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# ANALYSIS OF SOIL DYNAMIC RESPONSE DUE TO EARTHQUAKE IN INDONESIA

*Enden Mina[1], Rama Indera Kusuma[2], Woelandarai Fathonah[3], Restu Wigati[4], Aisi Farhah[5]

[1 2 3 4 5]Civil Engineering Department, Sultan Ageng Tirtayasa University, Indonesia,

*Corresponding Author, Received: June 23, 2021, Revised: August 27, 2021, Accepted: 30 Jan, 2022

**ABSTRACT:** Tangerang is one region in Banten Province Indonesia that has high earthquake potential because its located in the confluence zone of three continental tectonic plates that are continuously moving actively. Analysis of soil dynamic response is important as the first step in the earthquake-resistant structure's design. This study is aimed to give some descriptions of soil dynamics response results from a certain area due to seismic impulse. Seismic hazard analysis in this study used the Probabilistic Seismic Hazard Analysis (PSHA) method, while the earthquake acceleration profile and their response spectra have resulted from analysis of wave propagation theory with the assistance of NERA software. Based on the analysis result it can be concluded that the characteristics of the soil for the Tangerang region can be categorized as medium soil class. Earthquake acceleration value at bedrock was obtained in a range of values between 0.11g to 0.21g (g= gravity acceleration), while at the ground surface, the acceleration value was in the range of 0.18g to 0.38g. Based on the seismic zones, Tangerang Region can be included in the yellow zone according to the Indonesian Earthquake Map.

*Keywords: Seismic hazards analysis, Earthquake, Acceleration, Soil dynamic properties*

## 1. INTRODUCTION

The Indonesian region has relatively complex seismic activities with a high frequency of earthquake events. According to the Indonesian Climatology and Geophysics Meteorology Agency, it is stated that the southern coast of Banten Province is categorized as an earthquake-prone zone, where the Tangerang area is included. In general, some deformations that occurred in western Java have resulted from tectonic activities of subduction zones along the Javanese trench and active faults on Java island which became the source zone for earthquake events in this area [5].

According to Mahesworo [1] the efforts to reduce the risk of an earthquake disaster in one area is to explore and analyze all potential earthquake hazards, the preventive measures can be made through the design process and build earthquake-resistant structures. In the design process, one thing that must take into account is the level of earthquake hazard, by considering geological aspects, geotechnical aspects, and structural aspects of the building.

Seismic load in structure design is represented by the value of the earthquake acceleration parameter. Site-specific response spectra analysis of earthquake is a method to obtain earthquake acceleration on the ground surface through the theory of seismic wave propagation by taking into account local soil conditions that affect the earthquake velocity.

Through the process of seismic hazard analysis earthquake magnitudes are obtained that represent the magnitude of earthquake events for the Tangerang Region, the analysis used the probabilistic method which is known as probabilistic seismic hazard analysis (PSHA). The application of the PSHA method has been widely used by previous researchers such as in Sumatra Islands [7] and Japan [16]. The earthquake magnitude value (M) and rupture distance (R) from analysis results were then used as a parameter to obtain earthquake events data. The time history data is one of the important inputs in the NERA Program. Because the Indonesian region didn’t have any recorded time history data for earthquake events then the alternative method was used using the time history data from other locations then scaled according to parameters of bedrock movement. Several studies relating to soil site-specific response spectra and seismic hazards in Indonesia have been conducted for the Cilegon Banten region [2], for Bandung Region [3], and the Padang region [4].

## 2. RESEARCH SIGNIFICANCE

Analysis of soil dynamic response of one specific site can make it easier to estimate the effect of earthquakes in the area and provide more complete information about earthquake response data at the location as one of the input loads in the seismic-resistance structure design. The purpose of this study is to obtain soil dynamic responses for specific sites, the parameter of soil dynamic responses included the shear modulus profile, shear wave velocity, and earthquake acceleration profile from bedrock to the ground surface, which resulted from one dimension shear wave propagation analysis using Nonlinear Earthquake Site Response Analysis (NERA) Software.

## 3. LITERATURE REVIEWS

Sengara et. al. [5] developed earthquake micro zonation for Jakarta Capital Territory. For the Jakarta area, the earthquake acceleration value on the surface ranges from 0.26g to 0.31g with an amplification factor of around 1.2 to 1.6 for a 500 year return period. Whereas for the 2500 years return period the PSA (peak surface acceleration) values varied between 0.33g to 0.49g with amplification factors ranging from 0.9 to 1.4. The results of this analysis are then mapped in the form of accelerated contours and amplification contours in the earthquake micro zonation map in DKI Jakarta. Ridwan [3] conducted site-specific earthquake responses for Serang, Sukabumi, Cilacap, and Wonogiri areas by using the results of drilling and SPT data tests.

### 3.1 Site Specific Response Analysis

Concern about the interaction between structures of underground buildings and soil conditions due to earthquake activity is more significant today due to the high seismic activity in Indonesia. Interactions that occur can be in the form of the influence of seismic loads on the dynamic response of the underground structure or vice versa, such as the influence of soil condition on the behavior of earthquake wave propagation from the bedrock to the surface.

Referring to Irsyam et al. [6] and Aldiamar [7], analysis of site-specific Response spectra due to earthquake, in general, can be carried out in two stages, as follows :

a. Seismic hazard analysis in certain sites was determined based on all earthquake source data and time history earthquake data.
b. Analysis of wave propagation from bedrock to surface based on local soil parameters both from field test results and laboratory test results to determining seismic acceleration on the ground surface.

