RiESTech

Recent in Engineering Science and Technology

MBI

Article

Anomaly Response Spectrum of Various Cities in Indonesia Based on SNI 1726:2019

Anis Rosyidah [1,*], Ulil Albab [1], Rinawati [1], I Ketut Sucita [1], Latha M. S [2]

[1] Department of Civil Engineering, Politeknik Negeri Jakarta, Depok 16425, Indonesia
[2] Department of Civil Engineering Sri Venkateshwara College of Engineering, Bangalore, India
* Correspondence: anis.rosyidah@sipil.pnj.ac.id

Abstract: Response spectra that happened anomaly is seen after SNI 1726:2012 and SNI 1726:2019 pub-lished, this condition has happened because the value of response spectrum design is SE < SD < SC, SD < SE < SC, or SD < SC < SE, if this in normal condition, the value of response spectrum is SC < SD < SE. With applied methods and procedures found by Kircher & Associates (2015) they adjust the formula S_{MS} & S_{M1} wished response spectrum becomes normal. In this research, comparing spectrum response, with spectrum response with treatment, and comparing the value SDS dan SD1. From this research, it was found that there was a decrease in seismic loading on hard soil (SC) and an increase in medium soil (SD) and soft soil (SE).

Keywords: Anomaly; Kircher & Associates; Spectrum Response

Citation:. Rosyidah, A., Albab, U., Rinawati, Sucita, I. K., & Latha, M. S., (2023). The Spectra Response Anomaly of Various Cities in Indonesia Based on SNI 1726:2019. Recent in Engineering Science and Technology, 1(03), 32–48. https://doi.org/10.59511/riestech.v1i03.25

Academic Editor: Iwan Susanto

Received: 26 May 2023
Accepted: 12 June 2023
Published: 1 July 2023

1. Introduction

Earthquakes are disasters that cannot be avoided and accurately predicted when and where they will occur. Indonesia is a country with high earthquake intensity due to its location around the convergence of three tectonic plates: the Indo-Cina plate, the Indo-Australian plate, and the Philippine plate [1][2]. The impact of ground acceleration during earthquakes needs to be considered in the design of buildings and infrastructure. During an earthquake, buildings will experience shaking on the ground surface, leading to their destruction. Therefore, structural design regulations that accommodate earthquake loads are essential to reduce the damage caused by earthquakes in Indonesia [3][4].

In Indonesia, there are already earthquake-resistant building regulations that are updated every five years. Indonesia has had earthquake regulations starting from the Indonesian Load Regulation (PPI) in 1970, the Indonesian Earthquake-Resistant Building Planning Regulation (PPTI-UG) in 1983, SNI 1726:2002 - Standard for Earthquake Resistant Building Planning, SNI 1726:2012 - Guidelines for Earthquake Resistance Planning for Building and Non-Building Structures, and SNI 1726:2019 - Guidelines for Earthquake Resistance Planning for Building and Non-Building Structures. These regulations are based on the update of the National Seismic Map, which resulted in the Seismic Source and Hazard Map of Indonesia in 2017. This map is an enhancement of the Seismic Source Map in 2010 [5][6][7]. The increase in seismic sources will affect the magnitude of earthquake forces in earthquake-resistant building design [8]

Since the implementation of SNI 1726:2012 and SNI 1726:2019, many locations have been found to exhibit anomalous response spectra. These anomalies occur in the design for short periods (SDS) and are divided into three types as follows: Type I anomaly is SE < SD < SC, Type II anomaly is SD < SE < SC, and Type III anomaly is SD < SC < SE [4][5]. Here, SE represents earthquake acceleration on soft ground conditions, SD is earthquake acceleration on medium ground conditions, and SC is earthquake acceleration on hard ground conditions [6][9][10].

Response spectra represent a graph showing the relationship between earthquake acceleration Sa (y-axis) and vibration period T in the x-direction. The design response spectra referring to SNI 1726:2019 in various cities in Indonesia have experienced many anomalies [9][11]. Based on this condition, it is essential to determine the percentage of difference in earthquake acceleration on the design response spectra for soft, medium, and hard ground conditions during anomalies and after normalization using the Kircher & Associates method. These results can serve as considerations and references for structural designers to determine planned earthquake loads.

1.1. Respon Spektra

The text discusses the process of creating design response spectra according to SNI 1726:2019 and ASCE 7-16, along with the parameters of earthquake acceleration SS and S1 obtained from MCER (Maximum Considered Earthquake Response) maps.

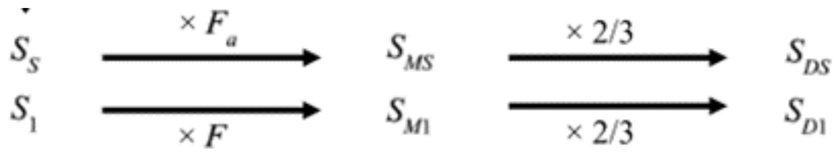

Figure 1. Shows a schematic illustration of the process of creating design response spectra.

The earthquake acceleration parameters, S_s and S_1, are mapped values obtained from the MCER map. To obtain the values of S_s and S_1 at specific latitude and longitude coordinates, interpolation is performed from the four nearest points on the grid. In this study, the website http://rsa.ciptakarya.pu.go.id/2021/ is used to determine the values of SS and S1, following SNI 1726:2019. These values can be obtained from the MCER map for short periods of 0.2 secondsGambar 1 memperlihatkan ilustrasi skematik pembuatan respon spektra desain menurut SNI 1726:2019 dan ASCE 7-16 [11][12].

