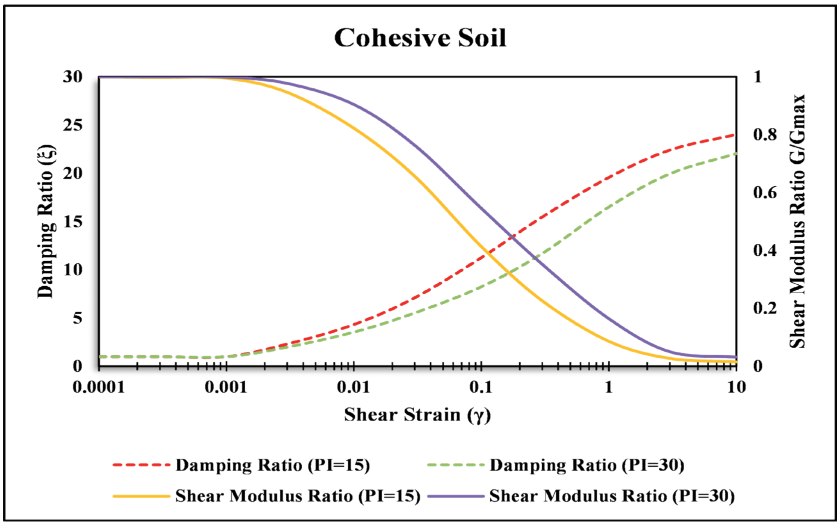


Figure 6. G/G_{max} curve and damping ratio for cohesive soils (Modified after Mase, 2017b).

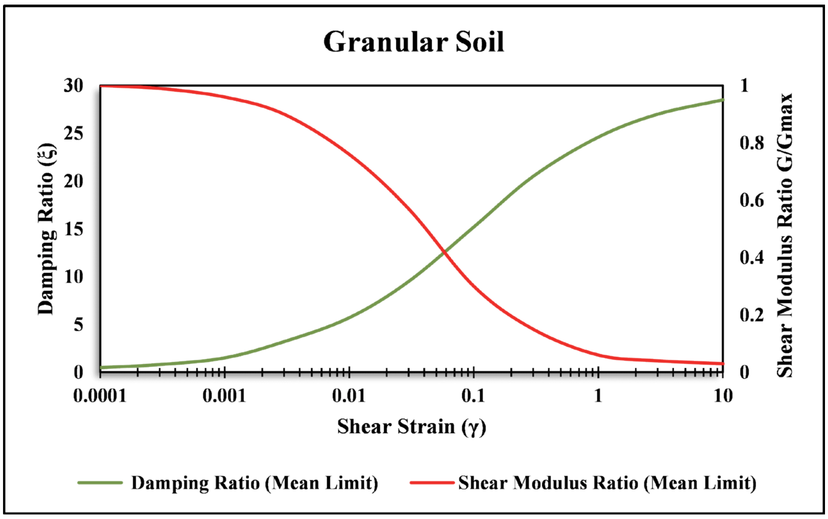


Figure 7. G/G_{max} curve and damping ratio for granular soils (Modified after Mase, 2017b).

A one-dimensional seismic response analysis is formed by applying an input motion to the bedrock. The modeling in Figure 8 illustrates a one-dimensional seismic response analysis, where the soil layer is modeled as a soil column that is vibrated horizontally by the input motion. The results of the one-dimensional seismic ground response analysis include PGA (peak ground acceleration), spectral acceleration, and amplification factor.

