Comparative Study of Earthquake Spectrum Response Parameters of SNI 1726-2012 Design Against SNI 1726-2019 in Batam City

Ni Kadek Astariani, I Putu Raditya Hiswara, I Gede Ardi Yudha Pratama, I Gede Kerta Yasa, I Putu Agus Harry Calvin

Program Studi Teknik Sipil Fakultas Sains dan Teknologi Universitas Ngurah Rai, Bali, INDONESIA

E-mail: kadek.astariani@unr.ac.id, radityahiswara@gmail.com, yudapramata12@gmail.com, gedekerta04@gmail.com, harrycalvin04@gmail.com

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ABSTRACT

This study analyzes the impact of the seismic standard transition from SNI 1726:2012 to SNI 1726:2019 on seismic design parameters in the Batam City region. The primary focus is to evaluate changes in design spectral acceleration values at short periods and 1-second periods across various site classifications, including hard, medium, and soft soil. The research methodology involves collecting geographic coordinates across all districts in Batam to determine base rock parameter values, which are subsequently adjusted using site coefficients according to the latest regulations. The analysis reveals a consistent upward trend in seismic design parameters throughout all research locations. The most significant increase occurred in the soft soil classification, where soil amplification effects in the latest standard yield higher earthquake load values compared to the previous standard. These findings emphasize that the updated national seismic map directly enhances the structural safety standards for buildings in Batam. The results of this study are expected to serve as a reference for construction practitioners and local authorities in designing earthquake-resistant buildings that align with the latest seismic risk levels to mitigate potential structural failures due to earthquake loads not accommodated in older designs.

Keywords: response spectrum, site classification, Batam City, spectral accelerationta.

INTRODUCTION

Indonesia is an earthquake-prone region because it is crossed by the meeting point of three major tectonic plates [1]. According to Syafitri et al. (2019), the three tectonic plates are the Indonesia-Australia Plate, the Eurasian Plate, and the Pacific Plate. Based on BMKG records, Indonesia has experienced various major earthquakes that have had significant impacts on infrastructure and casualties, such as the 2004 Aceh earthquake with a magnitude of 9.1–9.3 which triggered a tsunami, the 2006 Yogyakarta earthquake with a magnitude of 6.3, the 2009 Padang earthquake with a magnitude of 7.6, and the 2018 Palu–Donggala earthquake with a magnitude of 7.5 which was accompanied by a tsunami and liquefaction. Furthermore, the 2022 Cianjur earthquake, measuring 5.6 in magnitude, demonstrated that even moderate-magnitude earthquakes can cause serious damage, particularly in densely populated areas and with vulnerable geological conditions.

Batam City is geographically located in the Riau Islands, which is not considered an active earthquake zone due to its relative distance from major subduction zones and major active faults on Sumatra Island [2]. Nevertheless, Batam City remains vulnerable to earthquake shocks from distant sources, particularly from West Sumatra and Aceh, which have high seismic activity. These shocks, while not directly damaging, can affect the structural response of buildings, particularly high-rise buildings. Therefore, adequate earthquake resistance analysis is essential in structural design to reduce loss of life and material losses. Indonesia has regulations for designing earthquake-resistant building structures, which has been revised to the Earthquake Resistance Planning Procedure for Building and Non-Building Structures [3], established by the National Standardization Agency (BSN) [1]. The issuance of SNI 1726:2019 as a replacement for SNI 1726:2012 by BSN requires an analysis of changes in earthquake-resistant structural design parameters. Consequently, existing

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buildings need to undergo a safety evaluation process to align with the latest criteria in Indonesian building and non-building design standards 3], [4].

The development of earthquake resistance standards, namely SNI 1726:2012 and SNI 1726:2019, uses different input data and seismic load design processes, thus, it is expected to produce different structural response results [5]. Therefore, this study aims to compare the results of the earthquake response spectrum of SNI 1726:2012 with SNI 1726:2019 in 10 sub-districts in Batam City as samples to show the differences in the acceleration of the Design Response Spectrum of the two SNIs. The selected sub-districts are considered to be able to specifically represent the conditions of all areas in Batam City in general. This comparison is expected to provide an overview of the level of seismic response of structures in Batam City and become evaluation material in the planning and design of earthquake-resistant buildings in accordance with the provisions of applicable regulations in Indonesia.

Revision of the Seismic Standard from SNI 1726-2012 to SNI 1726-2019

The change in earthquake provisions from SNI 1726:2012 to SNI 1726:2019 represents an improvement in earthquake resilience planning standards based on the 2017 update of the Indonesian Earthquake Source and Hazard Map (Istiono & Lisawiyani, 2022). SNI 1726:2012 refers to the development of modern earthquake regulations (especially regulations in the United States) such as FEMA P-750, ASCE/SEI 7-10 (2010) and takes into account Indonesian seismic data up to 2010 as outlined in the 2010 Indonesian Earthquake Map. Meanwhile, SNI 1726:2019 refers to ASCE 7-16 and is based on an update of the National Earthquake Map that produced the Indonesian Earthquake Source and Hazard Map [6].