In this study, the seismic hazard stage was carried out using probability analysis to produce the earthquake magnitude (M) and Rupture distance (R) which has the most probability of occurrence by taking earthquake events with a return period of 500 years. The Second Stage was carried out using the NERA software using soil parameters data from field tests such as soil penetration test (SPT) and laboratory test results.

### 3.2 Seismic Hazard Analysis

McGuire (1993) [8] stated that seismic hazard analysis aimed to determine a certain earthquake intensity limit applied in one area based on a probability value that will occur or exceed at a certain period. Seismic hazard analysis is a method of analysis to determine the probability of ground motion (shaking) event at a certain level caused by an earthquake and calculated based on all earthquake source data and historical earthquake data that has occurred in certain sites.

Output results of seismic hazards analysis can illustrate the possibility of an earthquake intensity (acceleration, velocity, duration of shocks, and so on) within a certain period, during the useful life of a building. Seismic hazard analysis can be conducted in two methods, the Deterministic Seismic Hazard Analysis (DSHA) method when a certain earthquake scenario has been determined and the Probabilistic Seismic Hazard Analysis (PSHA) method that considers uncertainty in magnitude, location, and time of earthquake event.

The fundamental difference between the probabilistic method and the deterministic method is in how to treat earthquake magnitude as one of the calculation parameters. In the deterministic context, a credible maximum magnitude is determined, while in the probabilistic context it used the recurrence correlation of earthquake magnitude. Exposure analysis has been carried out in the utilization of the PSHA method combined with population distribution maps in Japan [16].

### 3.3 Ground Motion Database

The earthquake data records in Indonesia are more in the form of information about the location of the epicenter, magnitude, depth, and mechanism while in the form of time history data are still lacking because the numbers of earthquake recording stations in Indonesia are still very few when compared to the total area of Indonesia. The selection of ground motion data is important in wave propagation analysis from bedrock to the ground surface. The data is in the form of digitized data of the time history of earthquake acceleration. The most important thing to get accurate results is the selection of time history data that is suitable for the specific geological and seismological conditions of the site. If the location does not have its time history data, then three alternative methods can be used to obtain the time history digitization data in the bedrock, as follows:

a. Using acceleration time history data from areas that have geological and seismological conditions that are close to or similar to the location of the study.
b. Using an acceleration time history from another location which is then scaled according to the target parameters of the bedrock movement (maximum acceleration and period).
c. Make synthetic acceleration time history data that is adapted to the geological and seismological conditions of the study site.

The time history data selection method that is widely used in Indonesia is the method in points (b) and (c) because the earthquake events in Indonesia do not have time history data records. The PEER (Pacific Earthquake Engineering Research) database has a collection of ground motion data that is most widely recorded from around the world in active tectonic areas [18]. This database has one of the most comprehensive sets of metadata, including various distance measurements, various site types, and earthquake source data.

### 3.4 Shear Wave Propagation analysis

During earthquakes, waves will propagate from the bedrock to the ground surface then amplification or de amplification will occur. The travel of wave propagation is strongly influenced by the dynamic nature of the soil traversed by the earthquake wave. The influence of local soil conditions has been discussed by several researchers. Almost all researchers have assumed that the main response is caused by the propagation of shear waves from the bedrock to the ground surface. In this study, Analysis of earthquake wave propagation from bedrock to the ground surface using one-dimensional wave propagation theory with the assistance of NERA [9]. The Inputs needed in the NERA program are soil stratification data, soil density, and shear wave velocity parameters. In this study, shear wave velocity (Vs) value was obtained from empirical correlations with N-SPT data from field tests for several locations. Previous researchers have developed correlations between Vs and N SPT value [10],[11], [12], [13], [14], some correlations are shown in Table 1.

Table 1 Empirical correlation from N SPT value (for all types of soil) [15]

| Reference | Gmax(Kpa) | Vs(m/s) |
|---|---|---|
| Ohsaki & Iwasaki [10] | $11500N^{0.8}$ | |
| Ohta & Goto [11] | | $85.3\ N^{0.34}$ |
| Imai & Tonouchi [12] | $14070N^{0.68}$ | $96.9\ N^{0.314}$ |

## 4. RESULTS AND DISCUSSIONS

### 4.1 Data and Study Area

In this study, Sample data consisted of earthquake events data and soil investigation data from field and laboratory test results. The study areas were taken from four locations in the Tangerang region. The location and radius zone for collected seismic data for this study are shown in Figure 1. Sample data were obtained from four locations in Tangerang Region: Muhammadiyah University area (UMT) with coordinates (6°11'30"S, 106°37'50"E), H Apartment Residence with coordinates (6°09'34"S, 106°37'53"E), LV Apartment Residence with coordinates (6°13'37"S, 106°36'25"E), and East Taxiway of Soekarno Hatta International Airport with coordinates (6°07'31"S, 106°39'13"E) [20].