From the PGA values at the surface, the level of damage intensity can be predicted based on the MMI (Modified Mercalli intensity). The correlation between MMI and PGA can be estimated as suggested by Mase et al. (2023), using the equation:

$$\text{Log(PGA)}=\frac{1}{4}MMI+\frac{1}{4} \qquad (2)$$

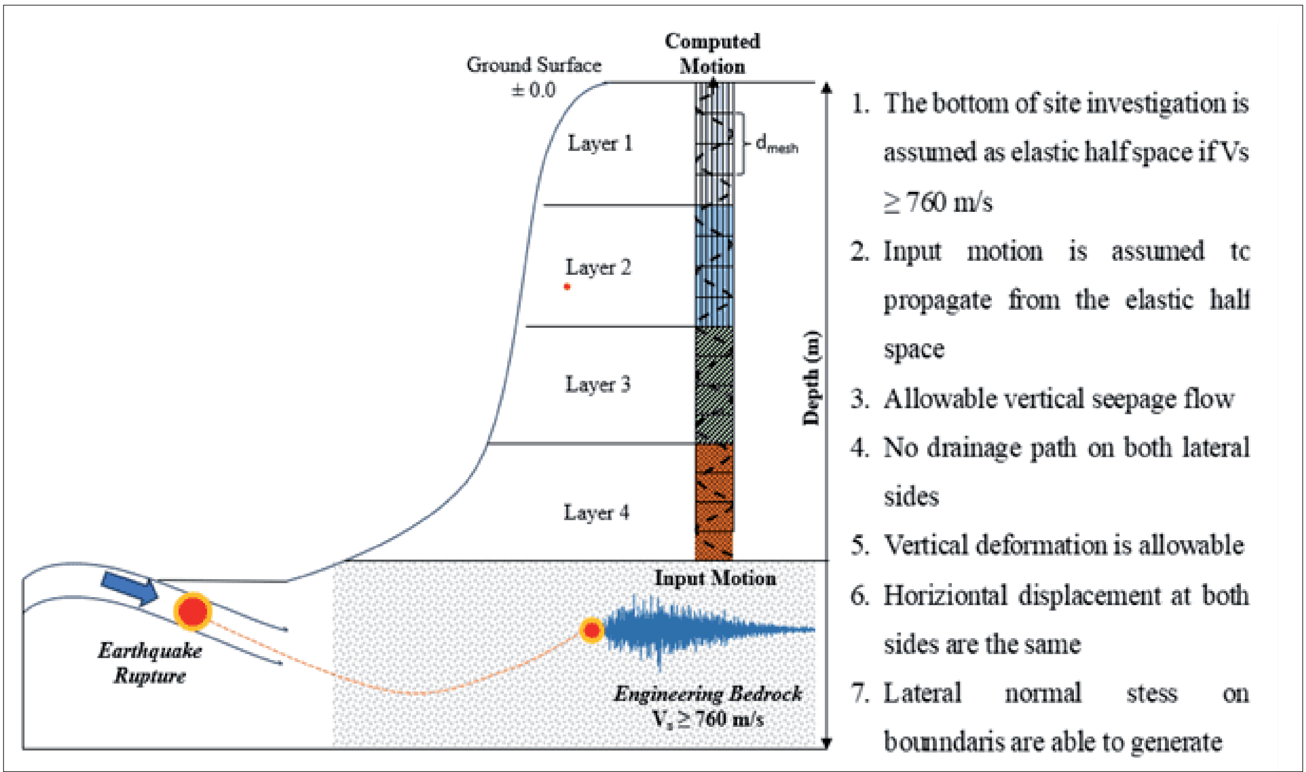


Figure 8. 1D earthquake wave propagation scheme (Modified after Sari et al., 2024).

4. Results and Discussion

Peak Ground Acceleration and Amplification Factor

The PGA value is used to determine the level of earthquake risk. Fathani et al. (2008) mentioned that the PGA value of 0.3 g- 0.4 g is included in the high risk, and the PGA value > 0.4g is included in the very high risk. The Kocaeli and Northridge input waves can cause a very high level of risk because they produce surface PGAs of 0.44g - 0.47g and 0.46g - 0.50g. Meanwhile, the 2007 Bengkulu-mentawai earthquake waves were classified as high, with surface PGA values ranging from 0.34g to 0.37g. The PGA at each soil layer can be seen in Figure 9.

