Engineering and Technology Journal e-ISSN: 2456-3358
Volume 10 Issue 09 September-2025, Page No.-7169-7175
DOI: 10.47191/etj/v10i09.29, I.F. – 8.482

A Comparative Study on the Effects of Earthquakes on Seismic Base Shear Force, Based on Indonesian Seismic Code 2012 and 2019 (Case Study of UNSRAT Building)

Prof. Dr. Ir. Ellen Joan Kumaat, M.Sc. DEA[1], Febriana Gracia Ompi[2], Banu Dwi Handono ST, MT [3]
[1,2,3] Sam Ratulangi University, Manado, Indonesia

ABSTRACT: Indonesia is a high-seismic-risk region, requiring structural design to be regularly updated in line with seismic data developments. This study aims to compare the effects of applying Indonesian Seismic Code 2012 and Indonesian Seismic Code 2019 on the seismic base shear force of a six-story Civil Engineering Department Building at Sam Ratulangi University (UNSRAT) in Manado, Indonesia. The analysis was conducted using equivalent static and dynamic response spectrum methods with *ETABS software*. The results of the study show an increase in response spectrum parameters *(S_{DS} & S_{D1})* and an increase in basic shear force of approximately 56.7% in the 2019 Indonesian Seismic Code. In addition, displacement and inter-story drift increased by approximately 5%, with some stories exceeding the allowable drift limit, indicating unsafe structural performance according to Indonesian Seismic Code 2019. These findings emphasize the importance of implementing the updated seismic code in structural design for buildings in earthquake-prone regions to ensuring adequate stiffness and strength within the prescribed safety limits.

KEYWORDS: Earthquake, Base Shear, Seismic Code, Inter-Story Drift Limit, Reinforced Concrete Building.

1. INTRODUCTION

1.1. Background

Changes in earthquake characteristics require structural planning that no longer relies on historical assumptions. Improvements in seismic mapping accuracy, technological advances, and empirical data from prone areas to major earthquakes such as Indonesia have prompted updates to seismic code over time. The Indonesian Seismic Code *(SNI 1726)* concerning procedures for *Earthquake Resistance Designing Procedures for Building and Non-building Structures*, has undergone several changes, one of which is from the Indonesian Seismic Code 2012 *(SNI 1726:2012)* to the Indonesian Seismic Code 2019 *(SNI 1726:2019)*, these changes reflect a shift in the design paradigm, including updates to zoning maps, local soil conditions, and design parameters such as seismic response spectrum.

The difference between these two seismic code has a significant impact on the calculation of the seismic base shear force that determines the strength and rigidity of the structure. A comparative study on the UNSRAT Building in Manado, Indonesian an area with high earthquake potential, aims to assess the impact of changes in standards and contribute to increasing the resilience of educational buildings in facing future earthquake risks.

1.2. Problem Formulation

The formulation of the problem of this study is how the impact caused by the change of *SNI 1726:2012* to *SNI 1726:2019* affects the design and calculation due to different seismic loads on the base shear force and the resulting displacement, particularly in the design of reinforced concrete building structures, as examined in the UNSRAT Building, located in a seismic-prone area.

1.3. Problem Limitations

The limitations of the problems of this research are as follows:

1. To compare the impact of seismic loads on base shear force and displacement resulting from the revision of the Indonesian Seismic Code from 2012 *(SNI 1726:2012)* to 2019 *(SNI 1726:2019)*, applied to the structural model of the UNSRAT Building in Manado, Indonesia.
2. Dynamic Analysis using the Response Spectrum method and Equivalent Static analysis with two types of seismic loads referring to *SNI 1726:2012* and *SNI 1726-2019*.
3. Loading calculation based on Minimum Design Loads and Related Criteria for Buildings and Other Structures *(SNI 1727:2020)*.
4. Modeling and analysis of the building structure using ETABS software.
5. The reinforced concrete building consists of 6 stories.

6. Base of the structure is assumed to be a fixed support.

1.4. Research objectives

This study aims to analyze the seismic load on the structure of the UNSRAT Building based on the comparison of Indonesian Seismic Code 2012 and 2019, assessing the difference in seismic base shear force, interstory drift, and their impact on structural design needs. In addition, this study provides an overview of the importance of implementing the latest Seismic Code for building planning in earthquake-prone areas such as Manado City, Indonesia.

1.5. Research Benefits

This study provides information on the effect of the change in the *SNI 1726:2012* to SNI 1726:2019 on the base shear force and displacement of reinforced concrete structures. The results can be a reference in the selection of design parameters that are in accordance with the needs of structural strength, especially in buildings in high earthquake zones such as Manado City, Indonesia, as well as the basis for the development of more complex structural analysis in the future.