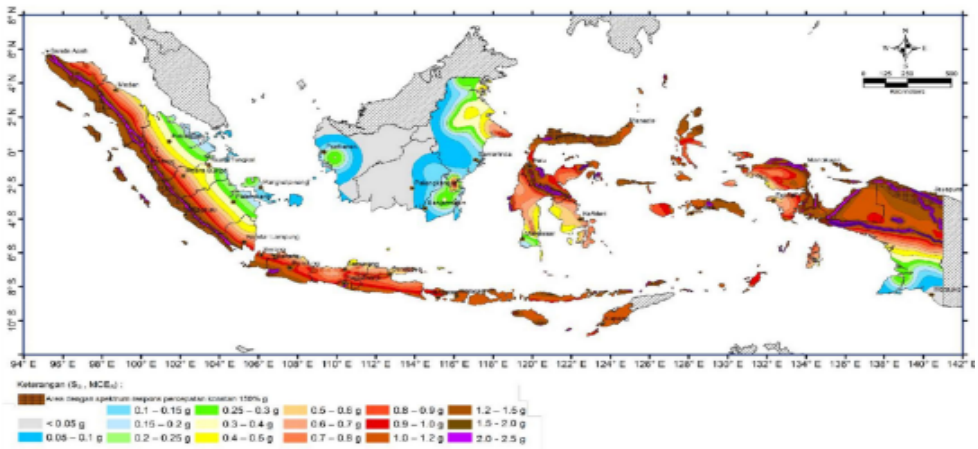

Figure 2. Depicts the Map of Spectrum Acceleration Response for 0.2 seconds 〖MCE〗_R (SNI 1726:2019) [11].

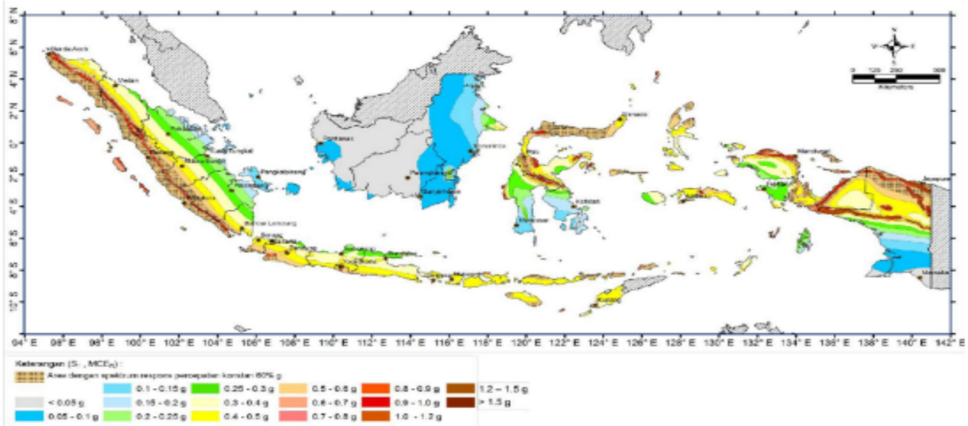

Figure 3. 1-second Response Spectrum Acceleration Map 〖MCE〗_R (SNI 1726:2019) [11]

Based on the provided text, it discusses the coefficients for site amplification Fa and Fv, and the differences between SNI 1726:2019 and ASCE 7-16. SNI 1726:2019 adopted the results of a study from the Pacific Earthquake Engineering Research (PEER), which shows slight differences compared to ASCE 7-16. Research has identified weaknesses in the seismic design procedures ELF (Equivalent Lateral Force) and MSRA (Modal Spectral Response Acceleration) in ASCE 7, particularly regarding the use of two response periods (short period and 1.0-second period) to determine seismic forces in the design [14][15]. Kircher & Associates recommended this research to improve the seismic design requirements of NEHRP 2015 and ASCE 7-16 to avoid anomalies in the response spectra [14]. There are two parameters, Ca and Cv, for adjusting the shape of the response spectra, which are shown in Table 3 to Table 6 [9][11].

Table 1. Fa Site Coefficient [11]

Site Class	parameter of acceleration of MCER spectral response in short period (0.2 second)					
	SNI 1726:2019 $S_s \le 0,25$	SNI 1726:2019 $S_s = 0,5$	SNI 1726:2019 $S_s = 0,75$	SNI 1726:2019 $S_s = 1,0$	SNI 1726:2019 $S_s = 1,25$	SNI 1726:2019 $S_s \ge 1,5$
SA	0,8	0,8	0,8	0,8	0,8	0,8
SB	0,9	0,9	0,9	0,9	0,9	0,9
SC	1,3	1,3	1,2	1,2	1,2	1,2
SD	1,6	1,4	1,2	1,1	1,0	1,0
SE	2,4	1,7	1,3	1,1	0,9	0,8
SF	*Site-Specific* (SSA)					

Table 2. Site Coefficient Fv [11]

Site Class	**Parameter of MCER Spectral Response Acceleration in 1-Second Period**					
	SNI 1726:2019 $S_1 \le 0,1$	SNI 1726:2019 $S_1 = 0,2$	SNI 1726:2019 $S_1 = 0,3$	SNI 1726:2019 $S_1 = 0,4$	SNI 1726:2019 $S_1 = 0,5$	SNI 1726:2019 $S_1 \ge 0,6$
SA	0,8	0,8	0,8	0,8	0,8	0,8
SB	0,8	0,8	0,8	0,8	0,8	0,8
SC	1,5	1,5	1,5	1,5	1,5	1,4
SD	2,4	2,2	2,0	1,9	1,8	1,7
SE	4,2	3,3	2,8	2,4	2,2	2,0
SF	*Site-Specific* (SSA)					