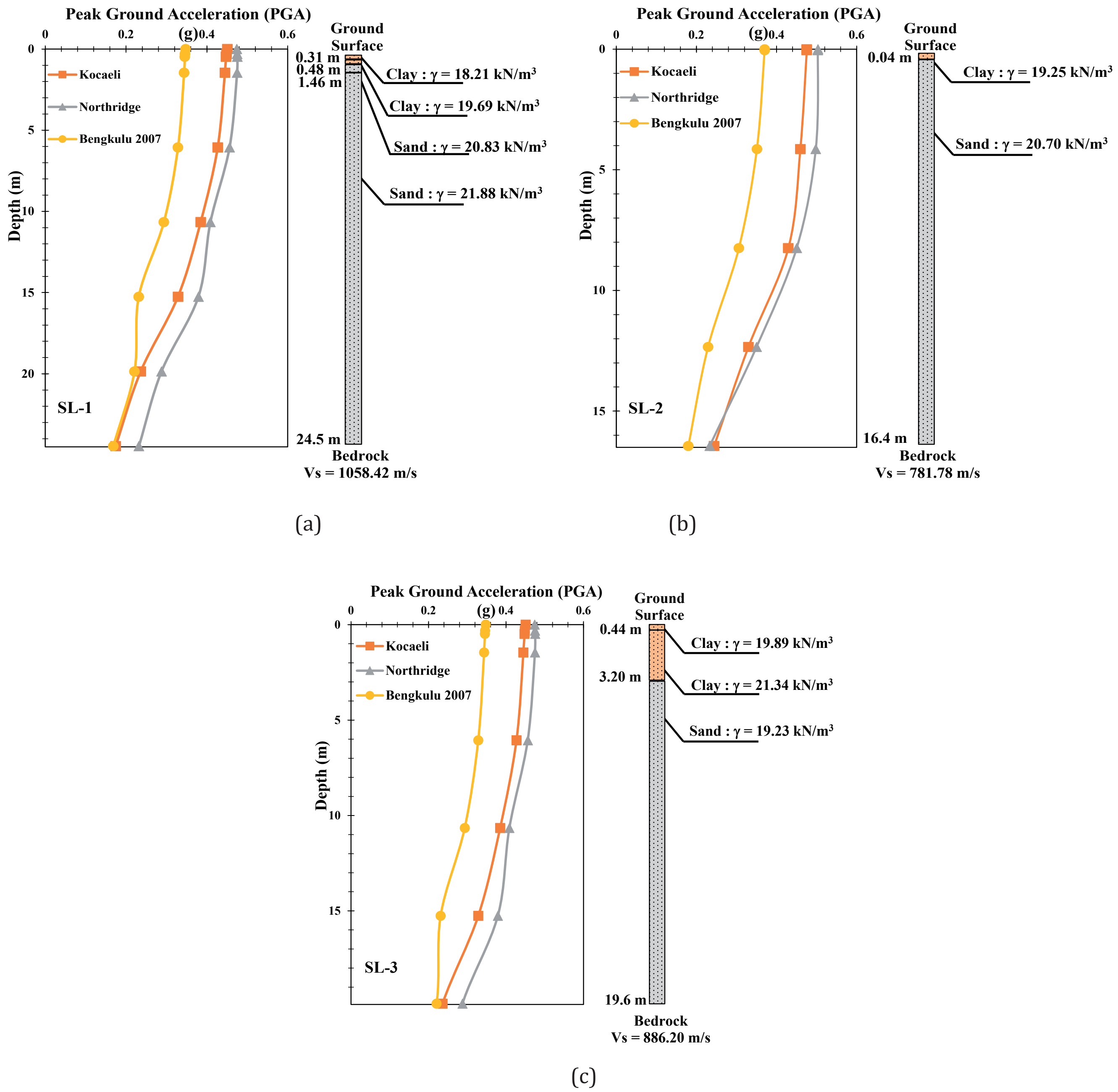


Figure 9. (a) PGAmax at each soil layer SL-1, (b) SL-2, and (c) SL-3.