Fig.1 Location of study (*Source: Google map, 2018)*

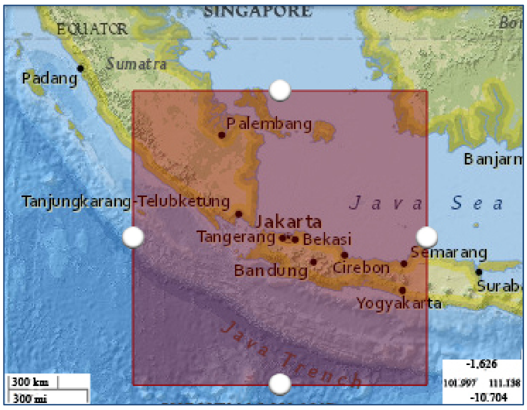
### 4.2 Seismic Hazards Analysis Results

Earthquake data such as earthquake magnitude (M) data, tectonic maps, and earthquake source events were collected from the USGS (United States Geological Survey) data catalog [17]. The method of seismic hazards analysis uses a probabilistic method known as Probabilistic Seismic Hazard Analysis (PSHA). This analysis resulted in the magnitude (M) and rupture distance (R) that can be represented as seismic data for the Tangerang region. the magnitude (M) and R data are needed in a way to search ground motion time history data. Because ground motion data records weren't available in Indonesia, then the alternative way was used to obtain them from other locations and scaled according to the target bedrock movement for Tangerang Region.

The earthquake events data were taken from the USGS earthquake data source from 1917 to 2019. Those are collected from numbers of points in a radius of 500 km from the location point as in

Figure 2. The results of data collection from the earthquake catalog of USGS obtained 1159 earthquake events that have a magnitude more than 5.0 and a maximum depth of 300 km. Earthquake data was used during the last 100 years, from January 1917 and most recently in December 2019. Earthquake event data from the USGS catalog consisted of a time of occurrence, location, depth of earthquake source point, earthquake magnitude, and earthquake mechanism.

Statistic and probability concept in analyzing data was applied through the magnitude scale conversion stage, dependency analysis to sort out the main earthquake (mainshock) and the aftershock, and in determining the epicenter and hypocenter distance of the earthquake source and the modeling of the earthquake source zone and its mechanism.




Source: Google Maps, 2018

Fig.2 Radius Boundary of seismic event For Tangerang Region


Source: USGS Catalog,2018

Fig.3 Distribution of point of earthquake event around Tangerang Region

The distribution of location points of earthquake events is shown in Figure 3 based on two types of mechanism: earthquake subduction mechanism from megathrust sources and fault mechanism from shallow crustal sources. Subduction source events are caused by collision movements between tectonic plates that occur along with the islands of Sumatra and Java, while the fault mechanism source events are caused by faults or cracks that occurred above the tectonic plates that underlie the islands of Sumatra and Java.

Seismic hazard analysis was carried out using the PSHA method for earthquake data with a return period of 500 years. The concept of this method uses total probability theory by calculating earthquake risk based on a collection of all earthquake events. The results of seismic hazard analysis are the magnitude M and the rupture distance R of earthquake sources which are dominant for a certain location. Dominant means the one that contributes the greatest danger to a location for certain return periods and certain building structure periods. Based on seismic hazard analysis using the PSHA method, recapitulation of the results of analysis of frequencies of M and R are shown in Table 2 and Table 3 for subduction earthquake mechanism.

Table 2. Recapitulation of magnitude frequency for subduction mechanism earthquake

| Range Interval M | Frequency of event | Cumulative Frequency M>5 |
|---|---|---|
| 5.00 - 5.29 | 87 | 782 |
| 5.29 - 5.58 | 100 | 695 |
| 5.58 - 5.87 | 461 | 595 |
| 5.87 - 6.16 | 98 | 134 |
| 6.16 - 6.45 | 24 | 36 |
| 6.45 - 6.74 | 6 | 12 |
| 6.74 - 7.03 | 2 | 6 |
| 7.03 - 7.32 | 0 | 4 |
| 7.32 - 7.61 | 2 | 4 |
| 7.61 - 7.90 | 2 | 2 |

Table 3. Recapitulation of rupture distance frequency of subduction mechanism earthquake

| Range Interval R | Frequency of event | Probability |
|---|---|---|
| 111.46 - 167.38 | 89 | 0.11 |
| 167.38 - 223.30 | 71 | 0.09 |
| 223.30 - 279.22 | 82 | 0.10 |
| 279.22 - 335.13 | 85 | 0.11 |
| 335.14 - 391.06 | 73 | 0.09 |
| 391.07 - 446.99 | 141 | 0.18 |
| 446.99 - 502.89 | 128 | 0.16 |
| 502.89 - 558.81 | 91 | 0.11 |
| 558.81 - 614.73 | 16 | 0.02 |
| 558.81 - 614.73 | 6 | 0.01 |
| Total | 782 | 1 |

Based on Table 2, it can be seen that the frequency of magnitude more than 5 Richter Scale which has the highest frequency is Magnitude 5.5 – 5.8. The highest Magnitude is 7.0 – 7.9 Richter scale. The results of analysis probability for rupture distance R are shown in Table 3. Based on Table 3, it can be seen that the highest frequency of rupture distance R is at 391.07 - 446.99 kilometers. The nearest distance is 111.46 – 167.38 kilometers. The results of analysis Probability for Magnitude M generally is shown in Table 7

Table 4. Analysis results of magnitude probability subduction mechanism earthquake

| Center Value M | Fm | PM = Fm * Delta M | %PM |
|---|---|---|---|
| 5.14 | 1.04 | 0.30 | 30.0 |
| 5.43 | 0.73 | 0.21 | 21.3 |
| 5.72 | 0.51 | 0.15 | 15.0 |
| 6.01 | 0.36 | 0.10 | 10.6 |
| 6.30 | 0.26 | 0.07 | 7.5 |
| 6.59 | 0.18 | 0.05 | 5.3 |
| 6.88 | 0.13 | 0.04 | 3.8 |
| 7.17 | 0.09 | 0.03 | 2.7 |
| 7.46 | 0.06 | 0.02 | 1.9 |
| 7.77 | 0.04 | 0.01 | 1.3 |

Using analysis of probabilities of earthquake occurrences, it can be concluded that the magnitude probability analysis results are presented in Table 4. Based on Table 4, the maximum Magnitude value for collected earthquake events for subduction mechanism in Tangerang Region is 7.7 Richter Scale with 1.3 % Probability. The highest probability is 30.0 % magnitude values 5.1 Richter scale as the most frequently to happen in this Region.