SNI 1726:2019 also clarifies soil site classifications (SA to SF) and soft soil evaluation criteria, requiring specific response spectrum analysis under certain conditions [7]. Furthermore, provisions for structural system selection, earthquake reduction factors (R), seismic importance factors (Ie), and dynamic analysis requirements are tightened, particularly for high-rise buildings and irregular structures. Overall, the implementation of SNI 1726:2019 results in generally larger design seismic forces than SNI 1726:2012, resulting in more conservative structural design and a more accurate reflection of the actual earthquake hazard level.

Acceleration Spectral Response Parameters of SNI 1726:2012

Acceleration Spectral Response 0.2 seconds (SS) and 1 second (S1)

Based on SNI 1726:2012, the Ss and S1 values are determined using spectral acceleration maps or official PuSGeN facilities based on site coordinates. Because these values still represent bedrock conditions, corrections are required using site coefficients (Fa and Fv) according to local soil classification to produce a design response spectrum. Earthquake maps can be seen in Figures 1 and 2.

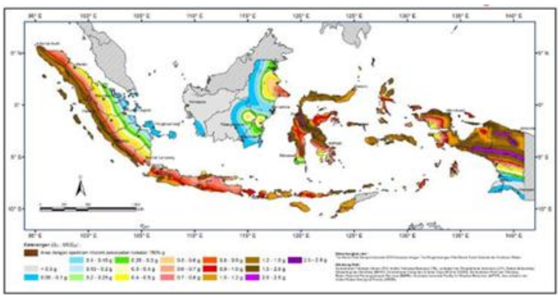

Figure 1. SNI 1726:2012 (SS) Earthquake Map

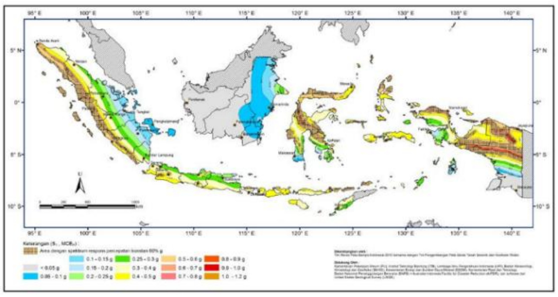

Figure 2. SNI 1726:2012 Earthquake Map (S1)

Site Classification

Site classification aims to determine the earthquake amplification factor from bedrock to the ground surface based on shear wave propagation velocity, SPT value, or non-linear shear strength [8]. Soil properties can be classified into site classes, including SA (hard soil), SB (rock), SC (hard, very dense soil, and soft rock), SD (medium soil), SE (soft soil), and SF (special soil [7]). Site class determination must be carried out through field and laboratory soil investigations, conducted by the competent authority or a certified geotechnical design expert, independently measuring two of the three soil parameters shown in Figure 3.

Kelas Situs	$\bar{v}_s$ (m/detik)	$\bar{N}$ atau $\bar{N}_{ch}$	$\bar{s}_u$ (kPa)
SA (batuan keras)	> 1500	N/A	N/A
SB (batuan)	750 sampai 1500	N/A	N/A
SC (tanah keras, sangat padat dan batuan lunak)	350 sampai 750	>50	≥ 100
SD (tanah sedang)	175 sampai 350	15 sampai 50	50 sampai 100
SE (tanah lunak)	< 175	<15	< 50
	Atau setiap profil tanah yang mengandung lebih dari 3 m tanah dengan karateristik sebagai berikut : 1. Indeks plastisitas, PI > 20, 2. Kadar air, w ≥ 40 %, dan 3. Kuat geser niralir $\bar{s}_u < 25kPa$		
SF (tanah khusus, yang membutuhkan investigasi geoteknik spesifik dan analisis respons spesifik-situs yang mengikuti Pasal 6.9.1) Keterangan: N/A = *tidak dapat dipakai*	Setiap profil lapisan tanah yang memiliki salah satu atau lebih dari karakteristik berikut: - Rawan dan berpotensi gagal atau runtuh akibat beban gempa seperti mudah likuifaksi, lempung sangat sensitif, tanah tersementasi lemah, - Lempung sangat organik dan/atau gambut (ketebalan H > 3 m), - Lempung berplastisitas sangat tinggi (ketebalan H > 7,5 m dengan Indeks Plasitisitas, PI > 75), - Lapisan lempung lunak/medium kaku dengan ketebalan H > 35 m dengan s_u < 50 kPa.		