1.6. Indonesia Earthquake Region

The territory of Indonesia is mapped based on the level of earthquake risk, which is determined on the basis of the magnitude of the acceleration of the bedrock peak. The classification of earthquake areas in Indonesia is shown through earthquake maps that provide seismic earthquake movement and risk coefficient of the Maximum Considered Earthquake (MCE) shown in the earthquake map image as seen in *figure 1* and *figure 2*, which is the division of the Indonesian earthquake area for the Spectral acceleration of bedrock in a short period (Ss):

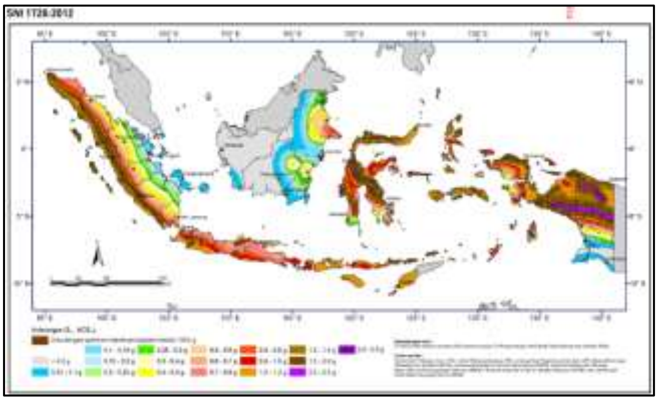

Figure 1. Distribution of Indonesian Earthquake Areas for Ss (SNI-1726:2012)

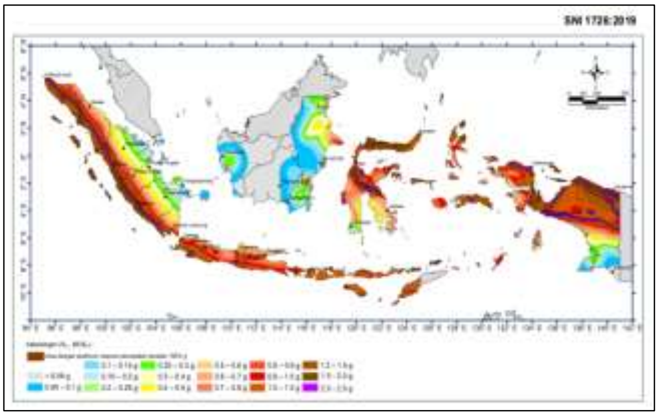

Figure 2. Distribution of Indonesian Earthquake Areas for Ss (SNI-1726:2019)

2. RESEARCH METHODS

2.1. Research Location

The research location is in Manado City, North Sulawesi, Indonesia. Geographically, the research location is at 1°45'80" S - 124°82'60" E.

Figure 3. Research Locations

2.1. Building Structure Data

This research was carried out in the lecture building of the Department of Civil Engineering UNSRAT. The building is a reinforced concrete structure comprising 6 stories + rooftop.

Structure System : Moment bearer frame system
Function of the Building : Lecture Venue
Height between floors ;

1st Story	:± 3.5 meters
Typical 2nd – 6th stories	:± 4 meters
Roof story	:± 3 meters
Total Building Height	:±26 meters (Z direction)
Building Width	:±18 meters (Y direction)
Building Length	:±36 meters (X direction)
Structure Material	:Reinforced Concrete

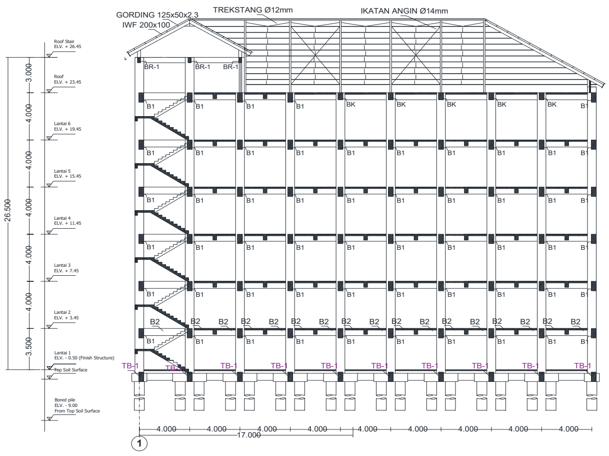

Figure 3. Visible Piece of the Portal AS-A Building Structure

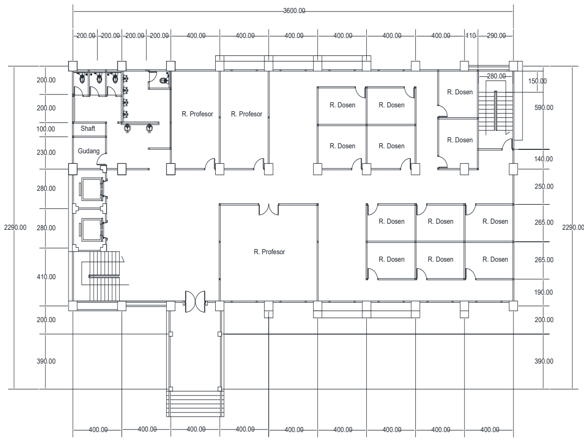

Figure 4. 3rd Floor Plan

2.3. Building Material Data

Material Specifications Used:

a) Specification of Concrete Material
Concrete Quality (f'c) 30 MPa
Specific Gravity (γ) = 2400 kg/m^3
Concrete Elasticity Modulus (Ec) = 4700√(f'c)
= 25742,9602 Mpa

b) Specification of Steel Material
The quality of the reinforcing steel includes ;
For d ≥ 13, fy = 400 MPa (BjTD 400)
For d < 13, fy = 240 MPa (BjTP 240)
Steel Modulus of Elasticity (Es) = 200000 Mpa

2.4. Load Parameters

The planned load consists of dead load (the structure's own weight and additional load), the live load per m^2 which is reviewed based on the function of the building according to *SNI 1727:2020*, and the earthquake load is analyzed based on *SNI 1726:2012* and *SNI 1726:2019*.

2.5. Soil Data

The soil data used is the result of a dynamic penetration test or *Standard Penetration Test (SPT).* Standard penetration was carried out with intervals of every 1.5 m at predetermined coordinate points in Manado City, Indonesia. For the depth calculated at 30 m from the top layer of the soil surface, the soil type includes/is categorized *as Medium Soil (SD).*

3. RESULTS AND DISCUSSION

3.1. Structural Modeling

3-Dimensional structure image modeled using *ETABS software;*

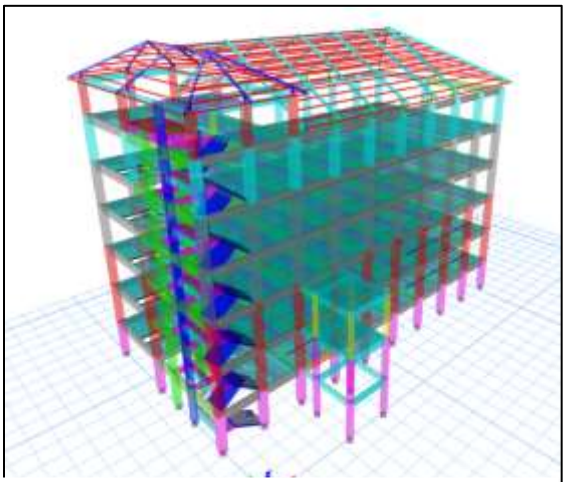

Figure 5. Geometry Structure 3D

In the model shown in *Figure 6*, the roof covering has been removed, so the load on the roof will become a joint load on the below structure.

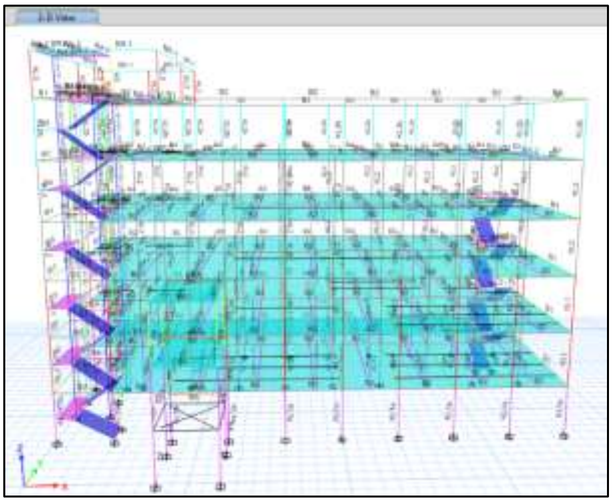

Figure 6. 3D Structure Modeling without roof covering

3.2. Structural Load Calculation

1. *Dead Load*
   - Self-weight structure;
     Reinforced concrete = 2400 kg/m^2 = 24 kN/m^2
   - Additional dead loads are evenly distributed on the roof plate;
     Total = 0,6 kN/m^2

2 Watertank **Total** = 120 kN/(Length x width of the area of the plate on which the water tank is placed) = 120 / (7,3 m x 4 m)
= **4,11 kN/m²**

2. *Live Load*
   - Roof Living Load;
     Roof Living Load *(lr)* = 0.96 kN/m²
   - The live load of each story; in accordance with the function of each floor, based on the provisions of *SNI 1727:2020.*
3. *Earthquake Load*

The earthquake priority factor (Ie) for risk category IV is 1.5, according to *SNI 1726*.

