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Research Article

Result Comparison of Spectral Matching Between *Seismomatch* and *Specmatch* Computer Program

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Abstract

The earthquake ground motion, or acceleration time history, caused by an earthquake event, is an earthquake acceleration wave that can be utilized as a basis to design earthquake-resistant civil engineering buildings. The earthquake acceleration time history is needed as a basis to determine the earthquake loading for the building structure design. A time history can be developed from recorded data using spectral matching software. In this process, the response spectra of the recorded time history are matched to a specific target spectrum. The target spectrum is developed based on the Indonesian National Standard known as SNI 2012 (SNI code). The response spectra derived from this standard are referred to as the design response spectrum. These response spectra adopted by the SNI code are based on the ASCE code from the US. Two spectral matching software programs, namely Seismomatch and Specmatch, are employed for this purpose. In this study, both of software programs are utilized to match the response spectra of a time history to a predefined response spectrum. The results of the matching process indicate that Seismomatch does not produce a satisfactory match between the response spectra of the time history and the target spectrum, whereas Specmatch provides a matching result where the response spectra of the time history nearly perfectly align with the target spectrum.

Keywords

Software, Time History, Spectral Matching, Response Spectra

1. Introduction

The earthquake ground motion, or acceleration time history, caused by an earthquake event, is an earthquake acceleration wave that can be utilized as a basis to design earthquake-resistant civil engineering buildings. This time history can be found by recording, as shown in Figure 1, for example.

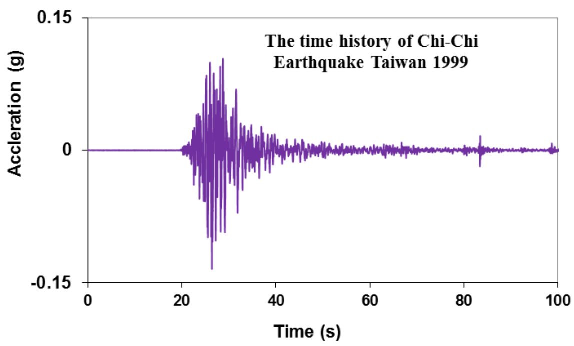

Figure 1. *Time history of an earthquake.*

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Generally, the time history recorded cannot be used directly as a basis for designing earthquake-resistant buildings because the location of the building may not match where the time history was recorded. Additionally, the earthquake vibrations recorded may not be strong enough to serve as a basis for calculating the earthquake resistance of a building. Given these conditions, it is necessary to develop a new time history that is appropriate for the specific location and vibration requirements of the building being constructed. The result of this time history development is referred to as the time history design or artificial time history. Experts have conducted extensive research and development of design time histories for use in designing earthquake-resistant buildings.

In this study, two different earthquake acceleration time histories will be developed using two different spectral matching software programs. One software, developed by SEIMOSOFT in the US, is called SEISMOMATCH version 2.1.0, while the other software, developed at the Islamic University of Indonesia in Yogyakarta by Makrup, is called SPECMATCH version 1 [1]. The earthquake vibrations or time histories generated by these two software programs will be applied to simulate the shaking of a building. Subsequently, the earthquake time history results from SEISMOMATCH will be compared to those from SPECMATCH, including a comparison and discussion of the building responses.

Experts have undertaken various studies on the development of earthquake acceleration vibrations or acceleration waves in the form of earthquake ground motion time histories. Nikolaou [2] conducted a study using the RASCAL computer program to develop earthquake acceleration time histories. Carlson et al. [3] developed artificial acceleration time histories based on 28 recorded time histories, which were then used as inputs for bilinear SDOF systems. Ergun and Ates [4] utilized recorded time histories to develop new time histories, focusing on observing the effects of near-fault and far-fault conditions on structures. Wood and Hutchinson [5] selected earthquake ground motion time histories using Probabilistic Seismic Hazard Analysis (PSHA) to create new time histories targeting specific spectra. Bayati and Sultoni [6] chose earthquake acceleration time histories from recorded results and deterministically developed artificial time histories for seismic design of RC frames to prevent collapse. Pavel and Vacareanu [7] selected actual time histories using probabilistic seismic hazard analysis and developed new artificial time histories targeting specific spectra. Makrup and Jamal [8] developed artificial acceleration time histories and design response spectra using PSHA and spectral matching in the time domain. Makrup [9] derived design ground motion using probabilistic seismic hazard analysis and seismic codes. Makrup and Muntafi [10] developed artificial ground motion for the cities of Semarang and Solo, Indonesia, based on probabilistic seismic hazard analysis and spectral matching.