Table 3. Short Term Spectrum Shape Adjustment Factor 0.2 , Ca [14]

Site Class	Parameter of MCER Spectral Response Acceleration in Short Period (0.2 second)					
	Ss ≤ 0,25	Ss = 0,5	Ss = 0,75	Ss = 1,0	Ss = 1,25	Ss ≥ 1,5
SA	0,9	0,9	0,9	0,9	0,9	0,9
SB	0,9	0,9	0,9	0,9	0,9	0,9
SC	0,9	0,9	0,9	0,9	0,9	0,9
SD	1,0	1,0	1,0	1,0	1,0	1,0
SE	0,95	1,0	1,1	1,15	1,2	1,25
SF	*Site-Specific* (SSA)					

Table 4. Long Term Spectrum Shape Adjustment Factor, Cv for sites with TL greater than or equal to 12 seconds [14]

Site Class	Parameter of MCER Spectral Response Acceleration in 1-Second Period					
	S_1 ≤ 0,1	S_1 = 0,2	S_1 = 0,3	S_1 = 0,4	S_1 = 0,5	S_1 ≥ 0,6
SA	1,0	1,0	1,0	1,0	1,0	1,0
SB	1,0	1,0	1,0	1,0	1,0	1,0
SC	1,0	1,05	1,05	1,05	1,0	1,1
SD	1,0	1,2	1,3	1,35	1,5	1,5
SE	1,0	1,3	1,5	1,75	1,9	2,0
SF	Site-Specific (SSA)					

Table 5. Long Term Spectrum Shape Adjustment Factor, Cv for sites with TL greater than or equal to 8 seconds [14]

Site Class	Parameter of MCER Spectral Response Acceleration in 1-Second Period					
	S_1 ≤ 0,1	S_1 = 0,2	S_1 = 0,3	S_1 = 0,4	S_1 = 0,5	S_1 ≥ 0,6
SA	1,0	1,0	1,0	1,0	1,0	1,0
SB	1,0	1,0	1,0	1,0	1,0	1,0
SC	1,0	1,0	1,0	1,0	1,0	1,05
SD	1,0	1,1	1,15	1,2	1,3	1,4
SE	1,0	1,15	1,35	1,55	1,65	1,8
SF	Site-Specific (SSA)					

Table 6. Long Term Spectrum Shape Adjustment Factor, Cv for sites with TL greater than or equal to 6 seconds [14]

Site Class	Parameter of MCER Spectral Response Acceleration in 1-Second Period					
	S_1 ≤ 0,1	S_1 = 0,2	S_1 = 0,3	S_1 = 0,4	S_1 = 0,5	S_1 ≥ 0,6
SA	1,0	1,0	1,0	1,0	1,0	1,0
SB	1,0	1,0	1,0	1,0	1,0	1,0
SC	1,0	1,0	1,0	1,0	1,0	1,0
SD	1,0	1,05	1,1	1,15	1,2	1,25
SE	1,0	1,05	1,2	1,4	1,5	1,6
SF	Site-Specific (SSA)					

"The coefficient parameters in Table 3-6 are necessary for adjusting the shape of the spectral response that occurs anomalously. Basically, the method of designing the spectral response that occurs anomalously is the same as designing it normally, but there are adjustments as depicted in the schematic in Figure 4 by multiplying the coefficients Ca and Cv [14].

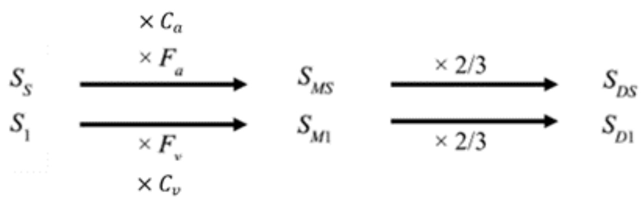

Figure 4. Shows the illustration schematic of the application of the Kircher & Associates design method on the Anomalous Spectral Response [14].

Figure 4: The Process of Applying the Kircher & Associates Design Method on Anomalous Spectral Response Design."Parameter koefisien pada Tabel 3-6 diperlukan untuk penyesuaian bentuk respon spektra yang terjadi anomali. Pada dasarnya cara mendesain respon spektra yang terjadi anomali sama dengan cara mendesain secara normal, tetapi ada penyesuain seperti skematik pada Gambar 4 dengan mengalikan koefisien Ca dan Cv [14].

2. Materials and Experiment Methods

Figure 5 illustrates the process of analyzing the spectral response and the process to make the spectral response normal.

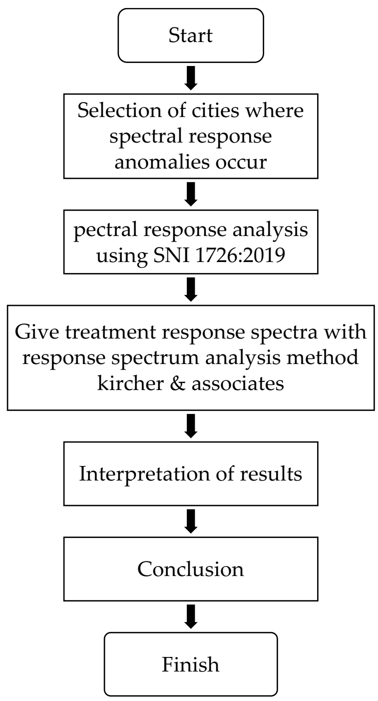

Figure 5. Flowchart of Spectral Response Analysis

The cities selected for this research are earthquake-prone areas, including Sumatra, Java, and Nusa Tenggara islands. The analysis of 15 cities with anomalous spectral responses was conducted using the website http://rsa.ciptakarya.pu.go.id/2021/. These 15 selected cities consist of (1) 5 cities with Type I anomalies, (2) 5 cities with Type II anomalies, and (3) 5 cities with Type III anomalies.