The Selebar district is dominated by alluvium terraces (Qat), and there are other geological formations such as andesite (Tpan), alluvium (Qa), and swamp deposits (Qs). These formations also comprise sand, silt, clay, gravel, andesite, boulders, and metamorphic rocks. The Qat Formation has a high seismic vulnerability index, making it susceptible to earthquake shaking and liquefaction (Sugianto et al., 2021). In addition, the Qat geological formation has elastoplastic dynamic properties that have the potential to cause fractures covering 32.84% of the Bengkulu city area. During the two major earthquakes that occurred in 2000 and 2007, ground damage was not found to be significant in this zone. However, structural damage was found to be considerable in this area. This is because this zone is composed of low-density materials at shallow depths. Therefore, amplification can occur during an earthquake. The complex geological conditions in this zone confirm why the PGA at the ground surface tends to be more significant.

The MMI level can be predicted from PGA at the ground surface, calculated by Eq. 3. Based on the calculation, the MMI for the investigated sites is IX and X. The calculation results can be seen in Table 1. MMI of IX indicates "Moderate-heavy damage to construction buildings, solid, shifting foundations, there is fracturing at ground level, and MMI of X indicates "Most stone buildings, columns, and foundations were destroyed, and wide cracks in the surface of landslides on slopes, severe damage". A large-magnitude earthquake and the geological conditions could significantly damage an area (Somantri et al., 2022).

Table 1. MMI Level

Research Point	Kocaeli	Northridge	Bengkulu- Mentawai 2007
SL-1	X	X	IX
SL-2	X	X	IX
SL-3	X	X	IX

The amplification factor is obtained by dividing the PGAmax at the surface by the input PGAmax. The input waves were generally amplified by 1.14 - 1.31 times (Figure 10). The Northridge earthquake waves produced the most significant amplification factors at all points, and the 2007 Bengkulu-mentawai earthquake waves produced the smallest ones. Point SL-2 produced the most excellent amplification for all earthquake sources.

The Selebar district is dominated by alluvium, which is composed of unconsolidated sedimentary material. Therefore, AF is relatively higher in this zone. The shallow depth of the bedrock is also the cause of the significant amplification. The depth of the bedrock affects the damping of the input wave as it travels to the surface layer. The shallower the bedrock, the smaller the damping that occurs (Misliniyati et al., 2019). Soil resistance also affects amplification; soils with little resistance can cause wave enlargement during earthquake wave propagation (Misliniyati, 2022). Soil resistance can be seen from V_S. At the depth of the base; it can be seen that each location is composed of a relatively thick layer of sand with considerable resistance until, at a depth of five meters, the soil is dominated by a layer of clay with low resistance, this is why amplification occurs when earthquake waves reach the surface.