Makrup, Sunardi, and Muntafi [11] developed design accelerograms through time and frequency domain matching based on seismic hazard in Sorowako Field of Sulawesi Island, Indonesia. Pawirodikromo et al. [12] conducted a review of bidirectional and directivity effect identifications of synthetic ground motions at selected sites in Yogyakarta city, Indonesia. Saputra and Makrup [13] performed hazard de-aggregation and developed synthetic ground motion for Riau Province, Indonesia. Erlangga et al. [14] evaluated the structure of the Faculty of Law building of the Universitas Islam Indonesia based on earthquake acceleration developed with a probabilistic concept. Pratiwi et al. [15] conducted structural dynamic evaluation of the Wadaslintang dam using earthquake acceleration based on the Indonesian seismic code 2019. Marzuko et al. [16] reviewed the effect of soil response on the change of frequency characteristics of earthquake ground motions. Makrup et al. [17] developed amplification factor (*Fa* and *Fv*) maps based on earthquake acceleration maps on the ground surface and in the base rock, as well as seismic code.

In this study, earthquake artificial acceleration time histories and their response spectra were developed using two different software programs: SEISMOMATCH version 2.1.0 and SPECMATCH version 1.0. The study site had soil characteristics and was located in the Mataram City Building, with coordinates of 110.37737^0E; 7.73937^0S. The results from the two software programs were then compared and discussed.

2. Actual Time History

The time history obtained from the recording will henceforth be referred to as the actual time history. For this study, the Parkfield earthquake of 2004 in the USA was utilized, with its time history depicted in Figure 2. The response spectra corresponding to this time history can be found in Figure 3.

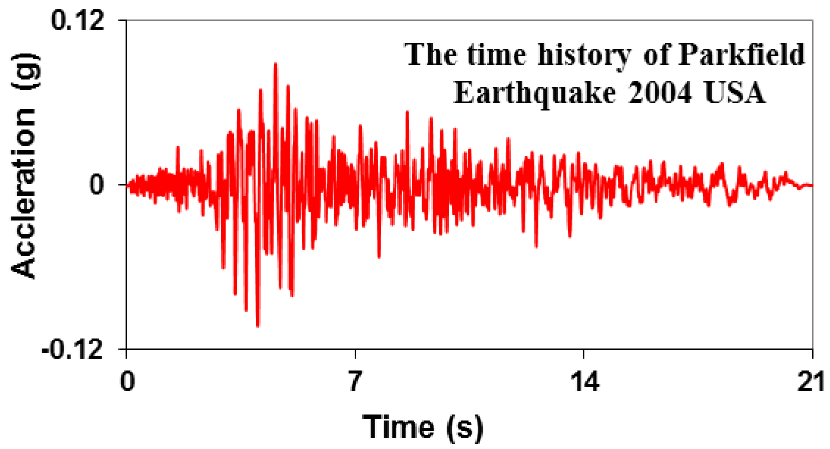

Figure 2. The time history of Parkfield earthquake USA 2004.

Table 1. Amplification factor for short period, (Fa).

	Mapped maximum considered earthquake Spectral response acceleration at short periods				
Site Class	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	a	a	a	a	a

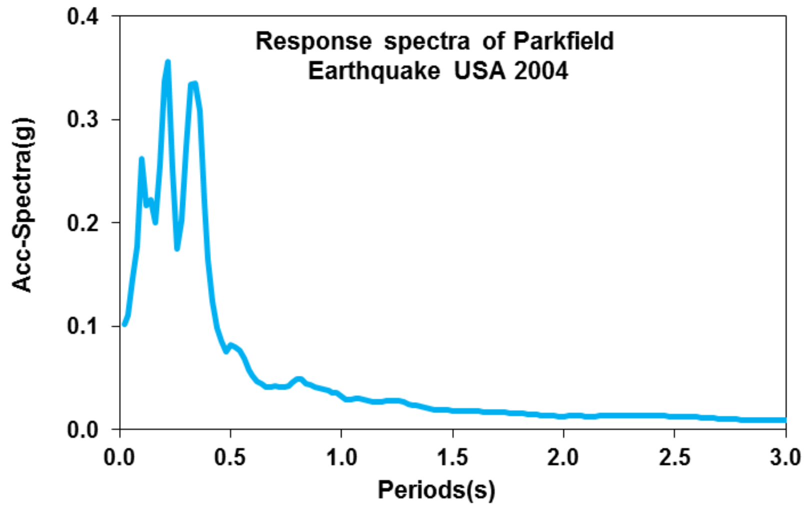

Figure 3. The response spectra of Parkfield earthquake USA 2004.