Figure 3. Site Classification according to SNI 1726:2012

Site Coefficient Factors Fa and Fv

The Ss and S1 values represent bedrock acceleration values, so an amplification factor (site coefficient) is required to modify these values according to existing soil conditions [9]. There are two amplification factors: Fa = site coefficient for short periods (at a period of 0.2 seconds), and Fv = site coefficient for long periods (at a period of 1 second) [10]. The following comparison of Fa and Fv values in SNI 1726:2012 is presented in Tables 1 and 2.

Table 1. Site Coefficient Fa

Site Class	Site Class Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) spectral response acceleration parameter at short periods, T = 0.2 seconds, Ss					
	Ss <	**Ss =**	**Ss =**	**Ss =**	**Ss =**	**Ss >**
	0,25	**0,5**	**0,75**	**1**	**1,25**	**1,5**
SA	0,80	0,80	0,80	0,80	0,80	0,80

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Site Class	Site Class Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) spectral response acceleration parameter at short periods, T = 0.2 seconds, Ss					
SB	0,90	0,90	0,90	0,90	0,90	0,90
SC	1,30	1,30	1,20	1,20	1,20	1,20
SD	1,60	1,40	1,20	1,10	1,00	1,00
SE	2,40	1,70	1,30	1,10	0,90	0,80
SF			SS[a]			

Table 2. Site Coefficient Fv

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Acceleration Parameters at Short Periods and at 1-Second Period (S1)					
	Ss <	**Ss =**	**Ss =**	**Ss =**	**Ss =**	**Ss >**
	0,1	**0,2**	**0,3**	**0,4**	**0,5**	**0,6**
SA	0,80	0,80	0,80	0,80	0,80	0,80
SB	0,80	0,80	0,80	0,80	0,80	0,80
SC	1,50	1,50	1,50	1,50	1,50	1,40
SD	2,40	2,20	2,00	1,90	1,80	1,70
SE	4,20	3,30	2,80	2,40	2,20	2,00
SF			SS[a]			

Spectral Acceleration Factor
SMS (Maximum Considered Earthquake Spectral Acceleration – Short Period)

SMS is the maximum design earthquake spectral acceleration (MCE) for a short period (T = 0.2 seconds) adjusted to local ground conditions. SMS can be determined using the equation:

$$\mathrm{SMS} = \mathrm{Fa} \times \mathrm{SS} \tag{1}$$

Where:
SMS = Short-period spectral acceleration response parameter (MCE) adjusted for site class.
Fa = Acceleration amplification factor for short-period vibrations.
SS = Baseline earthquake spectral acceleration at 0.2 seconds.

M1 (Maximum Considered Earthquake Spectral Acceleration – 1 Second Period)
SM1 is the maximum earthquake spectral acceleration (MCE) at 1 second, corrected for ground conditions. SM1 describes the earthquake response of medium- to long-period structures, such as mid-rise and high-rise buildings. SM1 can be determined using the equation:

$$\mathrm{SM1} = \mathrm{Fv} \times \mathrm{S1} \tag{2}$$

Where:
SM1 = Maximum earthquake spectral acceleration (MCE) at a period of 1 second.
Fa = Soil amplification factor for a period of 1 second.
S1 = Baseline earthquake spectral acceleration at a period of 1 second.

SDS (Design Spectral Acceleration – Short Period)
SDS is the design spectral acceleration at a short period (0.2 seconds) used directly in calculating the design seismic force. SDS can be determined using the equation:

$$\mathrm{SDS} = 2/3 \times \mathrm{SMS} \tag{3}$$

Where:
SDS = Design spectral acceleration at short periods (0.2 seconds).
SMS = MCE spectral response acceleration parameters at short periods adjusted for site class.

SD1 (Design Spectral Acceleration – 1 Second Period)
SD1 is the design spectral acceleration at a period of 1 second, which is also used in structural analysis. SD1 can be determined using the equation:

$$\mathrm{SD1} = 2/3 \times \mathrm{SM1} \tag{4}$$

Where:
SD1 = Design spectral acceleration at short periods (1 second).
SM1 = Maximum seismic spectral acceleration (MCE) at 1 second.

T0 (Initial Transition Period of Response Spectrum)
T0 is the initial transition period on the design response spectrum curve, marking the boundary between the constant acceleration region and the increasing acceleration region. T0 can be determined using the equation:

$$\mathrm{T0} = 0{,}2 \times \frac{\mathrm{SD1}}{\mathrm{SDS}} \tag{5}$$

Where:
T0 = Initial transition period on the design response spectrum curve.
SD1 = Design acceleration spectrum at short periods (1 second).
SDS = Design acceleration spectrum at short periods (0.2 seconds).