Table 5. Recapitulation of magnitude frequency for fault mechanism earthquake

| Range Interval M | Frequency of event | Cumulative Frequency M>5 |
|---|---|---|
| 5.00 – 5.24 | 30 | 181 |
| 5.24 – 5.48 | 9 | 151 |
| 5.48 – 5.71 | 76 | 142 |
| 5.71 – 5.95 | 42 | 66 |
| 5.95 – 6.19 | 11 | 24 |
| 6.19 – 6.43 | 6 | 13 |
| 6.43 – 6.66 | 5 | 7 |
| 6.66 – 6.90 | 2 | 2 |
| Total | 181 | |

The recapitulation of the results M and R for fault mechanism is presented in Table 5 and Table 6 and the result of the probability analysis of the magnitudes is presented in Table 7. Based on Table 5, it can be seen that the frequency of magnitude more than 5 Richter Scale which has the highest frequency is Magnitude 5.5 – 5.7. The highest magnitude is the 6.4 – 6.9 Richter scale. The results of analysis Probability for rupture distance R are shown in Table 6.

Table 6. Recapitulation of rupture distance frequency of fault mechanism earthquake

| Range Interval R (kilometers) | Frequency of event | Probability |
|---|---|---|
| 59.90 - 138.31 | 36 | 0.19 |
| 139.31 - 217.73 | 35 | 0.19 |
| 218.73 - 297.14 | 23 | 0.13 |
| 298.14 - 376.55 | 10 | 0.05 |
| 377.55 - 455.97 | 21 | 0.12 |
| 456.97 - 535.38 | 36 | 0.19 |
| 536.38 - 614.79 | 12 | 0.07 |
| 615.79 - 694.20 | 8 | 0.04 |
| Total | 181 | 1 |

Based on Table 6, it can be seen that the highest frequency of rupture distance is at 456.97-535.38 kilometers. The nearest distance is 59.90 – 138.31 kilometers. The results of analysis Probability for Magnitude M generally are shown in Table 7.

Table 7. Analysis results of magnitude probability for fault mechanism earthquake

| Center value M | Fm | PM = Fm * Delta M | % PM |
|---|---|---|---|
| 5.12 | 1.07 | 0.25 | 25.4 |
| 5.36 | 0.83 | 0.19 | 19.8 |
| 5.59 | 0.65 | 0.15 | 15.5 |
| 5.83 | 0.50 | 0.12 | 12.1 |
| 6.07 | 0.39 | 0.09 | 9.4 |
| 6.30 | 0.31 | 0.07 | 7.3 |
| 6.54 | 0.24 | 0.06 | 5.7 |
| 6.78 | 0.19 | 0.04 | 4.5 |

The maximum Magnitude value for collected earthquake events for fault mechanism is 6.7 Richter Scale with 4.5 % Probability as shown in Table 7. The highest probability is 25.4 % magnitude values 5.1 Richter scale as the most frequently to happen in this Region.

By using statistics and probabilistic concepts and the Gutenberg Richter method, it can be concluded that the value of earthquake magnitude (M) that representative for Tangerang Region was between 6.8 to 7.7 Richter scale for subduction mechanism earthquake, while for fault mechanism the magnitude resulted in 6.5 to 6.7 Richter scale. The rupture distance (R) that represents the earthquake event for the subduction earthquake mechanism was 111.6 km to 167.3 km and for the fault mechanism was 59.9 km to 138.32 km, those results can be shown in Table 8.

Table 8. The Magnitude Value M and Rupture Distance R based on PSHA method For Tangerang Region

| Earthquake mechanism | Rupture distance (km) | Magnitude (M) |
|---|---|---|
| Subduction | 111.5 – 167.3 | 6.8 – 7.8 |
| Fault | 60 – 139 | 6.5 – 6.7 |

(Source: Author, 2020)

### 4.2 Site Specific Response Analysis

One-dimensional wave propagation analysis using NERA software program carried out for 19 data points of the soil investigation results from Standard Penetration Test. Because there was no shear wave velocity data available from direct field tests, the correlation then was used using the N SPT values data as an input parameter of the soil profile in the NERA program. Besides the shear modulus and damping ratio profile, the output of this analysis results was displayed in earthquake acceleration, velocity and,d displacement profile from bedrock to the surface, amplification value with their amplification graph and the last is profiles of responses of the acceleration spectra, velocity, and movement of each point. Based on the results we can conclude the value of seismic acceleration for a certain site is more specific. In this stage, the time history data for ground motion is needed as input in analysis wave propagation from bedrock to the ground surface. Because in Indonesia Region the earthquake events mostly don't have time history data records, then the alternative ways are taken from another location and scaled with target parameter. Pacific Earthquake Engineering Research (PEER) provided a world catalog of ground motion data for earthquake events. Based on search results and scaled parameter with magnitude dan rupture distance, it can be concluded that the earthquake events of Borrego Mountain in 1968 dan Chichi Taiwan in 1999 can be used as ground motion source data for subduction mechanism in Tangerang Region, while for fault mechanism the ground motion data are taken from Northwest California-02 earthquake event in 1941 and Northridge-01 earthquake event in 1994. Table 9 and Table 10 show the results search for earthquake events that represent sources of ground motion data at bedrock taken from the PEER catalog. Search results for each earthquake event data resulted in ground motion data such as time-history data.

