Spectral matching and propagation ground motion earthquake from bedrock to surface

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Abstract: Ground motion earthquake is the acceleration data of ground during the earthquake. The tool used to obtain this data is called the accelerogram. In Indonesia, this data is difficult to obtain due to the limitations of the tool. It needed to analyze high-rise building because analysis structure of high-rise building used the dynamic load from the earthquake. This data is important in analyzing earthquake-resistant buildings. Besides from the accelerograms tool, this data can be obtained through seismic hazard analysis process. This was obtained by taking ground motion from elsewhere and then uniforming the spectrum response results with the location being reviewed. Wave propagation from bedrock to the soil surface will see the amplification process so this needs to be reviewed as well. Based on seismic hazard analysis results obtained ground motion suitable for matching process is San Fernando 1971. Peak ground acceleration on bedrock obtained is about 0.2608 g. After wave propagation to the surface, the peak ground acceleration is about 0.3001 g. Based on that, Amplification factor earthquake waves is about 1.12.

Keywords: Seismic Hazard Analysis, shallow crustal, ground motion.

1. Introduction
High-rise Building Structure must be analyzed using a dynamic load. Ground motion acceleration earthquake is one of the dynamic loads that used for building structural analysis. Structure analysis using ground motion acceleration earthquake is rarely done because the data is difficult to obtain. Generally, ground motion acceleration data is adopted from earthquake recording elsewhere without the process of matching because it is difficult. This way should not be done because a character of ground motion acceleration is not the same. So in this study, the response of high-rise building structure was evaluated using the ground motion acceleration that comes from the analysis of earthquake hazard using PSHA method.

Ground motion acceleration that used is the result matching of earthquake data in bedrock based on hazard de-aggregation analysis. Then the ground motion data in the bedrock is vertically propagated to obtain ground motion acceleration data at the surface. Ground motion acceleration at ground level is used in the evaluation of the structural response of the building.

Conducted seismic hazard analysis using the PSHA method (Probabilistic Seismic Hazard Analysis) with shallow crustal earthquake source for probability exceeded 10% in 500 years to know the
acceleration of peak land that occurred in Apartments and hotels Mataram City Yogyakarta. Peak ground acceleration obtained for 0.2608 g. After the hazard de-aggregation process obtained the distance of dominant 19.49 km with a dominant magnitude (Mw) of 6.31 from the Opak fault. Ground motion suitable for this location is San Fernando 1971 [1].

This research will be analyzed spectral matching ground motion San Fernando 1971 toward response spectrum of research location to obtain artificial ground motion. Earthquake wave propagation is very influential on soil properties. Therefore, the analysis of earthquake wave propagation from the bedrock to the surface is needed to obtain amplification factor of earthquake waves.

2. Method

2.1. Research sites
This research is located at the Apartment and hotel of Mataram City in Yogyakarta area. This location was chosen because Apartment and hotel Mataram City is one of the highest buildings in Yogyakarta so it is important to know the ground motion of the area as an effort to evaluate the structure of the building. The location of the study is shown in Figure 1.

2.2. Digitization Ground Motion
Digitization of ground motion is an acceleration recording data from the earthquake. There are 2 (two) methods to obtain ground motion data that is using ground motion data ever recorded around study location and using data of motion synthetic. The problem that arises is that almost all major cities in Indonesia do not have representative ground motion data for use in the seismic analysis [2]. Based on this, ground motion analysis can be done using ground motion synthetic derived based on hazard seismic analysis using PSHA method. After that done uniformity with the process of analysis of spectral matching.

2.3. Analysis of Dynamic Soil Response
Soil dynamics response is a soil behavior that occurs due to dynamic load/force. In geotechnical engineering of the earthquake, earthquake response is a parameter that must be calculated. The maximum acceleration and response spectrum occurring on the surface is strongly influenced by soil conditions such as the type of soil layer and the thickness of the soil layer [3]. This is evidenced by research conducted by Idriss and Kramer [4]. It is shown in Figure 2 and Figure 3.
The character and spread of earthquake damage are most influenced by the soil response to cyclic loads. The soil response is determined by the dynamic parameters of the soil. The dynamic parameters used in soil dynamics response analysis are the maximum shear modulus ($G_{\text{max}}$), shear wave velocity ($V_S$), and damping ($\xi$). Here is the correlation of N-SPT value with parameter acceleration of soil in Table 1.