TS (Primary Transition Period of the Response Spectrum)
TS is the primary transition period separating the constant acceleration region from the constant velocity region on the design response spectrum. TS can be determined using the equation:

$$\mathrm{TS} = \frac{\mathrm{SD1}}{\mathrm{SDS}} \tag{6}$$

where:
TS = Main Transition Period of the Response Spectrum
SD1 = Design spectral acceleration at short periods (1 second)
SDS = Design spectral acceleration at short periods (0.2 seconds)

SNI 1726:2012 Response Spectrum Graph

The earthquake response spectrum based on SNI 1726:2012 was compiled with reference to the 2010 Indonesian Earthquake Source and Hazard Map, which produces basic spectral acceleration values Ss and S1 as the main parameters forming the spectrum curve, as shown in Figure 4.

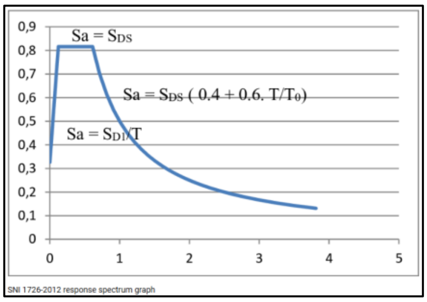

Figure 4. SNI 1726:2012 Response Spectrum Graph

The design response spectrum graph in SNI 1726:2012 has a standard curve shape consisting of regions of increasing acceleration, constant acceleration, constant velocity, and constant displacement, with a relatively lower spectrum ordinate compared to the latest regulations. The design acceleration spectra SDS and SD1 values are obtained by reducing the maximum seismic spectrum (MCE) by two-thirds, so that the resulting design seismic forces still reflect the level of seismic hazard based on the seismic data available at the time, particularly for medium- to long-period structures.

Acceleration Spectral Response Parameters of SNI 1726:2019

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Acceleration Response Spectra at 0.2 seconds (Ss) and 1 second (S1)

In SNI 1726:2012, the Ss and S1 values were obtained from the 2010 Indonesian Earthquake Map, while in SNI 1726:2019, the updated 2017 Indonesian Earthquake Map was used [9]. These values are determined based on the geographic coordinates of the building location and represent spectral acceleration under bedrock conditions with an earthquake recurrence period of 2,500 years. These values are then used as the basic parameters in generating the design response spectrum after considering local soil conditions [11]. The earthquake maps can be seen in Figures 5 and 6.

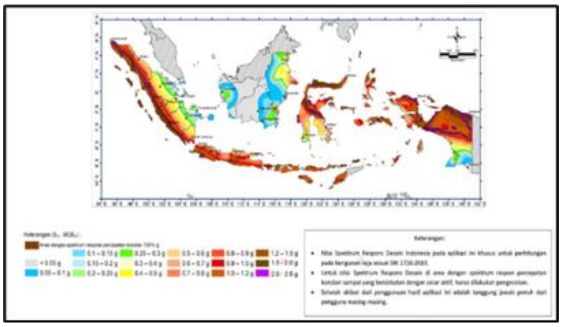

Figure 5. SNI 1726:2019 (SS) Earthquake Map

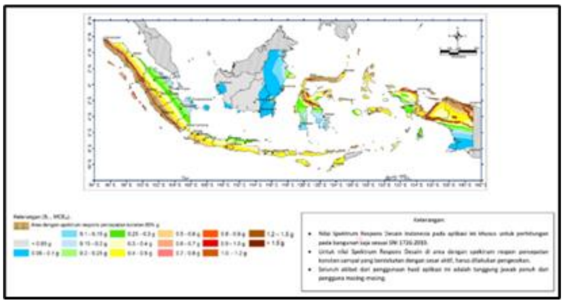

Figure 6. SNI 1726:2019 Earthquake Map (S1)

Site Classification

In general, the site class classification in SNI 1726:2012 and SNI 1726:2019 maintains the six main classes: SA (hard rock), SB (rock), SC (hard soil), SD (medium soil), SE (soft soil), and SF (special soil), which are determined based on geotechnical parameters such as average shear wave velocity (Vs30), N-SPT value, and undrained shear strength (cu). However, in the site class classification, the site coefficient values have changed, with significant changes occurring in the SE (soft soil) site class [7]. The SNI 1726:2019 site class classification can be seen in Figure 7.

Kelas situs	$\bar{v}_s$ (m/detik)	$\bar{N}$ atau $\bar{N}_{ch}$	$\bar{s}_u$ (kPa)
SA (batuan keras)	>1500	N/A	N/A
SB (batuan)	750 sampai 1500	N/A	N/A
SC (tanah keras, sangat padat dan batuan lunak)	350 sampai 750	>50	≥100
SD (tanah sedang)	175 sampai 350	15 sampai 50	*50 sampai100*
SE (tanah lunak)	< 175	<15	*< 50*
	Atau setiap profil tanah yang mengandung lebih dari 3 m tanah dengan karateristik sebagai berikut : 1. Indeks plastisitas, $PI > 20$, 2. Kadar air, $w \geq 40\%$, 3. Kuat geser niralir $\bar{s}_u < 25$ kPa		
SF (tanah khusus,yang membutuhkan investigasi geoteknik spesifik dan analisis respons spesifik-situs yang mengikuti 6.10.1)	Setiap profil lapisan tanah yang memiliki salah satu atau lebih dari karakteristik berikut: - Rawan dan berpotensi gagal atau runtuh akibat beban gempa seperti mudah likuifaksi, lempung sangat sensitif, tanah tersementasi lemah - Lempung sangat organik dan/atau gambut (ketebalan $H > 3$ m) - Lempung berplastisitas sangat tinggi (ketebalan $H > 7{,}5$ m dengan indeks plasitisitas $PI > 75$) Lapisan lempung lunak/setengah teguh dengan ketebalan $H > 35$ m dengan $\bar{s}_u < 50$kPa		