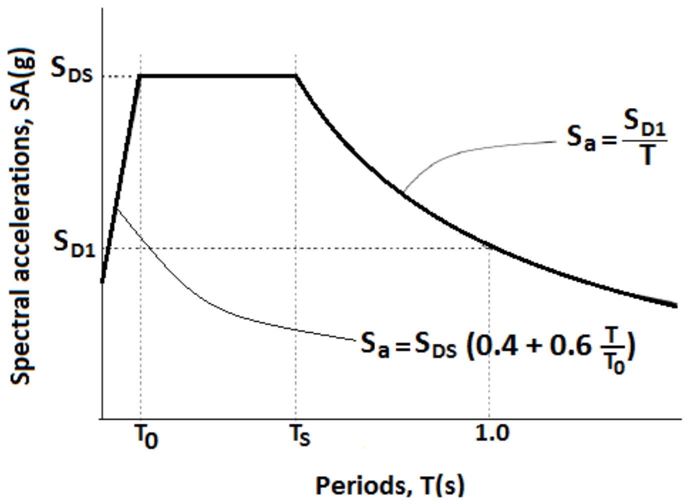

Figure 4. *Standard form of ASCE 7-10 design response spectrum design.*

Table 2. *Amplification factor for period 1.0 second, (Fv).*

Site Class	Mapped maximum considered earthquake Spectral response acceleration at 1.0 second periods				
	$S_1 \leq 0.1$	**$S_1 = 0.2$**	**$S_1 = 0.3$**	**$S_1 = 0.4$**	**$S_1 \geq 0.5$**
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	A	a	a	a	a

a is a location that should be geotechnical investigation

3. Target Spectrum

The target spectrum is developed based on the Indonesian National Standard known as SNI 2012 (SNI code). The response spectra derived from this standard are referred to as the design response spectrum. These response spectra adopted by the SNI code are based on the ASCE code from the US. The standard form of the SNI code 2012 design response spectra can be seen in Figure 4. To determine the new design response spectra from the SNI code, Tables 1 and 2, as well as the seismic hazard maps for Indonesia depicted in Figures 5 and 6, are utilized.