Table 9. Recommended ground motion data events for megathrust earthquake source

| Earthquake event | Mw | Rrup (km) | Stations |
|---|---|---|---|
| Borrego Mtn. (1968) | 6.63 | 129.11 | San Onofre |
| Chichi Taiwan (1999) | 7.62 | 152.65 | KAU039 |

Table 10. Recommended ground motion data events for shallow crustal earthquake source

| Earthquake event | Mw | Rrup (km) | Stations |
|---|---|---|---|
| Northwest Calif-02 (1941) | 6.6 | 91.22 | Femdale City Hall |
| Northridge-01 (1994) | 6.69 | 85.9 | Phelan-Wilson Ranch |

The time-history data from each event were displayed as graphs of ground motion such as shown in Figure 4 from the Borrego Mt earthquake event, Fig.5 from Chichi Taiwan 1991, Fig. 6 for Northridge-01 1994, Fig.7 for the Northwest California-02 1941 earthquake event. The time history data for earthquake events that represented Tangerang Region are used as input of seismic analysis of response spectra using NERA software. Through NERA software, time history data of ground motion was propagated based on soil conditions at each point of investigation. Based on propagation wave theory, the acceleration propagated from based to surface resulted in amplification or de amplification of acceleration. The output included propagation wave results such as earthquake acceleration profile from bedrock to the ground surface, amplification or de amplification ratio values, and spectral responses.

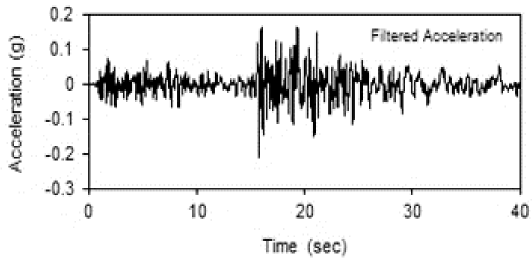



Fig. 4 Ground motion display for Borrego Mt. 1968 earthquake Event

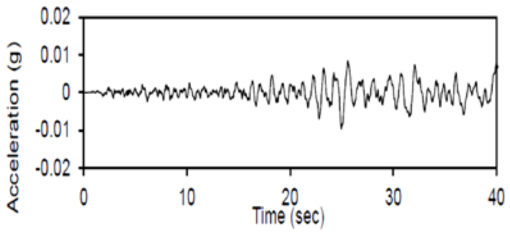



Fig.5 Ground motion display for Chichi Taiwan 1991 earthquake Event

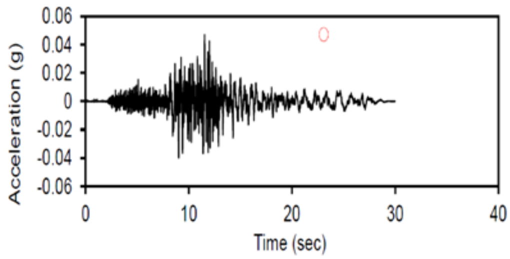



Fig.6 Ground motion display for Northridge-01 1994 earthquake Event

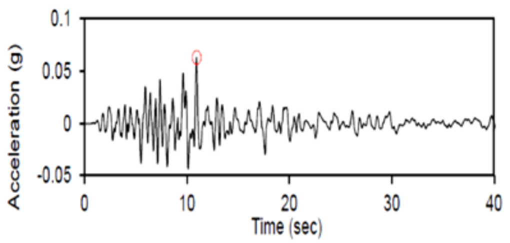



Fig.7 Ground motion display for Northwest California-02 1941 earthquake Event

### 4.3. Soil Site Classification

Soil classification in this study was determined based on boring test results from 19 investigation points from four locations in the Tangerang area. Based on the N SPT value it can be concluded that the soil can be divided into three soil categories which are for the average N SPT less than 15 is categorized as soft soil, for N SPT between 15 and 50 is categorized as medium soil and for N SPT average above of 50 is categorized as hard soil according to Indonesian Earthquake Regulations. Soft soil categories are generally found in UMT Location and H Residence Apartment area. Medium soils are found in the LV North Mass Residence area, and East Crossway Soekarno Hatta Airport. Shear wave velocity profile (Vs) by depth is made based on N SPT values using correlation which are developed by several researchers such as shown in Table 1.

Sample Input data of soil parameters in the NERA program are shown in Table 11 and Figure 8. Profile of shear wave velocity and N SPT value based on soil depth are shown in Figure 9 and Figure 10 that represent 19 points of investigation from four locations in the Tangerang Region.