CATATAN: N/A = tidak dapat dipakai

Figure 7. SNI 1726:2019 Site Classification

Site Coefficients Fa and Fv

The coefficient values for both Fa and Fv have undergone some changes, but not significant changes. Explain that the difference in Fa values between SNI 1726:2012 and SNI 1726:2019 for the Rock (SB) site class shows a decrease of 0.1 for all Ss values. Furthermore, for the Hard Soil (SC) site class, all Ss values increase by 0.1 and 0.2, respectively [7], [12]. Meanwhile, for the Soft Soil (SE) site class, some Ss values increase by 0.1 and 0.2, some remain constant, and some decrease by 0.1. The site coefficients for Fa are outlined in Table 3.

Table 3. Site Coefficients Fa

Site Class	**Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short Period, T = 0.2 Seconds, Ss**					
	Ss <	**Ss =**	**Ss =**	**Ss =**	**Ss =**	**Ss >**
	0,25	**0,5**	**0,75**	**1**	**1,25**	**1,5**
SA	0,80	0,80	0,80	0,80	0,80	0,80
SB	0,90	0,90	0,90	0,90	0,90	0,90
SC	1,30	1,30	1,20	1,20	1,20	1,20
SD	1,60	1,40	1,20	1,10	1,00	1,00
SE	2,40	1,70	1,30	1,10	0,90	0,80
SF			SS(a)			

Furthermore, many Fv values from SNI 1726:2012 to SNI 1726:2019 experienced increases of 0.1, 0.2, 0.3, and 0.7. The largest increase was 0.7 for the SE site class with S1 ≤ 0.1. Furthermore, many values remained constant or decreased by 0.1 and 0.2. When viewed by site class, for the Hard Rock (SA) site class, all Ss values showed no increase (the values remained constant). Then, for the Rock (SB) site class, all S1 values decreased by 0.2, except for S1=0.2, where the values remained constant. Furthermore, for the other site classes, all Ss values showed variations in conditions, with some experiencing increases, some remaining constant, or some decreasing. The site Fv coefficients are outlined in Table 4.

Table 4. Site Fv Coefficients

Site Class	**Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Acceleration Parameters at Short Periods and at 1-Second Period (S1)**					
	Ss <	**Ss =**	**Ss =**	**Ss =**	**Ss =**	**Ss >**
	0,1	**0,2**	**0,3**	**0,4**	**0,5**	**0,6**

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Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Acceleration Parameters at Short Periods and at 1-Second Period (S1)					
SA	0,80	0,80	0,80	0,80	0,80	0,80
SB	0,80	0,80	0,80	0,80	0,80	0,80
SC	1,50	1,50	1,50	1,50	1,50	1,40
SD	2,40	2,20	2,00	1,90	1,80	1,70
SE	4,20	3,30	2,80	2,40	2,20	2,00
SF			SS(a)			

Spectral Acceleration Factors

The spectral acceleration parameters, consisting of SMS, SM1, SDS, SD1, T0, and TS in SNI 1726:2019, use the same mathematical formulation as those in SNI 1726:2012. Therefore, the differences in the design response spectra between the two standards are not caused by changes in the spectrum-forming equations, but rather by updates to the seismicity parameter values and soil condition factors used. These updates impact changes in the response spectrum ordinates, particularly in the medium to long periods.

SNI 1726:2019 Response Spectrum Graph

Essentially, the response spectra of SNI 1726:2019 and SNI 1726:2012 have the same curve shape, but differ in the magnitude of the spectral acceleration ordinates. The response spectrum of SNI 1726:2019 shows higher acceleration values and a longer period range compared to SNI 1726:2012, especially in the short to medium periods (Ohorella et al., 2023). This difference is caused by updates to the seismic parameters and soil amplification factors in SNI 1726:2019, resulting in a more conservative design response spectrum compared to SNI 1726:2012. The response spectrum graph of SNI 1726:2019 is presented in Figure 8.