**Table 1.** Correlation between $G_{\text{max}}$ and $V_S$ with SPT (Irsyam, 2000)

| Reference             | $G_{\text{max}}$ Correlation (kPa) | $V_S$ Correlation (m/det) | R    | Type of soil         |
|-----------------------|-----------------------------------|---------------------------|------|----------------------|
| Ohsaki, Iwasaki       | $G_{\text{max}} = 11500N^{0.8}$   |                           | 0.888| All (Japan)          |
| Ohta, goto (1978)     |                                   | $V_S = 85.3N^{0.341}$     | 0.72 | All (Japan)          |
| Imai, Tonouchi (1982) | $G_{\text{max}} = 14070N^{0.68}$  | $V_S = 96.9N^{0.314}$     | 0.867| All (Japan)          |
| Seed et al (1983)     | $G_{\text{max}} = 6220N$          |                           |      | Sand (USA)           |
| Sykora, Stokoe (1983) |                                   | $V_S = 101N^{0.29}$       | 0.84 | Sand (USA)           |
3. Results and Discussion

3.1. Ground Motion Recording
After performing the de-aggregation process, the parameters obtained such as dominant distance (R) and dominant magnitude (Mw) are used as reference in determining ground motion soil/time history according to the condition of research location. The ground motion used was obtained from Ground Peer Motion Database that can be accessed and downloaded at the site Ground Peer Motion Database.

From these results obtained that the recording ground motion/time history following the location of the location review is San Fernando earthquake data in 1971 recorded at Pasadena earthquake recording station - Old Seismo Lab. This quake has a magnitude 6.61 with a distance of 21.5 km. The following is the graph of the earthquake in Figure 4.

![Figure 4. San Fernando 1971 Ground Motion](image)

3.2. Spectral Matching
After obtaining ground motion data on the Peer Ground Motion Database site that matches the characteristics and source of the earthquake in the reviewed location, the ground motion can be used in the spectral matching process. The spectral matching process is done so that ground motion obtained according to the condition of the study site. This process does by matching the response of the target location spectral studied. In this study, the target spectral used is a spectral response in bedrock from the source of a shallow crustal earthquake. The matching process is presented in Figure 5.

![Figure 5. Matching Process of Response Spectrum Acceleration](image)
The actual response spectrum is a response spectrum acceleration original of the 1971 San Fernando earthquake. Response spectrum acceleration of the target is obtained from the analysis of seismic hazard at the site which is reviewed in this study. Then response spectrum scaled is the spectral response of the matching result. The result of matching the response spectrum produces a motion synthetic ground in Figure 6.

![Figure 6. Ground Motion Matching Result](image)

The comparison between ground motion before and after the matching process is shown in Figure 7. The graph shows that there is an increase in peak ground acceleration. This is because the location of the review has a higher peak ground acceleration value.

![Figure 7. Ground Motion Comparison](image)

### 3.3. Dynamic Soil Parameters
The soil has a layered texture. Each layer has different properties that have different patterns and behaviors in the wave propagation process. Therefore, the dynamic parameters of the soil need to be analyzed. The soil dynamic parameters required for dynamic soil response analysis are $G_{\text{max}}$ and $V_s$. This value can be known through the results of land borlog at the research location which can then be correlated. The following results of N-SPT at the study sites are presented in Figure 8.
To determine the correlation between the number of blow (N) with dynamic soil parameters in the form of shear wave velocity ($V_s$) using the equation correlation formula Ohta, Gotto (1978) [5] and Imai, Tonouchi (1982) [6]. Graph of propagation results in the form of correlation $G_{max}$ and $V_s$ depend on depth after analyzed in Figure 9.

**Figure 8. Borlog Data**

**Figure 9. Correlation $G_{max}$ and $V_s$ to the depth at Apartment and Hotel Mataram City, Sleman, Yogyakarta**
3.4. Ground Motion Acceleration on Surface

Analysis of wave propagation from bedrock to the surface is done to determine the effect of soil on wave propagation. After the analysis ground motion process in bedrock, then does wave propagation from bedrock to the surface. This process is done by analyzing the dynamic parameters of the soil in each layer. The ground dynamic parameters included are the maximum shear modulus value ($G_{\text{max}}$) and shear wave velocity ($V_s$). The following in Figure 10 is the ground surface acceleration motion after being propagated to the surface.

![Figure 10 Ground Motion Acceleration On Surface](image)

Based on the wave propagation results, the peak acceleration value on the surface has increased after being propagated from the bedrock. This increase is called the amplification factor. This factor may change depending on the soil condition of the study location. In this study, the peak ground acceleration at bedrock is about 0.2679 g while the peak ground acceleration on the surface increased is about 0.3001 g. Therefore, it can be concluded that the magnitude of amplification factor in the research area is 1.12.

4. Conclusion

After doing the analysis process, there are several conclusions that resulted from this research. The conclusions obtained in this study are as follows:

1) Peak ground acceleration on bedrock after doing spectral matching analysis process at building location is 0.2679 g.
2) Peak ground acceleration on the surface after propagating the wave from bedrock using NERA software to the surface at the research location is 0.3001 g.
3) There is an amplification factor in the earthquake wave propagation. The amplification factor of the wave propagation from the bedrock to the soil surface obtained in this study is about 1.12.

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