Table 11. Sample input of soil parameters in NERA Program

| Layer | Soil Type | Thickness Of layer (m) | Gmax (Mpa) | Shear Wave Velocity (m/s) |
|---|---|---|---|---|
| 1 | 1 | 2.5 | 51.98 | 178.52 |
| 2 | 1 | 2.0 | 56.52 | 186. 16 |
| 3 | 2 | 2.0 | 150.70 | 278.94 |
| 4 | 1 | 2.0 | 56.52 | 186.16 |
| 5 | 1 | 2.0 | 72.92 | 211.44 |
| 6 | 1 | 2.0 | 87.35 | 231.43 |
| 7 | 1 | 2.0 | 106.69 | 255.76 |
| 8 | 2 | 2.0 | 150.70 | 278.94 |
| 9 | 2 | 2.0 | 175.62 | 301.12 |
| 10 | 2 | 2.0 | 193.00 | 315.67 |
| 11 | 2 | 2.0 | 212.17 | 330.97 |
| 12 | 2 | 2.0 | 212.17 | 330.97 |

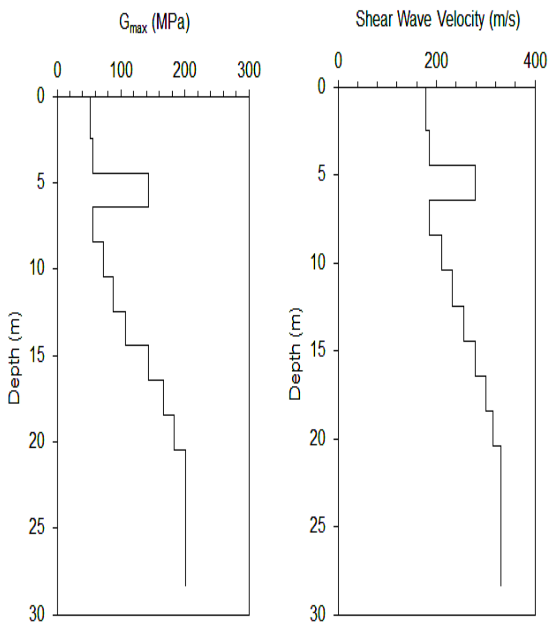



Fig. 8 One of display of shear modulus maximum (Gmax) profile and shear wave velocity (Vs) profile from bedrock to surface

Figure 8 shows the profile of shear wave velocity (Vs) and maximum shear modulus (Gmax) by depth. The Vs profile is taken based on the N SPT value using empirical correlation as shown in Table 1. The Gmax value is obtained based on its relationship with the Vs value which depends on the density of the soil. Figure 9 shows the Vs profile by depth for all points of investigation in each location.

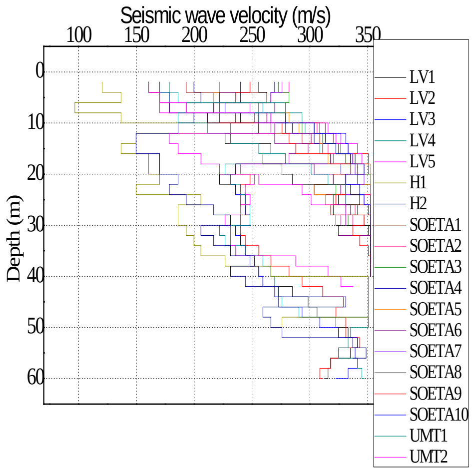



Fig.9 Shear wave velocity (Vs) profile for each point location study in Tangerang Region

Figure 10 shows the N SPT profile by depth for all points of investigation in each location study**.** Based on Figure 10, the value of shear wave velocity has a minimum value of 120 m/s at the ground surface and a maximum value value of e 350 m/s at hard soil layer.

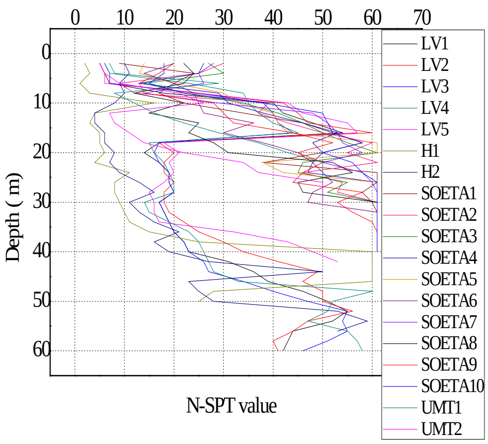



Fig.10 N SPT profile for each point location study in Tangerang Region

Based on Figure 10, at the depth of 20 meters, the N SPT value starts to increase indicating that the hard soil layer mostly began at a depth of 20 meters. But at some locations, hard soil layers could be found at a depth of 40 meters.

### 4.4. Response Spectra Results

4.4.1. *Response Spectrum Subduction Mechanism Earthquake.*

For the Subduction Mechanism, the earthquake acceleration profile from bedrock to the ground surface of four locations was summarized in Figure 11 and Figure 12. Using ground motion data input from Borrego Mt 1968 earthquake event and Chichi earthquake 1991 event, the acceleration response spectra are presented in Figure 13 and Figure 14.

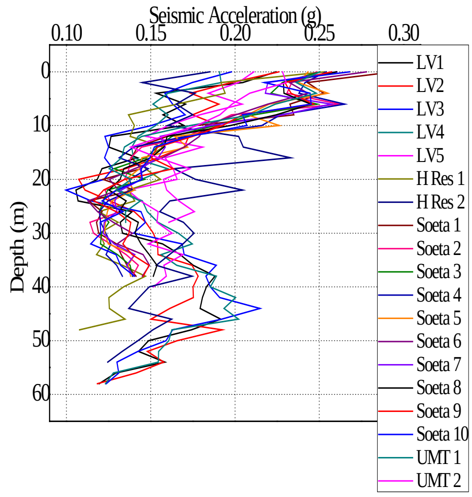



Fig.11 Profile of earthquake acceleration using ground motion data of Borrego Mt. 1968 earthquake event