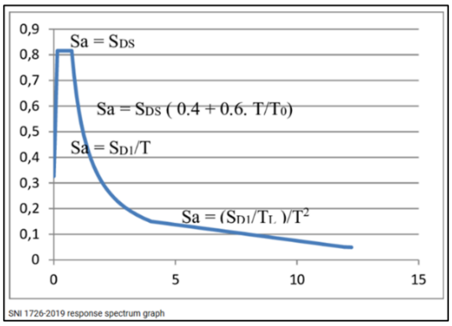

Figure 8. Response Spectrum Graph of SNI 1726:2019

RESEARCH METHODS

This research was conducted by surveying ten sub-districts on batam island to analyze earthquake response spectrum parameters based on applicable regulations, which are presented in figure 9 below.

No.	Kecamatan	Bangunan	Titik Kordinat	
			Lintang	Bujur
1.	Sekupang	Laboratorium Fisika Dasar Institut Teknologi Batam	110803105168063	103978590825506
2.	Batu Ampar	Sekolah Dhammasekha Amitabha	115519609341808	104007610862541
3.	Batu Aji	Fakultas Teknik Universitas Riau	10491453752853	103967832844904
4.	Bengkong	SMPN 004 Batam	11606736682404	104019341311927
5.	Lubuk Baja	Vihara Budhi Bhakti	113948434825015	104010563483769
6.	Nongsa	SMK PENERBANGAN BATAM	114172629631969	104138643090256
7.	Sagulung	SMK Negeri 5 Batam	102761819812035	103962625680163
8.	Sungai Beduk	SMK Negeri 3 Batam	10241714061372	104058328066543
9.	Batam Kota	Auditorium Politeknik Negeri Batam	111852859707464	104048354217436
10.	Belakang Padang	SMA Negeri 7 Batam	107316618163901	103823633166537

Figure 9. Research locations

Determining Coefficients and Parameters

To determine these coefficients and parameters, these values can be obtained from the response spectra maps of SNI 1726-2012 and SNI 1726-2019 (Ada & Tuwanakotta, 2024). However, for more accurate results, you can use the website program provided by the Ministry of Public Works and Housing. The Ss and S1 parameter values for SNI 1726-2012 are obtained from the website https://rsa.ciptakarya.pu.go.id/2010 and for SNI 1726-2019 from the website https://rsa.ciptakarya.pu.go.id/2019. The calculation steps include:

Determining the Study Location

Determine the study location by entering the location name or geographic coordinates (latitude and longitude) obtained from Google Maps as a reference point.

Soil Site Class Determination

Identify the soil site class at the study site (SC, SD, or SE) based on local geological and geotechnical characteristics.

Earthquake Parameter Data Extraction (Ss and S1)

Download short-period (Ss) and 1-second (S1) bedrock spectral acceleration values from official earthquake data source websites (e.g., national earthquake portals, online response spectrum maps, or valid earthquake data APIs) for the same location according to the provisions of both SNI versions.

Site Coefficient Determination (Fa and Fv)

Obtain Fa and Fv values according to the designated soil site class, using the Fa and Fv tables in SNI 1726:2012 and SNI 1726:2019.

Spectral Response Parameter Calculation

Calculate design spectral response parameters for SNI 1726:2012 and SNI 1726:2019:

SMS = Fa × Ss

SM1 = Fv × S1

SDS = (2/3) × SMS

SD1 = (2/3) × SM1

Determining the Spectral Period (T0, Ts, TL)

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Calculate the transition period:

T0 = 0.2 × (SD1 / SDS)

Ts = SD1 / SDS

and select a long-period TL according to the provisions of SNI 1726:2012 and SNI 1726:2019.

Creating a Comparison Graph

Drawing a graph of the spectrum responses of SNI 1726:2012 and SNI 1726:2019 on a single coordinate plane to demonstrate the differences in their spectral characteristics.

RESULTS AND DISCUSSION

Site Coefficients Fa and Fv SNI 1726:2012 and SNI 1726:2019

The Ss and S1 values represent spectral acceleration under bedrock conditions, so they need to be modified using site coefficients to adjust for the influence of local soil conditions. These coefficients consist of Fa for short periods and Fv for 1-second periods. A comparison of Fa and Fv values in SNI 1726:2012 and SNI 1726:2019 for 10 sub-districts on Batam Island is presented in Table 5 and Tables 6 below.