The spectral responses experiencing anomalies are then subjected to specific treatments to normalize them. The spectral response is considered normal if the earthquake acceleration for soft soil is greater than that of medium soil, and medium soil acceleration is greater than that of hard soil (SE > SD > SC). The normalization of the spectral response utilizes the spectral response design method introduced by Kircher & Associates, involving the multiplication of coefficients Ca & Cv (Figure 4) as the adjustment factors for short and long-period spectrum shapes [14].

In seismic-resistant building design, it is essential to accommodate the design earthquake loads. One way is to determine the seismic design loads using spectral response acceleration. The spectral response varies for each region and also depends on the soil site class, resulting in different accelerations. The creation of the design spectral response requires data in the form of acceleration parameters and site coefficients. The acceleration parameters obtained from the spectral acceleration map via the website http://rsa.ciptakarya.pu.go.id/2021/ are presented in Table 7 [16].

Table 1. Coefficient Site 15 cities

No	**City**	**Coefficient** S_s	S_1
1	Banda Aceh	1.37	0.60
2	Bengkulu	1.12	0.51
3	Mataram	0.96	0.38
4	Padang	1.35	0.60
5	Yogyakarta	1.28	0.47
6	Bogor	0.88	0.36
7	Denpasar Bali	0.98	0.36
8	Jember	0.84	0.40
9	Ngawi	0.90	0.38
10	Salatiga	0.92	0.41
11	Bandar Lampung	0.75	0.32
12	Kebumen	0.85	0.42
13	Kediri	0.84	0.34
14	Malang	0.78	0.33
15	Purwokerto	0.84	0.34

In Table 7, cities numbered 1-5 belong to Type 1 anomalies, numbers 6-10 belong to Type 2 anomalies, and numbers 11-15 belong to Type 3 anomalies.

3. Results and Discussion

This section presents the seismic amplification factor values (Fa and Fv) from various regions experiencing anomalies (Table 8). The spectral responses experiencing anomalies are then normalized using the Kircher & Associates design method presented in Table 9.

Table 8. Coefficient Values F_a and F_v Based on SNI 1726:2019.

No	City	SC		SD		SE	
		F_a	F_v	F_a	F_v	F_a	F_v
1	Banda Aceh	1.2	1.4	1.0	1.7	0.9	2.0
2	Bengkulu	1.2	1.5	1.1	1.8	1.0	2.2
3	Mataram	1.2	1.5	1.1	1.9	1.1	2.5
4	Padang	1.2	1.4	1.0	1.7	0.9	2.0
5	Yogyakarta	1.2	1.5	1.0	1.8	0.9	2.3
6	Bogor	1.2	1.5	1.1	1.9	1.2	2.6
7	Denpasar Bali	1.2	1.5	1.1	1.9	1.1	2.6
8	Jember	1.2	1.5	1.1	1.9	1.2	2.6
9	Ngawi	1.2	1.5	1.1	1.9	1.2	2.5
10	Salatiga	1.2	1.5	1.1	1.9	1.2	2.4
11	Bandar Lampung	1.2	1.5	1.2	2.0	1.3	2.7
12	Kebumen	1.2	1.5	1.2	1.8	1.2	2.2
13	Kediri	1.2	1.5	1.2	2.0	1.3	2.6
14	Malang	1.2	1.5	1.2	2.0	1.3	2.7
15	Purwokerto	1.2	1.5	1.2	2.0	1.2	2.6

Table 9. Coefficient Values Fa and Fv After Normalization

No	City	SC		SD		SE	
		F_a	F_v	F_a	F_v	F_a	F_v
1	Banda Aceh	1.2	1.402	1.2	1.702	1.2	2.004
2	Bengkulu	1.2	1.5	1.2	1.8	1.2	2.2
3	Mataram	1.2	1.5	1.2	1.916	1.2	2.464
4	Padang	1.2	1.4	1.2	1.7	1.2	2
5	Yogyakarta	1.2	1.5	1.2	1.835	1.2	2.27
6	Bogor	1.2	1.5	1.2	1.944	1.2	2.576
7	Denpasar Bali	1.2	1.5	1.2	1.94	1.2	2.56
8	Jember	1.2	1.5	1.142	1.943	1.184	2.572
9	Ngawi	1.2	1.5	1.2	1.918	1.2	2.47
10	Salatiga	1.2	1.5	1.2	1.886	1.2	2.372
11	Bandar Lampung	1.2	1.5	1.2	1.98	1.2	2.72
12	Kebumen	1.2	1.5	1.2	1.964	1.2	2.656
13	Kediri	1.2	1.5	1.2	1.961	1.2	2.644
14	Malang	1.2	1.5	1.2	1.969	1.2	2.676
15	Purwokerto	1.2	1.5	1.166	1.961	1.232	2.644

The parameters of acceleration response spectra at short period (S_MS) and 1.0-second period (S_M1) are adjusted according to the site classification and seismic amplification factor. To determine the anomalies that occur, three site class conditions are needed: hard soil (SC), medium soil (SD), and soft soil (SE) [17].

Table 10 presents the values of acceleration response spectra parameters that experience anomalies at short period (S_MS) and 1.0-second period (S_M1). These values are the result of multiplying the site classification with the seismic amplification factor based on SNI 1726:2019. Table 11 shows the values of acceleration response spectra parameters at short period (S_MS) and 1.0-second period (S_M1). These results are a step towards normalization using the Kircher & Associates method.