Based on Figure 11 and Figure 12, it can be concluded that seismic acceleration at bedrock is between 0.108g to 0.208g, while at the ground surface is between 0.185g to 0.38g. The acceleration increases in value with amplification factor values in a range between 5.42 to 42.25. the amplification factor values can be seen in Table 11

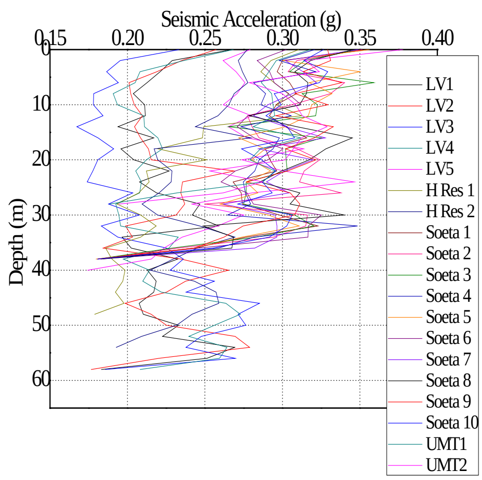



Fig.12 Profile of earthquake acceleration using ground motion data of Chichi Taiwan 1991 earthquake event

The earthquake acceleration response spectra graph in Figure 13 showed that acceleration value on the surface at a period time (T) = 0.0 seconds has a range value between 0.185g to 0.294g, for T= 0.2 s has the value between 0.366g to 0.809 g, and for T= 1 s has the value between 0.242g to 0.330g.

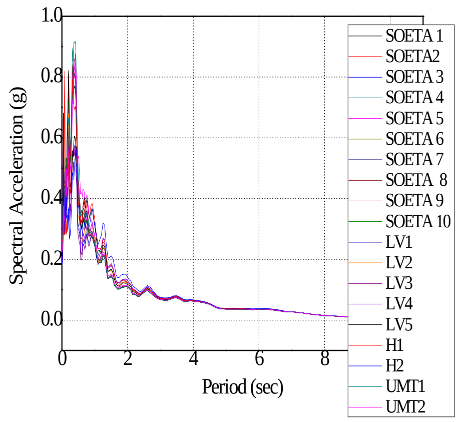



Fig.13 Response spectra using ground motion data of Borrego Mt 1968 earthquake event.

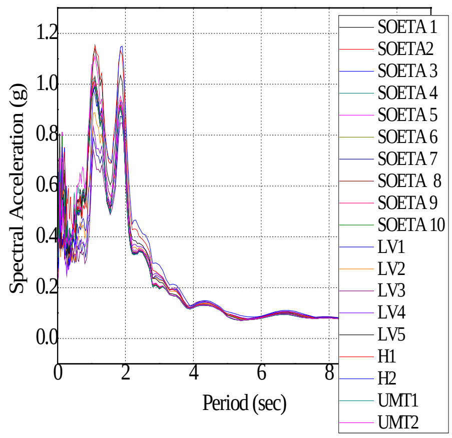



Fig.14 Response spectra using ground motion data of Chichi Taiwan 1991 earthquake event

Figure 14 shows the response spectra graph for acceleration at the ground surface using ChiChi Taiwan 1991 earthquake event ground motion data input for subduction mechanism. It Shows that the acceleration at period time T= 0.0 has value in a range 0.233g to 0.378 g, and for T= 0.2s has value in a range between 0.314g to 0.752g, and for T = 1s has value in a range between 0.633g to 1,076g.

4.4.2. *Response Spectrum Shallow crustal Mechanism Earthquake*

For the fault mechanism, the acceleration profile from the bedrock to the ground surface for 19 points reviewed is presented in Figure 15 and Figure 16 using the input events of the Northwest California02 1941 earthquake event and Northridge earthquake event 1994**.** The acceleration response spectra are presented in Figure 17 and Figure 18.

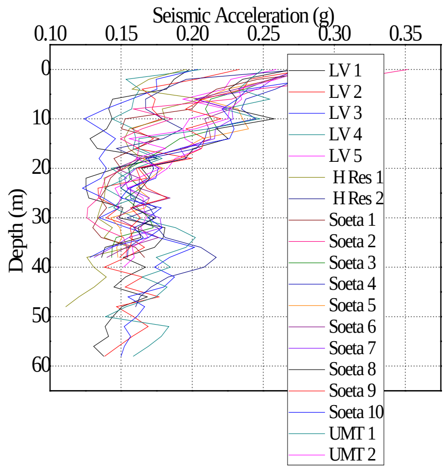
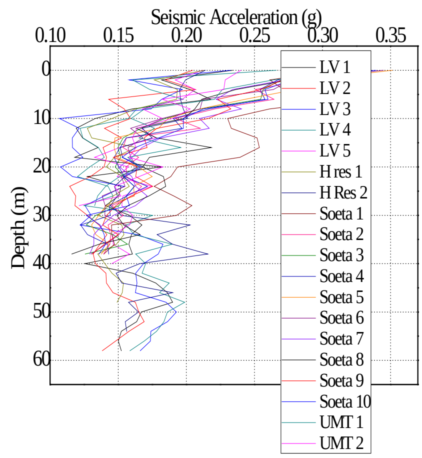



Fig.15 Profile of earthquake acceleration using ground motion data of Northridge-01 1994 earthquake event.

Based on Figure 15 and Figure 16, it can be concluded that seismic acceleration at the ground surface for this location is between 0.195g to 0.351g. The acceleration at bedrock is between 0.111g to 0.166g. The acceleration increases in value with amplification factor values in a range between 5.42 to 42.25. the amplification factor values can be seen in Table 11.