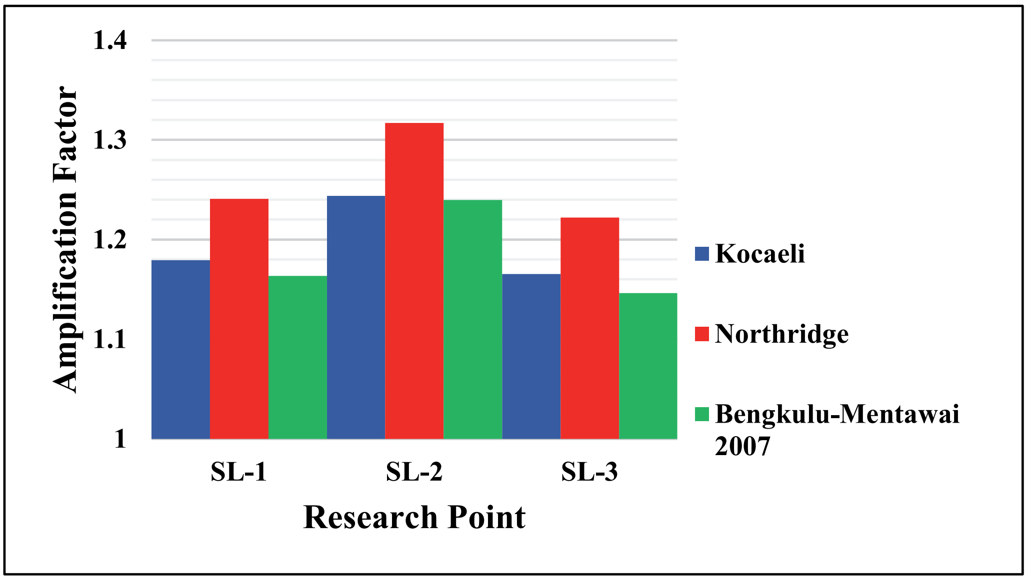
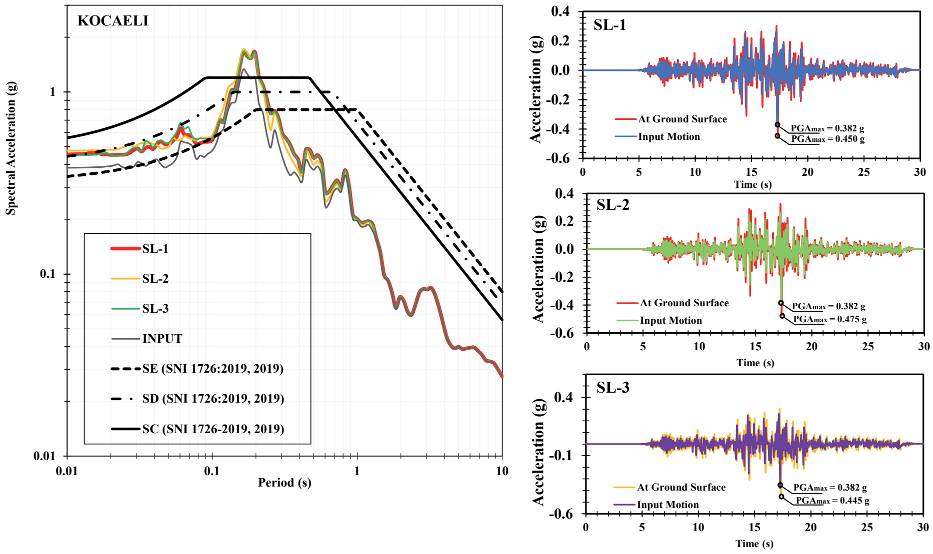
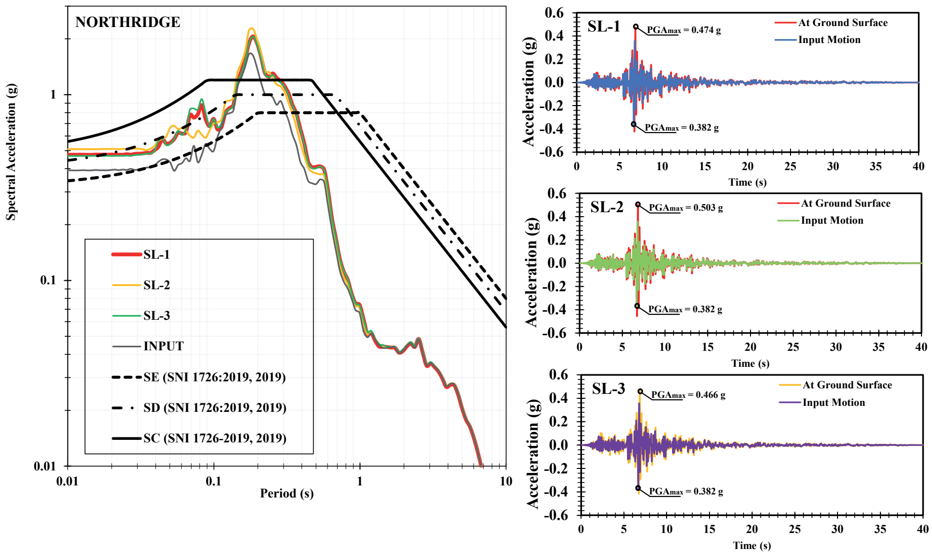