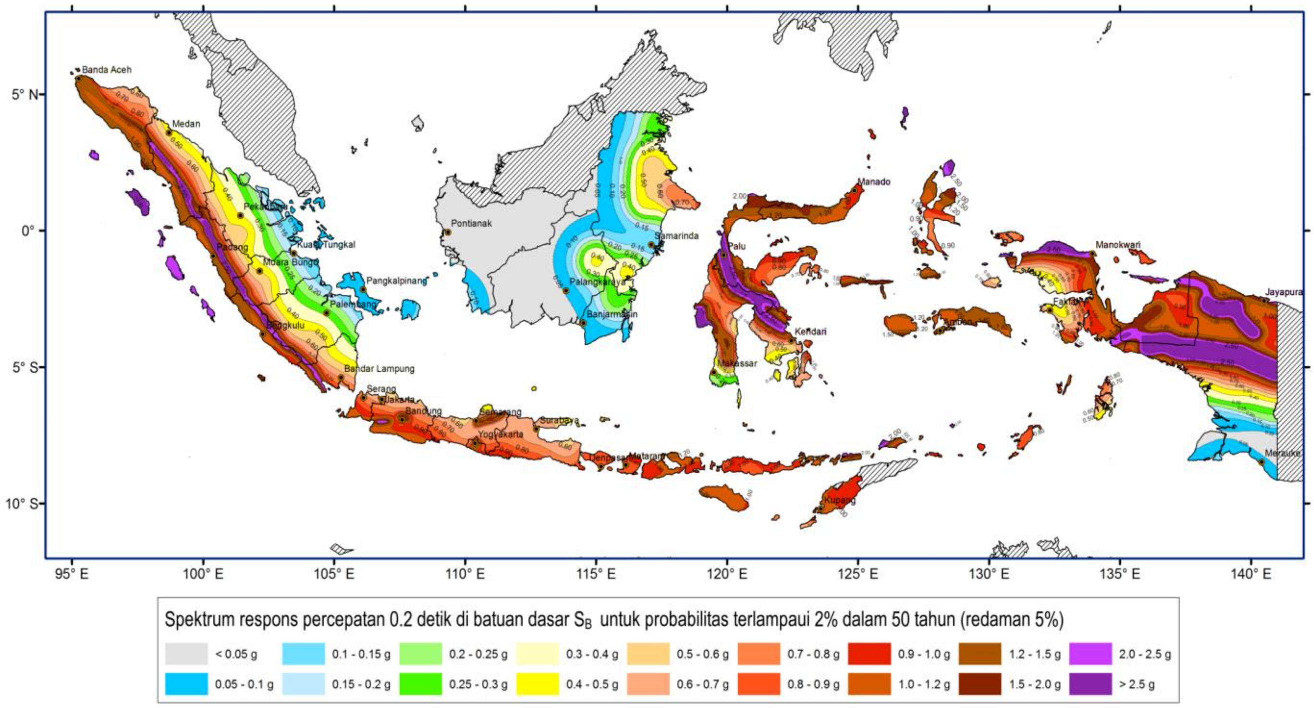

__Figure 5.__ Seismic hazard map for Indonesia (2012) of 0.2 second wave period.

From Figure 5, the short period acceleration is obtained as Ss = 0.63g, and from Figure 6, the 1.0 second period acceleration is found to be S1 = 0.32g.

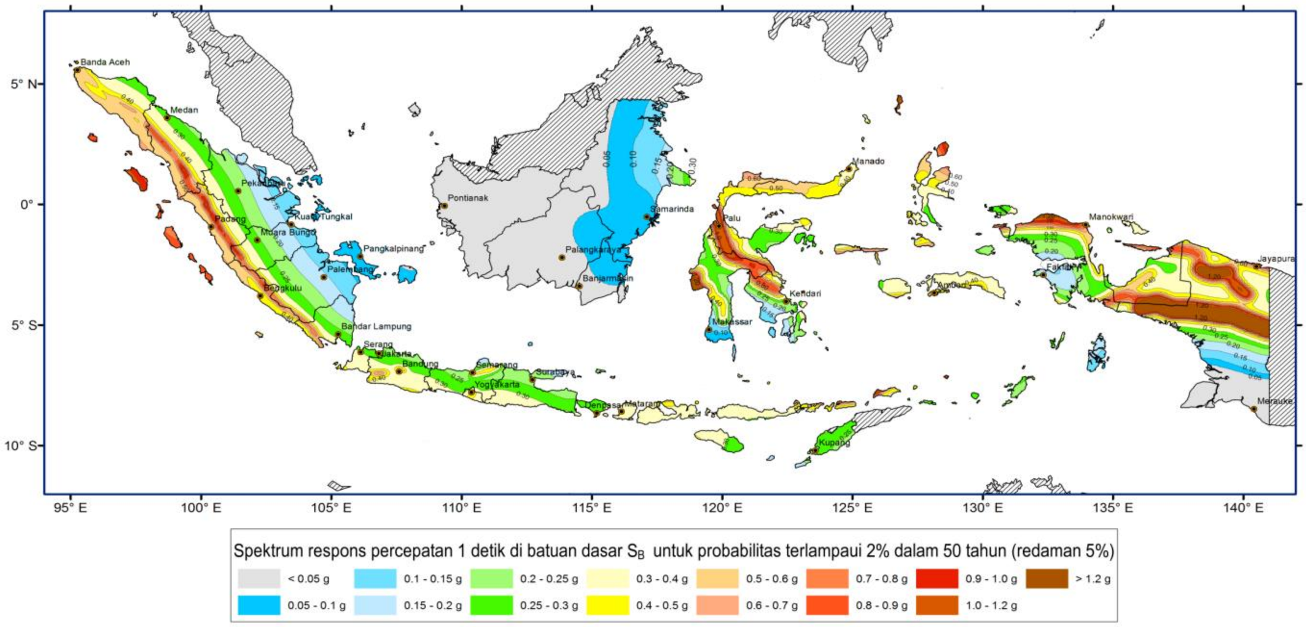

__Figure 6.__ Seismic hazard map for Indonesia (2012) of 1.0 second wave period.

The design spectrum for the Mataram City Building (MCB), located at coordinates 110.37737^0E; 7.73937^0S, will be developed as the focus of this study. The drilling log results around the MCB site can be seen in Figure 7.

Table 3. *Soil site classification.*

Site Class	Vs	N	Su
A	>5000 ft/s	Not	not
Hard rock	>1500 m/s	Applicable	aplicable
B	2500 to 5000 ft/s	Not	not
Rock	760 to 1500 m/s	Applicable	aplicable
C	1200 to 2500 ft/s	>50	>2000 psf
Very dense soil	370 to 760		>100 kPa
and soft rock			
D	600 to 1200 ft/s	15 to 50	1000 to 2000 psf
Stiff soil	180 to 370 m/s		50 to 100 kPa
E	<600 ft/s	<15	<1000 psf
Soft	<180 m/s		<50 kPa
Soil	Any profile with more than 10 ft (3 m) of soil having character		
	* Plasticiy index PI > 20		
	*Moisture content, w > 40%		
	*Undrained shear strength, Su < 500 psf		
F	a. Soil vurnerable to potential failure or collapce		
Soil requiring the	b. Peats and/or highly organic clays		
site-specific	c. Very high plasticity clays		
Evaluation	d. Very thick soft/medium clays		