Table 5. Fa Values

No.	Kecamatan	Nilai Fa					
		Tanah Keras (Sc)		Tanah Sedang (SD)		Tanah Lunak (SE)	
		2012	2019	2012	2019	2012	2019
1.	Sekupang	1,20	1,30	1,60	1,60	2,50	2,40
2.	Batu Ampar	1,20	1,30	1,60	1,60	2,50	2,40
3.	Batu Aji	1,20	1,30	1,60	1,60	2,50	2,40
4.	Bengkong	1,20	1,30	1,60	1,60	2,50	2,40
5.	Lubuk Baja	1,20	1,30	1,60	1,60	2,50	2,40
6.	Nongsa	1,20	1,30	1,60	1,60	2,50	2,40
7.	Sagulung	1,20	1,30	1,60	1,60	2,50	2,40
8.	Sungai Beduk	1,20	1,30	1,60	1,60	2,50	2,40
9.	Batam Kota	1,20	1,30	1,60	1,60	2,50	2,40
10.	Belakang Padang	1,20	1,30	1,60	1,60	2,50	2,40

Tabel 6. Nilai Fv

No.	Kecamatan	Nilai Fv					
		Tanah Keras (Sc)		Tanah Sedang (SD)		Tanah Lunak (SE)	
		2012	2019	2012	2019	2012	2019
1.	Sekupang	1,70	1,50	2,40	2,35	3,50	4,00
2.	Batu Ampar	1,70	1,50	2,40	2,36	3,50	4,02
3.	Batu Aji	1,70	1,50	2,40	2,36	3,50	4,00
4.	Bengkong	1,70	1,50	2,40	2,36	3,50	4,03
5.	Lubuk Baja	1,70	1,50	2,40	2,36	3,50	4,02
6.	Nongsa	1,70	1,50	2,40	2,37	3,50	4,06
7.	Sagulung	1,70	1,50	2,40	2,35	3,50	4,00
8.	Sungai Beduk	1,70	1,50	2,40	2,35	3,50	3,98
9.	Batam Kota	1,70	1,50	2,40	2,36	3,50	4,02
10.	Belakang Padang	1,70	1,50	2,40	2,34	3,50	3,95

The comparison table shows that the site coefficient values Fa and Fv in SNI 1726:2019 generally changed compared to SNI 1726:2012. For Fa, there was an increase in hard and medium soils, while it tended to remain the same or decrease slightly in soft soils. Meanwhile, Fv values in SNI

1726:2019 were generally smaller than in SNI 1726:2012, especially in medium and soft soils. This change reflects updated earthquake maps and a more conservative and realistic approach to ground response evaluation in SNI 1726:2019.

Acceleration Spectra Response Parameters SDS and SD1

The comparison of SDS values from SNI 1726:2012 and SNI 1726:2019 in 10 sub-districts for the Hard (SC), Medium (SD), and Soft (SE) site classes is shown in Figures 10, 11, and 12.

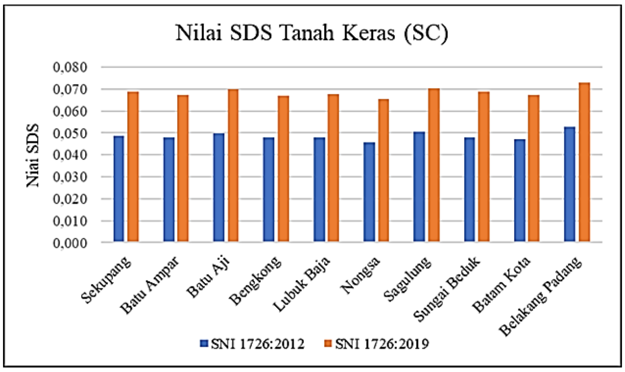

Figure 10. SDS values for stiff soil (SC)

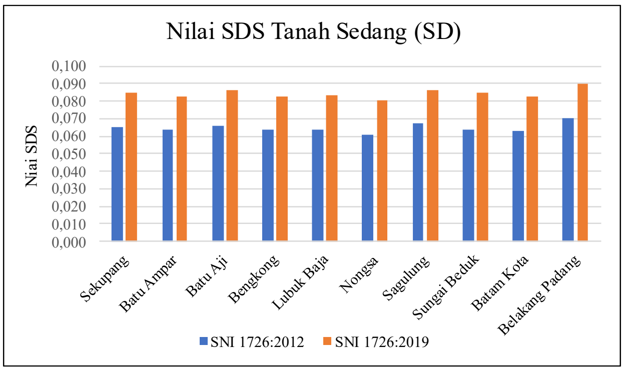

Figure 11. SDS Value of Medium Soil (SD)

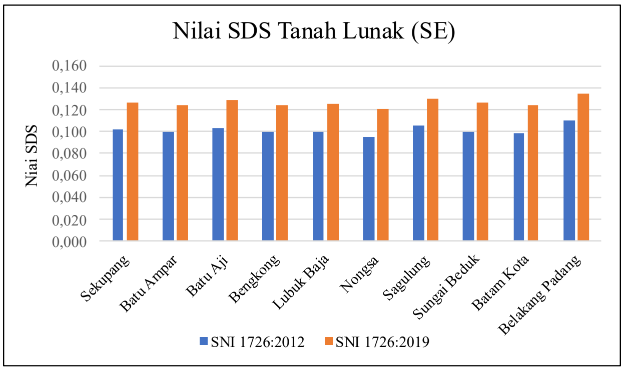

Figure 12. Soft Soil SDS Value (SE)