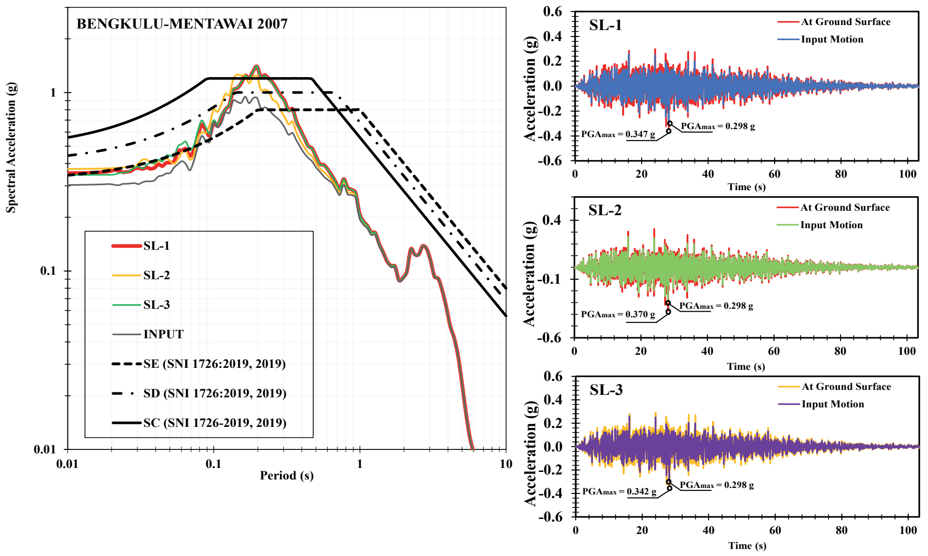
Figure 10. Amplification Factor.



(a)



(b)



(c)

Figure 11. Comparison of spectra acceleration Kocaeli (a), Northridge (b), and Bengkulu-Mentawai 2007 (c).

Spectral Acceleration

A comparison of the design spectra and analyzed spectra at the surface layer can be seen in Figure 11. For the Kocaeli earthquake wave, the ground surface of Selebar district, Bengkulu City, is found to have an SA range at a period of 0.2 seconds of 1.61g to 1.65g. The Northridge earthquake wave generated SA variations of 1.87g to 1.99g. Meanwhile, for the 2007 Bengkulu - Mentawai earthquake waves, the spectra of earthquake acceleration at the surface in the seconds were found to be 1.23g to 1.40g. The resulting acceleration spectra generally exceeded the design spectra for the second. Low-rise buildings tend to experience more significant impacts during large earthquakes. According to Mase (2020), acceleration spectra at 0.2 s may reflect the response of low-rise buildings. This seems realistic as massive damage was found in this area, especially during the Bengkulu-Mentawai Earthquake in 2007 and the Bengkulu-Enggano Earthquake in 2000 (Mase, 2018b). Alluvium, swamp deposits, andesite, and alluvium rocks dominate the geological conditions in the Selebar district of Bengkulu City. These constituent materials are underlain by shallow bedrock, so the spectral acceleration tends to be greater at short periods. Shallower bedrock results in greater spectral acceleration at short periods. The constituent materials are also still categorized as uncompacted materials, which allows for a more significant response during seismic wave propagation.

For the SA period of 1.0 seconds, the 2007 Bengkulu-Mentawai earthquake waves produced the highest spectral acceleration with a range of 0.20g to 0.21g. This could be caused by the duration of the 2007 Bengkulu-Mentawai earthquake waves. The longer duration content of the earthquake waves is predicted to cause the resulting acceleration response values to be more variable, especially at long periods (Misliniyati, 2022). According to Irsyam et al. (2015), the acceleration value at 1.0 s spectral period is used to reflect the response of high-rise buildings.

The results show that the design spectra published by SNI 1726-2019 can still be used as a reference, especially in the extended period. However, in the short period, the acceleration spectra generated by the three earthquake sources have exceeded the design spectra. Therefore, local governments must be careful when granting building permits, especially for buildings that do not consider local earthquake loads in the design.

5. Conclusions

The following are some of the conclusions that can be drawn from this research.