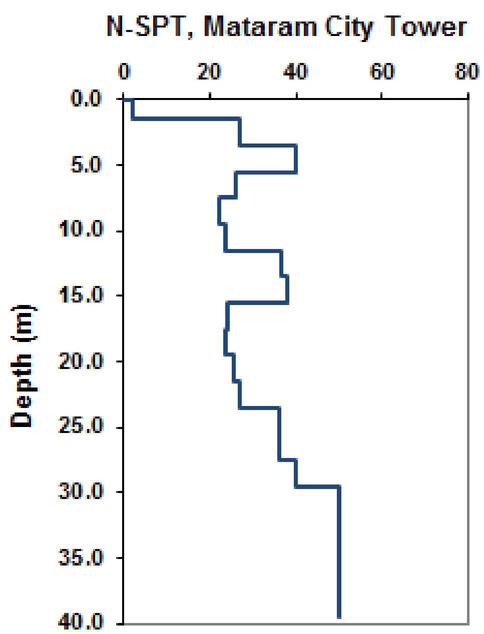

Figure 7. *N-SPT data from drilling result.*

From Figure 7, the mean N-SPT is determined to be 18.3817. By referencing the soil classification table in Table 3, it is established that the soil site class is D. Based on Ss = 0.63*g* from Table 1, Fa is calculated to be 1.296, and based on $S_1 = 0.32g$ from Table 2, Fv is calculated to be 1.76.

The calculation of other response spectra parameters is performed using the following equations.

$$S_{MS} = F_a\ S_S = 0.8165g \quad (1)$$

$$S_{DS} = (2/3)\ S_{MS} = 0.5443g \quad (2)$$

$$S_{M1} = F_v\ S_1 = 0.5632g \quad (3)$$

$$S_{D1} = (2/3)\ S_{M1} = 0.3755g \quad (4)$$

$$Ts = \frac{S_{D1}}{S_{DS}} = 0.6898s \quad (5)$$

$$T_0 = 0.2\ T_S = 0.1380s \quad (6)$$

For $T \le T_0$ to $T \le T_S$, so

$$Sa = S_{DS} = 0.5443g \quad (7)$$

For T < T0, then

$$Sa = S_{DS}\left(0.4 + 0.6\frac{T}{T_0}\right). \quad (8)$$

Therefore, for

$$T = 0,\ Sa = 0.2177g \quad (9)$$

For T > T_S,
$$Sa = \frac{S_{DS}}{T} \quad (10)$$

The results of the design response spectrum calculation are presented in Figure 8 below. This figure serves as the target spectrum for spectral matching analysis.

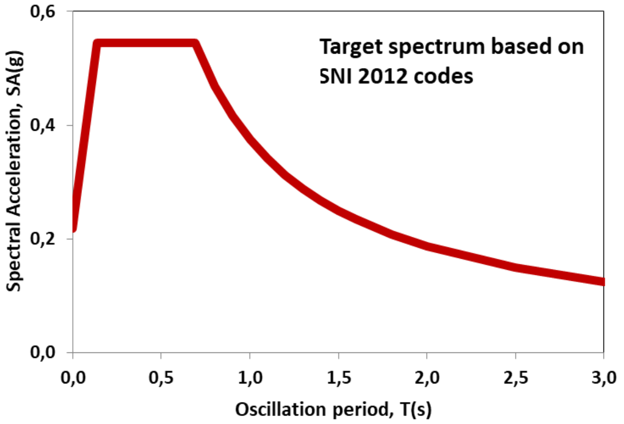

Figure 8. Target spectrum for the spectral matching calculation.

4. Spectral Matching

Spectral matching can be conducted in the time domain or the frequency domain, and in this case, spectral matching will be performed in the frequency domain. The process involves matching the actual response spectra (Figure 3) to the target response spectra (Figure 8).

4.1. Spectral Matching with Seismomatch

The results of spectral matching with Seismomatch can be observed in Figures 9 and 10. Figure 9 illustrates the matching outcome in the form of response spectra.