Table 10. Values of S_MS and S_M1 Based on SNI 1726:2019.

No	**City**	**SC**		**SD**		**SE**	
		S_{MS}	S_{M1}	S_{MS}	S_{M1}	S_{MS}	S_{M1}
1	Banda Aceh	1.645	0.838	1.371	1.018	1.168	1.198
2	Bengkulu	1.348	0.761	1.180	0.913	1.125	1.115
3	Mataram	1.151	0.576	1.071	0.736	1.086	0.946
4	Padang	1.625	0.839	1.354	1.018	1.162	1.198
5	Yogyakarta	1.540	0.698	1.283	0.853	1.138	1.056
6	Bogor	1.058	0.534	1.012	0.692	1.053	0.917
7	Denpasar Bali	1.172	0.540	1.084	0.698	1.093	0.922
8	Jember	1.004	0.593	0.956	0.767	0.991	1.016
9	Ngawi	1.076	0.574	1.023	0.733	1.060	0.945
10	Salatiga	1.107	0.621	1.043	0.781	1.072	0.982
11	Bandar Lampung	0.900	0.480	0.900	0.634	0.975	0.870
12	Kebumen	1.022	0.635	0.987	0.759	1.038	0.925
13	Kediri	0.956	0.509	0.941	0.665	1.006	0.896
14	Malang	0.940	0.497	0.929	0.652	0.997	0.886
15	Purwokerto	1.002	0.509	0.974	0.665	1.029	0.896

Table 11. Normalized Values of S_MS and S_M1

No	City	SC		SD		SE	
		S_{MS}	S_{M1}	S_{MS}	S_{M1}	S_{MS}	S_{M1}
1	Banda Aceh	1.481	0.921	1.645	1.526	2.014	2.394
2	Bengkulu	1.213	0.766	1.348	1.326	1.583	2.127
3	Mataram	1.036	0.605	1.151	0.987	1.314	1.618
4	Padang	1.462	0.922	1.625	1.527	1.984	2.395
5	Yogyakarta	1.386	0.71	1.54	1.207	1.858	1.95
6	Bogor	0.953	0.561	1.058	0.919	1.192	1.504
7	Denpasar Bali	1.055	0.567	1.172	0.929	1.343	1.521
8	Jember	0.904	0.622	0.956	1.02	1.119	1.669
9	Ngawi	0.968	0.602	1.076	0.974	1.215	1.612
10	Salatiga	0.996	0.652	1.107	1.02	1.255	1.506
11	Bandar Lampung	0.81	0.504	0.9	0.83	0.99	1.349
12	Kebumen	0.875	0.529	0.972	0.871	1.081	1.426
13	Kediri	0.861	0.534	0.956	0.877	1.061	1.432
14	Malang	0.846	0.521	0.94	0.857	1.04	1.397
15	Purwokerto	0.902	0.534	0.974	0.877	1.149	1.432

Tables 10 and 11 represent the acceleration spectrum design parameters used to create the design spectrum response graph. This graph is utilized to determine the planned earthquake loads in the form of base shear forces caused by the earthquake. The design spectrum response is obtained by dividing the surface acceleration response parameters (SMS and SM1) by a 1.5 margin against collapse [8][18].

Table 12 shows the values of the spectral acceleration parameters at short period (SDS) and 1.0-second period (SD1) that experience anomalies. Table 13 contains the values of the spectral acceleration parameters at short period (SDS) and 1.0-second period (SD1) that have been normalized using the Kircher & Associates method.

Table 12. Values of SDS and SD1 Based on SNI 1726:2019.

No	**City**	**SC**		**SD**		**SE**	
		S_{DS}	S_{D1}	S_{DS}	S_{D1}	S_{DS}	S_{D1}
1	Banda Aceh	1.097	0.559	0.914	0.679	0.778	0.799
2	Bengkulu	0.898	0.507	0.787	0.608	0.750	0.744
3	Mataram	0.767	0.384	0.714	0.490	0.724	0.631
4	Padang	1.083	0.559	0.903	0.679	0.775	0.799
5	Yogyakarta	1.026	0.465	0.855	0.569	0.759	0.704
6	Bogor	0.706	0.356	0.675	0.461	0.702	0.611
7	Denpasar Bali	0.782	0.360	0.722	0.466	0.728	0.614
8	Jember	0.670	0.395	0.637	0.512	0.661	0.677
9	Ngawi	0.717	0.383	0.682	0.489	0.707	0.630
10	Salatiga	0.738	0.414	0.695	0.520	0.715	0.654
11	Bandar Lampung	0.600	0.320	0.600	0.422	0.650	0.580
12	Kebumen	0.681	0.424	0.658	0.759	0.692	0.616
13	Kediri	0.638	0.339	0.628	0.443	0.671	0.598
14	Malang	0.626	0.331	0.620	0.434	0.665	0.591
15	Purwokerto	0.668	0.339	0.649	0.443	0.686	0.598

Table 13. Normalized Values of SDS and SD1

No	City	SC		SD		SE	
		S_{DS}	S_{D1}	S_{DS}	S_{D1}	S_{DS}	S_{D1}
1	Banda Aceh	0.987	0.614	1.097	1.017	1.343	1.596
2	Bengkulu	0.809	0.511	0.898	0.884	1.055	1.418
3	Mataram	0.690	0.403	0.767	0.658	0.876	1.079
4	Padang	0.975	0.614	1.083	1.018	1.322	1.597
5	Yogyakarta	0.924	0.473	1.026	0.805	1.238	1.300
6	Bogor	0.635	0.374	0.706	0.613	0.795	1.003
7	Denpasar Bali	0.703	0.378	0.782	0.619	0.895	1.014
8	Jember	0.603	0.415	0.637	0.680	0.746	1.112
9	Ngawi	0.645	0.402	0.717	0.649	0.810	1.075
10	Salatiga	0.664	0.434	0.738	0.680	0.837	1.004
11	Bandar Lampung	0.540	0.336	0.600	0.553	0.660	0.899
12	Kebumen	0.583	0.353	0.648	0.871	0.721	0.950
13	Kediri	0.574	0.356	0.638	0.585	0.707	0.955