1. The PGA values at the surface layer resulting from the Kocaeli and Northridge earthquake waves of 0.44g - 0.47g and 0.46g - 0.50g have the potential to cause damage impacts with a very high risk, while the 2007 Bengkulu-Mentawai earthquake waves with PGA values of 0.34g - 0.37g have the potential to cause damage with a high risk. From these PGA values, MMI level X is obtained for the Kocaeli and Northridge waves and IX for the 2007 Bengkulu-Mentawai earthquake waves. This considerable PGA value is due to the Selebar district of Bengkulu City, comprising unconsolidated materials. The shallow depth of the bedrock and the minor resistance of the soil at the surface also caused an amplification of 1.22 - 1.31, causing wave enlargements during the propagation of earthquake waves.
2. Based on the one-dimensional seismic response analysis, the design spectral acceleration can still cover the resulting spectral acceleration at long periods. However, the analyzed spectral acceleration quickly exceeded the design spectral acceleration. The proposed design tends to be insufficient to meet the spectral acceleration in the short period. Therefore, using local spectra in building structure design can be a recommendation for local engineers to consider the impact of earthquakes on the central area of Selebar District, Bengkulu City.
3. This research was only conducted at three points in the central area of the District of Selebar, Bengkulu City, representing essential locations in the area. This research also only evaluates earthquake hazards based on the seismic response parameters generated; in the future, it is necessary to conduct research with a larger number of points and conduct research on the interaction between soil and buildings to determine the impact if an earthquake occurs in District Selebar, Bengkulu City.

Acknowledgments

The authors would like to thank Mase's Geotechnical Research Laboratory and Raihan Muhammad S.T. for assisting in collecting and processing the authors' research data.

References

A Hashash, Y. M. (2016). Nonlinear and Equivalent Linear Seismic Site Response of One-Dimensional Soil Columns User Manual. www.illinois.edu/~deepsoil

Farid, M., & Mase, L. Z. (2020). Implementation of seismic hazard mitigation based on ground shear strain indicator for a spatial plan of Bengkulu city, Indonesia. International Journal of Geomate, 18, 199–207. https://doi.org/10.21660/2020.69.24759

Fathani, T. F., Adi, A. D., Pramumijoyo, S., & Karnawati, D. (2008). Determination of Peak Ground Acceleration at Bantul Regency, Yogyakarta Province, Indonesia, in Karnawati, D. (ed), The Yogyakarta earthquake of May 27, 2006. STAR Publishing Company Inc., California, pp. 7-1 to 7-15

Irsyam, M., Hutabarat, D., Asrurifak, M., Imran, I., Widiyantoro, S., Hendriyawan, Sadisun, I., Hutapea, B., Afriansyah, T., Pindratno, H., Firmanti, A., Ridwan, M., Haridjono, S. W., & Pandhu, R. (2015). Development of seismic risk microzonation maps of Jakarta city. Geotechnics for Catastrophic Flooding Events - Proceedings of the 4th International Conference on Geotechnical Engineering for Disaster Mitigation and Rehabilitation, Gedmar 2014, 35–47. https://doi.org/10.1201/b17438-6

Mase, L.Z., Somantri, A.K., (2016). Development of Spectral Response Design for Bengkulu City Based on Deterministic Approach. In: Proceedings of the 20th Annual Meeting of Indonesian Society for Geotechnical Engineering. 15-16 November, Jakarta, Indonesia, pp. 147–152

Mase, L. Z. (2017a). Liquefaction potential analysis along the coastal area of Bengkulu province due to the 2007 Mw 8.6 Bengkulu earthquake. Journal of Engineering and Technological Sciences, 49(6), 721–736. https://doi.org/10.5614/j.eng.technol.sci.2017.49.6.2

Mase, L.Z. (2017b). Study of Liquefaction Mechanism in Chiang Rai Province. Ph.D diss, Chulalongkorn University.