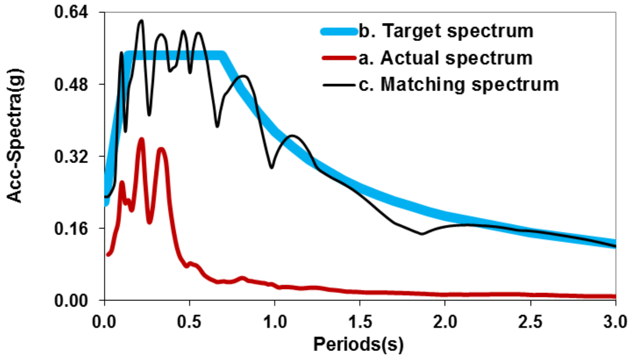

Figure 9. The response spectra of matching result with seismomatch.

Figure 10 is the matching result in form of the time history.

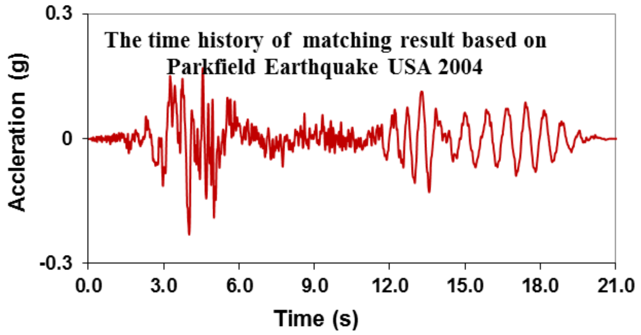

Figure 10. The time history of matching result with seismomatch.

4.2. Spectral Matching with Specmatch

The results of spectral matching with Specmatch are depicted in Figures 11 and 12. Figure 11 presents the spectral matching outcome in the form of response spectra, while Figure 12 illustrates it in the form of time history.

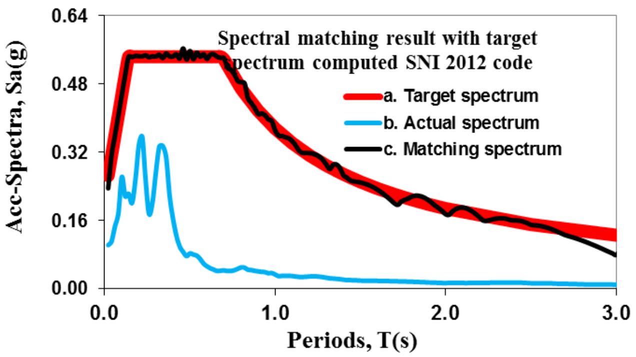

Figure 11. The response spectra of matching result with specmatch.

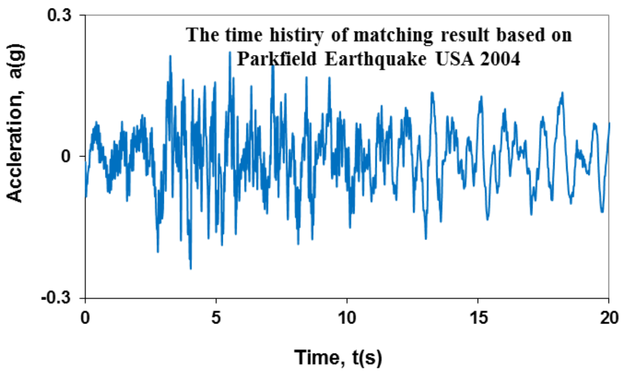

Figure 12. *The time history of matching result with specmatch.*

Figure 13. *Mataram City Tower (MCT), Yogyakarta, Indonesia.*

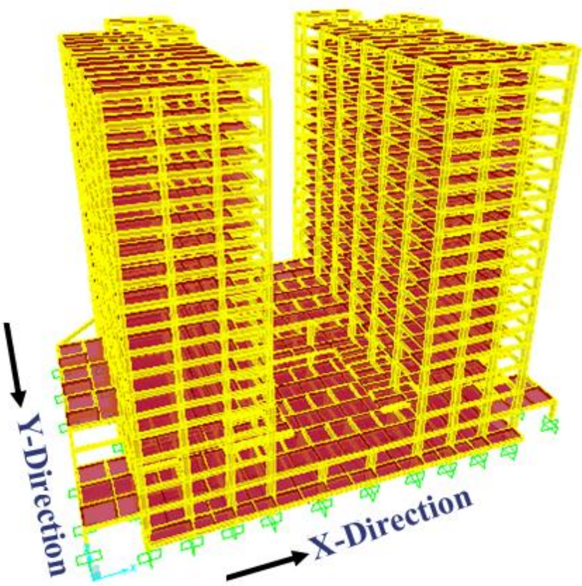

Figure 14. *Mataram City Tower structure.*

5. Structure′S Response to Ground Motion

To assess the structural response to ground motion, the time history ground motions depicted in Figures 10 and 12 will be applied as case studies to shake the 20-story Mataram City Tower (MCT) building in Yogyakarta, Indonesia (refer to Figures 13 and 14). Structural analysis has been conducted on the building depicted in Figure 14. The results of the structural analysis are presented in Figure 15, which illustrates the displacements of the MCT structure in both the X and Y directions. Displacement-1, shown in red, is caused by the time history depicted in Figure 10, developed by the SEISMOMATCH computer program. Displacement-2, depicted in blue, is caused by the time history depicted in Figure 12, developed by the SPECMATCH computer program.