14	Malang	0.564	0.348	0.626	0.572	0.693	0.932
15	Purwokerto	0.601	0.356	0.649	0.585	0.766	0.955

The normalization of the site class spectral response graph for Hard Soil (SC) shows a decrease in SDS values by an average of 10%, and an increase in SD1 values by an average of 5%. For Medium Soil (SD), the S_DS values increase by an average of 7.74%, and the SD1 values increase by an average of 34.95%. For Soft Soil (SE), the S_DS values increase by an average of 25.06%, and the SD1 values increase by an average of 69.99%.

The results of the plot of the spectral response anomalies and the normalized spectral responses from 15 cities are presented together in Figures 6 - 20. The spectral response anomalies are depicted with solid lines, while the treated design spectral responses are presented with dashed lines. The curves in blue, yellow, and red respectively represent Soft Soil (SE), Medium Soil (SD), and Hard Soil (SC) site classes.

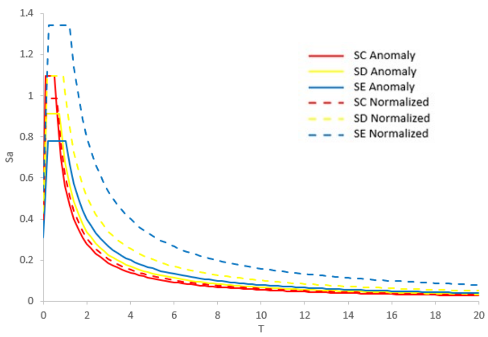

Figure 6. Design Spectral Response of Banda Aceh City

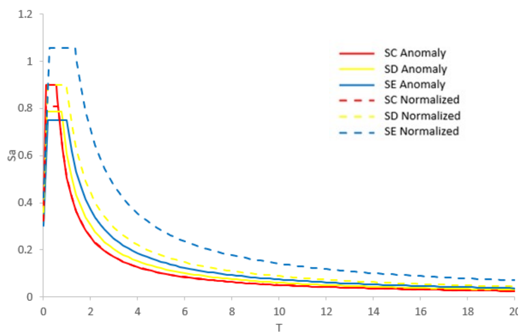

Figure 7. Design Spectral Response of Bengkulu City

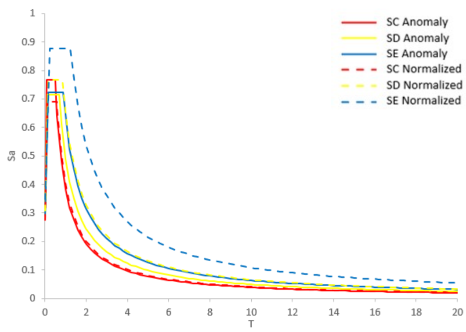

Figure 8. Design Spectral Response of Mataram City

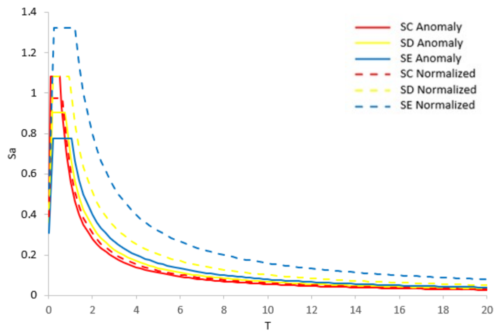

Figure 9. Design Spectral Response of Padang City

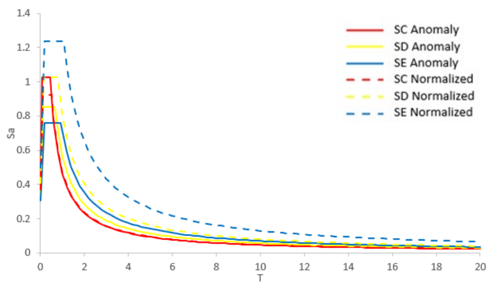

Figure 10. Design Spectral Response of Yogyakarta City

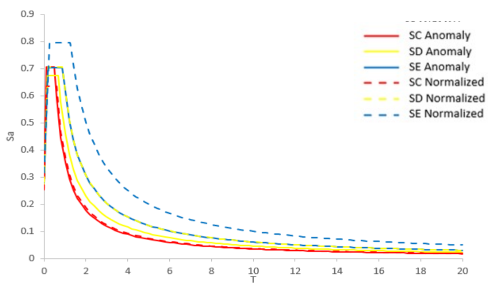

Figure 11. Design Spectral Response of Bogor City

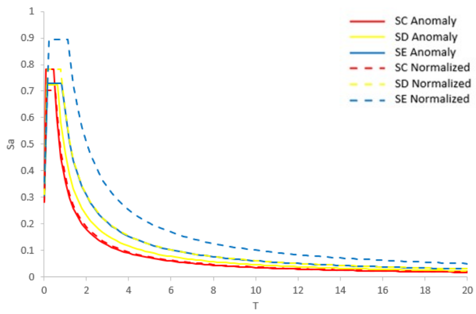

Figure 12. Design Spectral Response of Bali City

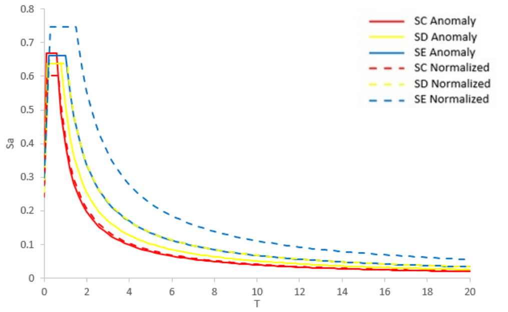

Figure 13. Design Spectral Response of Jember City

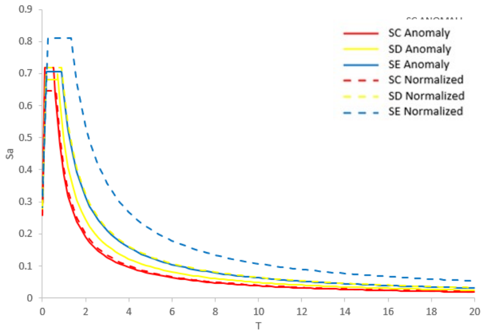