Mase, L. Z., Tetsuo. T., Liketlersuang. S. (2017) One-Dimensional Analysis of Liquefaction Potential: A Case Study In Chiang Rai Province, Northern Thailand. Journal of Japan Society of Civil Engineers, Ser A1 (Structural Engineering and Earthquake Engineering), 73(4), I_135_I_147. https://doi.org/10.2208/jscejseee.73.I_135

Mase, L. Z. (2018). Reliability study of spectral acceleration designs against earthquakes in Bengkulu City, Indonesia. International Journal of Technology, 9(5), 910–924. https://doi.org/10.14716/ijtech.v9i5.621

Mase, L. Z. (2020). Seismic Hazard Vulnerability of Bengkulu City, Indonesia, Based on Deterministic Seismic Hazard Analysis. Geotechnical and Geological Engineering, 38(5), 5433–5455. https://doi.org/10.1007/s10706-020-01375-6

Mase, L. Z., & Likitlersuang, S. (2021). Implementation of Seismic Ground Response Analysis in Estimating Liquefaction Potential in Northern Thailand. Indonesian Journal on Geoscience, 8(3), 371–383. https://doi.org/10.17014/ijog.8.3.371-383

Mase, L.Z., Fathani, T.F., Adi, A.D. (2021). A simple shaking table test to measure liquefaction potential of prambanan area, Yogyakarta, Indonesia. In ASEAN Engineering Journal, 11(3), 89-108. https://doi.org/10.11113/aej.v11.16874

Mase, L. Z. (2022). Local seismic hazard map based on the response spectra of stiff and very dense soils in Bengkulu city, Indonesia. Geodesy and Geodynamics, 13(6), 573–584. https://doi.org/10.1016/j.geog.2022.05.003

Mase, L. Z., & Keawsawasvong, S. (2022). Seismic Hazard Maps of Bengkulu City, Indonesia, Considering Probabilistic Spectral Response for Medium and Stiff Soils. The Open Civil Engineering Journal, 16(1). https://doi.org/10.2174/18741495-v16-e221021-2022-49

Mase, L. Z., Somantri, A. K., Chaiyaput, S., Febriansya, A., & Syahbana, A. J. (2023). Analysis of ground response and potential seismic damage to sites surrounding Cimandiri Fault, West Java, Indonesia. Natural Hazards, 119(3), 1273–1313. https://doi.org/10.1007/s11069-023-06157-w

Misliniyati, R., Sahadewa, A., Hendriyawan, & Irsyam, M. (2019). Parametric study of one-dimensional seismic site response analyses based on local soil condition of Jakarta. Journal of Engineering and Technological Sciences, 51(3), 392–410. https://doi.org/10.5614/j.eng.technol.sci.2019.51.3.7

Misliniyati, R. (2022). Development of Earthquake Hazard Map for Jakarta City by Considering the Influence of Dynamic City Parameters and Bedrock Topography on Seismic Response at the Surface. Ph.D. diss, Bandung Institute of Technology.

Pender, M. J., Orense, R. P., Wotherspoon, L. M., & Storie, L. B. (2016). Effect of permeability on the cyclic generation and dissipation of pore pressures in saturated gravel layers. Geotechnique, 66(4), 313–322. https://doi.org/10.1680/jgeot.SIP.15.P.024

Sari, E. Y., Mase, L. Z., Hardiansyah, H., Misliniyati, R., & Amri, K. (2024). Implementation of the Equivalent Linear and Nonlinear Methods in Predicting the Seismic Response of Kampung Melayu Area, Bengkulu City. Geosaintek Journal, 10(2), 159–172. https://doi.org/10.12962/j25023659.v10i2.1723

SNI 1726-2019 (2019): Earthquake resistance planning procedures for building and non-building structures. National Standardization Agency, Jakarta, Indonesia.

Somantri, A. K., Mase, L. Z., Susanto, A., Gunadi, R., & Febriansya, A. (2023). Analysis of Ground Response of Bandung Region Subsoils due to Predicted Earthquake Triggered by Lembang Fault, West Java Province, Indonesia. Geotechnical and Geological Engineering, 41(2), 1155–1181. https://doi.org/10.1007/s10706-022-02328-x

Sugianto, N., Refrizon, Mase, L. Z., & Anggeraini, S. (2021). The updated zonation of seismic vulnerability index and ground shear strain at Bengkulu City, Indonesia. AIP Conference Proceedings, 2320. https://doi.org/10.1063/5.0037597