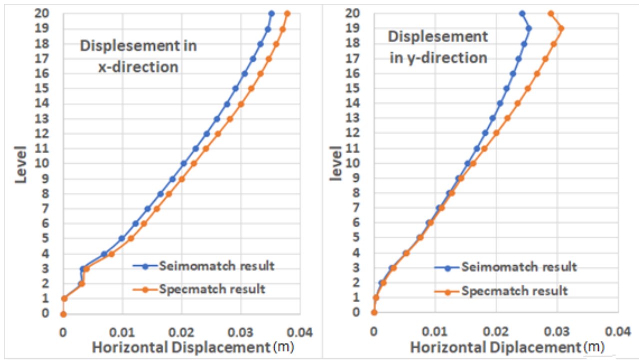

Figure 15. *Structural displacement (a) in X-direction and (b) in Y-direction in meter.*

Figure 15 shows that the time history developed by SEISMOMATCH resulted in smaller horizontal displacements of the structure levels compared to SPECMATCH. The displacement is caused by SEISMOMATCH time history smaller than the SPECMATCH time history probable because the mean acceleration of SEISMOMATCH time history is smaller than the SPECMATCH time history.

6. Structure Analysis Review

The Mataram City Tower building in Yogyakarta falls under building group category C1 due to its concrete reinforcement frame structure, as per FEMA 310, 1998 [14] and FEMA 356, 2000 [15]. This building type includes residential units where many people live and carry out activities. The structure's response to the two time-histories, as shown in Figures 10 and 12, can be observed in Figure 15. From Figure 15, it is evident that the structure's displacement due to the time history loads developed by SEISMOMATCH is smaller than that developed by SPECMATCH. Several factors may contribute to this difference, such as variations in response spectrum patterns and differences in the time history patterns used to shake the structure. In the figure, it can be observed that the horizontal structure displacement values produced by the two time histories are not significantly different for stories 1 to 4. However, significant discrepancies can be seen in the displacements for the following stories. The less uniform change in the structure frame from the 4th to the 5th story results in additional horizontal displacement influenced by the time history developed by SPECMATCH.

7. Discussion

The wave pattern of earthquake acceleration time history is depicted by its response spectrum pattern. Fourier analysis (the Fourier series) is a powerful tool used to modify the wave pattern of the time history to match a specific target spectrum. The results of this study, as shown in Figure 10, indicate that the time history with the matching spectrum from SEISMOMATCH software (Figure 9) does not perfectly match the target spectrum. Conversely, Figure 12 displays the time history with matching spectra from SPECMATCH software (Figure 11), where the matching spectrum closely aligns with the target spectrum. Visually, the matching result of the SPECMATCH software appears to be much better than that of the SEISMOMATCH software. Additionally, the structural analysis results indicate that the time history from SEISMOMATCH yields smaller displacements compared to the time history from SPECMATCH, as illustrated in Figure 15.

8. Conclusion

Two software programs, SEISMOMATCH and SPECMATCH, were utilized to perform spectral matching and generate earthquake acceleration time histories. The matching results from SPECMATCH are notably closer to perfect compared to those from SEISMOMATCH. Both software programs generated two time histories from a single measurement result. The time history produced by SEISMOMATCH exhibits a significantly different pattern compared to the time history produced by SPECMATCH. Moreover, the maximum acceleration generated by SEISMOMATCH is smaller than that produced by SPECMATCH. Consequently, when these two time histories are used to simulate the shaking of the structure, the resulting displacements indicate that the time history from SEISMOMATCH yields smaller displacements compared to SPECMATCH.

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Author Contributions

Hanindya Kusuma Artati: Conceptualization, Software, Validation, Writing – original draft, Writing – review & editing

Lalu Makrup: Conceptualization, Funding acquisition, Validation

Jafar: Software, Writing – review & editing

Pranowo: Investigation, Software, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] L. Makrup, "Change the frequency characteristics of the earthquake acceleration wave by fourier analysis," *Int. J. Civ. Eng. Technol.*, vol. 8, pp. 1045–1055, Dec. 2017.

[2] A. S. Nikolaou, *A GIS Platform for Earthquake Risk Analysis*. State University of New York at Buffalo, 1998.