The three SDS graphs show that in all sub-districts in Batam City there was an increase in SDS values from SNI 1726:2012 to SNI 1726:2019 for all soil site classes (SC, SD, and SE). On average, SDS values increased from approximately 0.05 to 0.07 in hard soils, from approximately 0.07 to 0.09 in medium soils, and from approximately 0.11 to 0.13 in soft soils. The largest increase occurred in soft soils, reflecting the more significant influence of soil amplification in SNI 1726:2019 [13]-[15]. No sub-districts experienced a decrease in SDS values, so overall SNI

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1726:2019 produces a more conservative design spectral acceleration than SNI 1726:2012. Next, comparing the SD1 values from SNI 1726:2012 and SNI 1726:2019 in 10 sub-districts for the Tanah Kersa (SC), Medium (SD) and Soft (SE) site classes will be shown in Figures 13, 14 and 15 below.

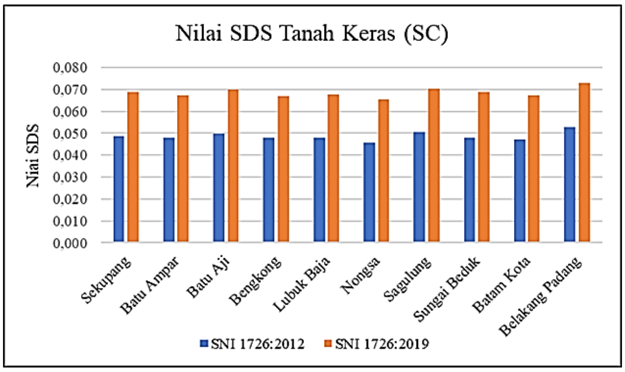

Figure 13. SDS values for hard soil (SC)

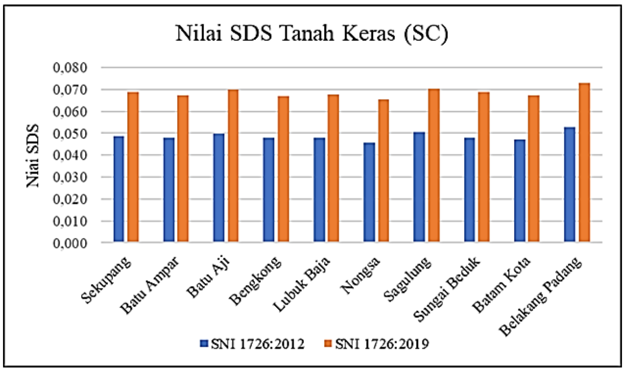

Figure 14. SDS Value of Medium Soil (SD)

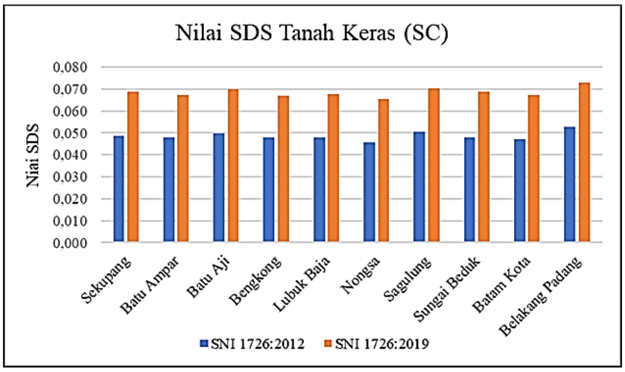

Figure 15. Soft Soil (SE) SDS Values

Overall, there was an increase in SD1 values across all sub-districts when switching from the SNI 1726:2012 standard to SNI 1726:2019 across all soil classifications. The most significant increase was seen in the Soft Soil (SE) class, with values reaching around 0.33, followed by Medium Soil (SD) and Hard Soil (SC). This upward trend was uniform across all locations with no decrease, confirming the increased earthquake acceleration parameter standards and greater amplification effects of the new regulation.

CONCLUSION

The results of this study conclude that the comparison of earthquake response spectra between SNI 1726:2012 and SNI 1726:2019 in 10 sub-districts in Batam City yielded seismic parameter values that were generally higher than those of SNI 1726:2012. Changes in site coefficient values indicate that Fa tends to increase in hard and medium soils, while soft soils remain relatively constant or decrease slightly. Meanwhile, Fv values in soft soils experience a significant increase. The impact of these changes is reflected in the design spectral response parameters, where SDS and SD1 values for hard soil (Sc), medium soil (SD), and soft soil (SE) site classes increased without any decrease across all sub-districts reviewed. The largest increase occurred in soft soils, for both SDS and SD1. Overall, SNI 1726:2019 provides a more conservative design response spectrum and reflects more actual earthquake hazard levels. Therefore, its implementation has implications for increasing structural design requirements in Batam City, particularly in locations with moderate to soft soil conditions.

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