Figure 14. Design Spectral Response of Ngawi City

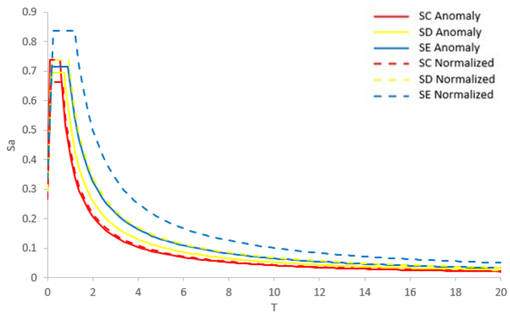

Figure 15. Design Spectral Response of Salatiga City

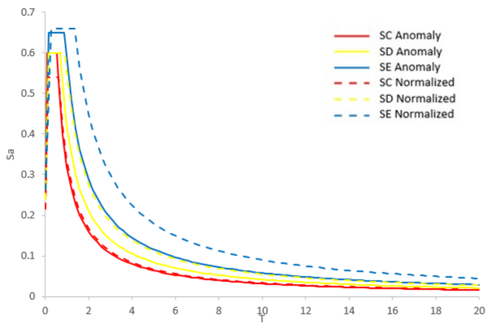

Figure 16. Design Spectral Response of Bandar Lampung City

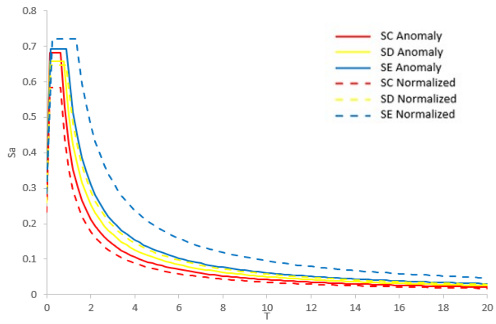

Figure 17. Design Spectral Response of Kebumen City

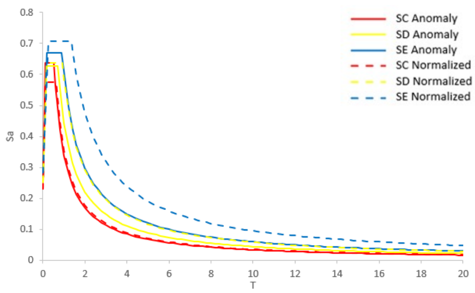

Figure 18. Design Spectral Response of Kediri City

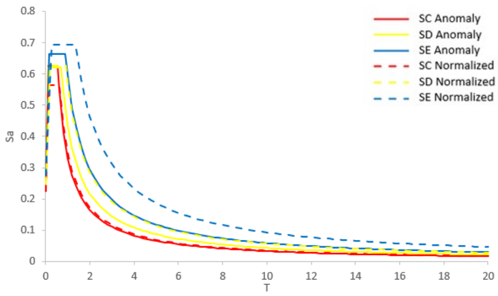

Figure 19. Design Spectral Response of Malang City

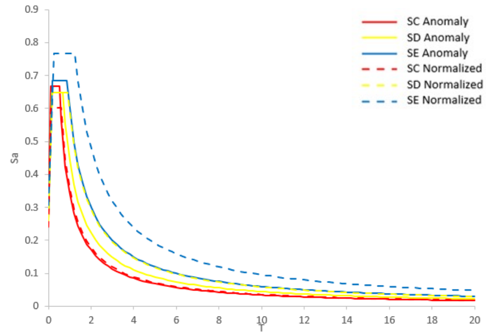

Figure 20. Design Spectral Response of Purwokerto City

The text describes the spectral response graphs from Figure 6 to Figure 20, indicating anomalies in earthquake-prone cities where the Ss value is above 0.75 g [9][19]. After normalization, the spectral response graphs appear normal, with earthquake accelerations in the Hard Soil (SC) site class being lower than those in the Medium Soil (SD) site class, which in turn are lower than those in the Soft Soil (SE) site class.

The results of normalizing the spectral response for Medium Soil (SD) and Soft Soil (SE) using the Kircher & Associates design method show a significant increase in earthquake acceleration compared to when anomalies were present. On the other hand, the normalization of the spectral response for Hard Soil (SC) results in a decrease in earthquake acceleration compared to when anomalies were present. Based on the spectral response graphs in Figures 6 to 10, it is observed that anomalies of Type 1 experience the most significant changes after normalization, followed by Type II anomalies (Figures 11-15), and finally Type III anomalies (Figures 16-20) [9][19].