Source: Author, 2020

Fig.16 Profile of earthquake acceleration using ground motion data of Northwest California-02 1941 earthquake event.

Figure 17 shows response spectra of seismic acceleration at the ground surface using ground motion data from the Northridge-01 earthquake event. It shows that at a time period (T)= 0.0 seconds the acceleration is between 0.195g to 0.297g, for T = 0.2 seconds between 0.317g to 0.863g, and at T = 1 seconds the value is 0.366g to 0.526g.

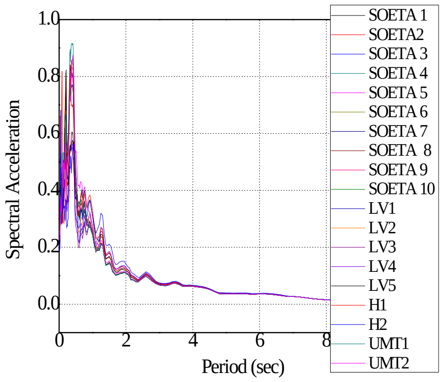



Fig.17 Response spectra of acceleration at the ground surface using ground motion data of Northridge-01 1994 event (Source: Author, 2020)

Figure 18 shows response spectra of the earthquake acceleration spectra at the ground surface using ground motion data from the Northwest California-02 earthquake event. It shows that earthquake acceleration values at time period T = 0.0 seconds is between 0.205g to 0.351g, for T = 0.2 seconds has value 0.256g to 0.756g, and at T = 1 second the value is between 0.114g to 0.477g.

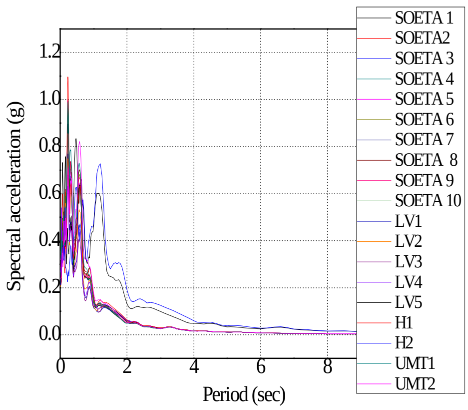



Fig.18 Response spectra of acceleration at the ground surface using ground motion data of Northwest California-02 1941 event (Source: Author, 2020)

In this area study, it can be concluded that the acceleration at bedrock is between 0.108g to 0.208g. The earthquake acceleration on the surface is between 0.185g - 0.378g with an amplification factor value between 5.48 to 42.25.

The seismic acceleration value at bedrock can be categorized as blue zone according to SNI 1726: 2012, while at the ground surface the acceleration value can be categorized in the yellow zone for seismic risk according to SNI 1726: 2012 [19].

Table 12. Earthquake acceleration value from Bedrock to surface for the study area

| Location | Acceleration at Bed rock (g) | | Acceleration At ground Surface (g) | |
|---|---|---|---|---|
| | min | max | min | max |
| UMT | 0.121 | 0.195 | 0.228 | 0.378 |
| LV Apart. | 0.118 | 0.208 | 0.191 | 0.279 |
| H. Res Apart | 0.108 | 0.193 | 0.183 | 0.311 |
| Soeta Airport | 0.116 | 0.183 | 0.243 | 0.356 |

g= acceleration of gravity (Source: Author 2020)

Summary of recapitulation of acceleration value at bedrock and the ground surface for every location is shown in Table 12. The acceleration at the ground surface at Soeta Airport has the highest value at 0.356g and the lowest value at 0.183g from H Residence Apartment location.

Table 13. Amplification values for each study area

| Location | Maximum Amplification | |
|---|---|---|
| | min | max |
| UMT | 9.26 | 27.63 |
| LV Apart. | 8.05 | 13.66 |
| H. Res Apart | 5.48 | 12.61 |
| Soekarno Hatta Airport | 6.88 | 42.25 |

The amplification factor values for each location in this area study are shown in Table 13. The amplification factor is a result of the comparison between the seismic acceleration value on the surface to the acceleration value at the bedrock. In this study, the acceleration increased after it propagated through the soil layer conditions in those locations.

## 5. CONCLUSIONS

Based on soil dynamic properties data, site soil classification for Tangerang Region can be classified from soft to medium soil. The earthquake event data according to PSHA method results, the value of magnitude that represented earthquake event that has high risk in this location is between magnitude 6.5 to 7.7, while rupture distance of earthquake source is between 59.9 kilometers to 167.8 kilometers. Based on the results of spectra response analysis using the NERA program the earthquake acceleration values at bedrock for the Tangerang region are between 0.108g to 0.208g for exceeding probability 10% in 50 years or 500 years return period. At the ground surface, the seismic acceleration values are between 0.185g to 0.378g which are included in the yellow zone according to the earthquake map in Indonesia SNI1726: 2012.

## 6. SUGGESTIONS

Future studies are expected to use more earthquake history data from various earthquake catalog sources and use analysis support programs or software such as SEISRISK III, USHA PSHA or Open SHA Program, Ez-Frisk, EQ-Risk, CRISIS 2007, etc. in conducting hazard analysis earthquake so that it has a comparison of results. More extensive and evenly distributed land survey results are suggested for the study area so micro zonation can be carried out in the region which is very useful for earthquake-resistant building infrastructure planning, land use management, estimation of building damage, and fatalities**.**

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