[3] C. Carlson, D. Zekkos, and J. McCormick, "Impact of time and frequency domain ground motion modification on the response of a SDOF system," *Earthquakes Struct.*, vol. 7, pp. 1283–1301, Dec. 2014, https://doi.org/10.12989/eas.2014.7.6.1283

[4] M. Ergün and Ş. Ateş, "Selecting and scaling ground motion time histories according to Eurocode 8 and ASCE 7-05," *Earthquakes Struct.*, vol. 5, Aug. 2013, https://doi.org/10.12989/eas.2013.5.2.129

[5] R. Wood and T. Hutchinson, "Effects of ground motion scaling on nonlinear higher mode building response," *Earthquakes Struct.*, vol. 3, Dec. 2012, https://doi.org/10.12989/eas.2012.3.6.869

[6] Z. Bayati and M. Soltani, "Ground motion selection and scaling for seismic design of RC frames against collapse," *Earthquakes Struct.*, vol. 11, pp. 445–459, Sep. 2016, https://doi.org/10.12989/eas.2016.11.3.445

[7] F. Pavel and R. Vacareanu, "Scaling of ground motions from Vrancea (Romania) earthquakes," *Earthquakes Struct.*, vol. 11, pp. 505–516, Sep. 2016, https://doi.org/10.12989/eas.2016.11.3.505

[8] L. Makrup, "The Earthquake Ground Motion and Response Spectra Design for Sleman, Yogyakarta, Indonesia with Probabilistic Seismic Hazard Analysis and Spectral Matching in Time Domain," *Am. J. Civ. Eng.*, vol. 4, no. 6, p. 298, Jan. 2016, https://doi.org/10.11648/j.ajce.20160406.15

[9] L. Makrup, "Generating Design Ground Motion by Probabilistic Seismic Hazard Analysis and Code," *Electron. J. Geotech. Eng.*, vol. 22, no. Bundle 5, 2017.

[10] L. Makrup and Y. Muntafi, "Artificial ground motion for the cities of semarang and solo indonesia generated based on probabilistic seismic hazard analysis and spectral matching," *Electron. J. Geotech. Eng.*, vol. 21, pp. 6587–6602, Jan. 2016.

[11] L. Makrup, B. Sunardi, and Y. Muntafi, "Design accelerograms by time and frequency domain matching based on seismic hazard in sorowako field of Sulawesi Island, Indonesia," *Electron. J. Geotech. Eng.*, vol. 21, pp. 6629–6644, Jan. 2016.

[12] W. Pawirodikromo, L. Makrup, M. Teguh, and M. Anggit, "Bidirectional and Directivity Effect Identifications of Synthetic Ground Motions At Selected Site in Yogyakarta City, Indonesia," *Int. J. Civ. Eng. Technol.*, vol. 10, no. 11, pp. 149–166, 2019.

[13] E. Saputra and L. Makrup, "Deagregasi Hazard Dan Rekomendasi Ground Motion Sintetik Di Provinsi Riau," *AGREGAT*, vol. 6, no. 1 SE-Articles, May 2021, https://doi.org/10.30651/ag.v6i1.8323

[14] W. Erlangga, L. Makrup, M. Musthofa, and Suharyatmo, "Evaluasi struktur gedung Fakultas Hukum Universitas Islam Indonesia Berdasarkan Percepatan Gempa menggunakan Konsep Probabilistik," *Teknisia*, vol. 27, no. 1 SE-Articles, pp. 34–45, Jun. 2022, https://doi.org/10.20885/teknisia.vol27.iss1.art4

[15] D. A. W. W. Pratiwi, L. Makrup, and I. Setiawan, "The Structural Dynamic Evaluation of Wadaslintang Dam to the Earthquake Acceleration Based on Indonesian Seismic Code 2019," *Am. J. Civ. Eng.*, vol. 10, no. 3, pp. 125–134, 2022, https://doi.org/10.11648/j.ajce.20221003.15

[16] A. Marzuko, L. Makrup, and M. R. Abdurrazak, "The Effect of the Soil Response to the Change of the Frequency Characteristic of the Earthquake Ground Motions," *Am. J. Civ. Eng.*, vol. 10, no. 4, pp. 145–152, 2022, https://doi.org/10.11648/j.ajce.20221004.11

[17] L. Makrup, E. Saputra, and B. Suryo, "Development of the Amplification Factor Fa and Fv map based on the Earthquake Acceleration Map on ground surface and in Base Rock and Seismic Code," *Curr. Trends Civ. Struct. Eng.*, pp. 1–12, 2023, https://doi.org/10.33552/CTCSE.2023.09.000721