4. Conclusions

The text discusses the anomalies observed in the design spectral response graphs for 15 earthquake-prone cities, categorized into three types: (1) Type I anomaly where SE < SD < SC, (2) Type II anomaly: SD < SE < SC, and (3) Type III anomaly: SD < SC < SE. The spectral responses experiencing anomalies were normalized using the Kircher & Associates method. The normalization process resulted in a decrease in earthquake acceleration for Hard Soil (SC) and an increase in earthquake acceleration for Medium Soil (SD) and Soft Soil (SE).

In earthquake-prone areas in Indonesia, it is common to experience anomalies in the spectral response graphs. These graphs are used to determine the planned earthquake loads for structural design. To ensure that a location experiences anomalies or not, it is essential to display the design spectral responses for all soil conditions. Anomalous spectral responses can be identified by plotting all soil types in one graph.

The consequences of errors arising from anomalous design spectral responses without normalization can be catastrophic. For Medium and Soft Soil site classes, the earthquake acceleration values for the spectral responses experiencing anomalies are lower than those that have been normalized. As a result, the design earthquake loads become smaller. If a major earthquake occurs that exceeds the design earthquake loads, the building may collapse. It is crucial to properly account for anomalies and perform normalization to ensure the safety and stability of structures in earthquake-prone areas.

References

1. BMKG, "Kejadian Gempa Bumi Merusak Di Indonesia Tahun 2022," *Kementerian Energi dan Sumber Daya Mineral Badan Geologi*, 2023. [Online]. Available: https://vsi.esdm.go.id/index.php/kegiatan-pvmbg/kegiatan-diseminasi-informasi/4041-kejadian-gempa-bumi-merusak-di-indonesia-tahun-2022.
2. J. Supriyanto *et al.*, "'Sistem Informasi Gempa Bumi Menggunakan data XML Berbasis pengolahan Teks Parsing dan Concatenation,'" *Telematika*, vol. 16, no. 1, pp. 35–42, 2019.
3. A. Wicaksana and A. Rosyidah, "PEMBANDINGAN DESAIN BANGUNAN TAHAN GEMPA MENGGUNAKAN SNI 1726 : 2012 DAN SNI 1726:2019," no. 11, 2020.
4. J. P. Stewart and E. Seyhan, "Semi-empirical nonlinear site amplification and its application in NEHRP site factors," *Berkeley, United States Am. Pacific Earthq. Eng. Res. Cent.*, no. November, 2013.
5. P. S. G. Nasional, *Peta Sumber Dan Bahaya Gempa Indonesia Tahun 2017*. 2017.
6. S. Sutjipto and I. Sumeru, "Comparison of the RSNI 1726:2018 and the SNI 1726:2012 design response spectra of 17 major cities in Indonesia," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 650, no. 1, pp. 0–10, 2019.
7. C. B. Surya Permana, "Design Response Spectra Based on Earthquake Hazard Maps and Specific Soil Properties at Indonesian Ports According to SNI 1726 2019," *J. Tek. Sipil*, vol. 17, no. 1, pp. 41–54, 2021.
8. M. Sitompul, H. M. Pasaribu, and T. Oktaviani, "Studi Perbandingan Spektrum Respons Desain SNI 1726:2019 terhadap SNI 1726:2012 di Provinsi Sumatera Utara," *J. Tek. Sipil*, vol. 11, no. 1, pp. 30–39, 2022.
9. S. Sutjipto and I. Sumeru, "Anomaly Phenomena on the New Indonesian Seismic Code SNI 1726:2019 Design Response Spectra," in *6th International Conference on Civil, Offshore and Environmental Engineering, ICCOEE 2020*, 2021, vol. 132, pp. 375–384.
10. S. Sutjipto, "Anomali Spektrum Respons Desain SNI 1726 : 2012," in *Prosiding Seminar dan Pameran Himpunan Ahli Konstruksi Indonesia (HAKI) 2015*, 2015, pp. 1–14.
11. SNI 1726, *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Nongedung*. Bandung: Badan Standardisasi Indonesia, 2019, p. 254.
12. ASCE 7-16, *Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7-16)*. 2016.
13. M. Irsyam, B. M. Hutapea, and I. Imran, "Zonasi Hazard Gempa Bumi untuk Wilayah Jakarta," *J. Tek. Sipil*, vol. 24, no. 2, pp. 159–166, 2017.
14. Kircher & Associates, "Investigation of an identified short-coming in the seismic design procedures of ASCE 7-10 and development of recommended improvements for ASCE 7-16," *Seism. Des. Proced. Study*, 2015.
15. I. W. Sengara *et al.*, "New 2019 Risk-Targeted Ground Motions for Spectral Design Criteria in Indonesian Seismic Building Code," *E3S Web Conf.*, vol. 156, p. 03010, 2020.
16. 1726-2019 SNI, *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Non Gedung*. Badan Standarisasi Nasional, Jakarta, 2019.
17. J. X. Zhao *et al.*, "Attenuation relations of strong ground motion in Japan using site classification based on predominant period," *Bull. Seismol. Soc. Am.*, vol. 96, no. 3, pp. 898–913, 2006.
18. A. Cipta, P. Cummins, M. Irsyam, and S. Hidayati, "Basin resonance and seismic hazard in jakarta, Indonesia," *Geosci.*, vol. 8, no. 4, Apr. 2018.
19. S. Sutjipto, "Perbandingan Spektrum Respons Desain RSNI 1726 : 2018 dan SNI 1726-2012 Pada 17 Kota Besar Di Indonesia," in *Konferensi Nasional Teknik Sipil ke-12 2018*, 2018, pp. 1–7.