- Earthquake Load According to SNI 1726:2012 ;
- Earthquake Acceleration Parameters, and Seismic Design Category *(SDC).*

  Ss = 1.036 g , Fa = 1.08560
  S_1 = 0.442 g , Fv = 1.558

  Fa & Fv are the result of linear interpolation in Site Coefficients, from *SNI 1726:2012 Article 6.2.*

  S_{MS} = Fa x Ss = 1.0856 x 1.036 = 1.12468 g
  S_{M1} = Fv x S_1 = 1.558 x 0.442 = 0.6886 g
  S_{DS} = 2/3 S_{MS} =0.74978 g
  S_{D1} = 2/3 S_{M1} =0.4590906 g

  The SDS value ≥ 0.50 and SD1 ≥ 0.20 were determined as structures with a seismic design category *(SDC) D.*
- Earthquake Load According to SNI 1726:2019 ;
- Earthquake Acceleration Parameters, and Seismic Design Category *(SDC).*

  Ss = 1.0610 g , Fa = 1.07560
  S_1 = 0.4722 g , Fv = 1.8278

  Fa & Fv are the result of linear interpolation in Site Coefficients, from SNI 1726:2019 *Article 6.2.*.

  S_{MS} = Fa x Ss = 1.0756 x 1.0610 = 1.1412116 g
  S_{M1} = Fv x S_1 = 1.8278 x 0.4722 = 0.8631 g
  S_{DS} = 2/3 S_{MS} =0.7608 g
  S_{D1} = 2/3 S_{M1} =0.5754 g

  The SDS value ≥ 0.50 and SD1 ≥ 0.20 were determined as structures with a seismic design category *(SDC) D.*

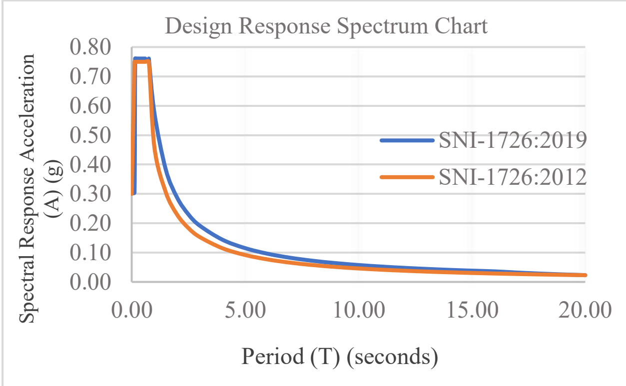

Figure 7. Comparison of SNI 1726 Spectrum Response Design

4. *Load Combination*
   - Load Combination in accordance with SNI 1726:2012; Article 4.2.2.
   - Load Combination in accordance with SNI 1726:2019; Article 4.2.2.

3.3. Analysis Results

1. Structural Fundamental Period Analysis.
   - Coefficients for Period Limits
     Cu = 1,4
     Ct = 0,0466
     x = 0,9 *(SNI 1726:2019; Article 7.8.2.1)*
     h = 26,98 m (Seismic Building Height)
   - Fundamental Period Approach
     $T_a = C_t \times h^x = 0{,}0466 \times (26{,}98)^{0.9} = 0{,}946$ second
2. Analysis of Diverse Mass Participation.

In accordance with *SNI 1726:2012 Article 7.9.1*, results in the *ETABS* analysis was performed up to the 24th mode. Based on the results, the X-direction at the 16th mode and the Y-direction at the 18th mode have already satisfied the minimum requirement of 90%, while in *SNI 1726:2019 Article 7.9.1.1* results in the *ETABS* analysis was performed up to the 81st mode to approach 100%. Based on the results, the X-direction at the 16th mode and the Y-direction at the 18th mode have already satisfied the minimum requirement of 90%.

3. Base Shear Analysis.

The calculation of the basic shear force (V) is with the formula: ($\boldsymbol{V} = \boldsymbol{Cs} \times \boldsymbol{W}$)

- Calculation of seimic base shear force (V) according to SNI 1726:2012;

$$\mathbf{Cs} = \frac{S_{DS}}{\left(\frac{R}{Ie}\right)} = \frac{0{,}74978}{\left(\frac{8}{1{,}5}\right)} = 0{,}1405$$

The value of Cs calculated in the above equation does not need to be exceeded;

$$\mathbf{Cs} = \frac{S_{D1}}{T\left(\frac{R}{Ie}\right)} = \frac{0{,}4591}{0{,}946\left(\frac{8}{1{,}5}\right)} = 0{,}09104$$

Cs should not be less than,

$$Cs = 0.044 S_{DS} I_e \geq 0.01$$

$$Cs = 0.044\,(0{,}74978)(1{,}5) = 0{,}049 \geq 0.01(ok)$$

So that the value of the seismic base shear force is obtained;

$V = 0{,}09104 \times 39480{,}3811$ kN = **3594,3087 kN**

- Calculation of seimic base shear force (V) according to SNI 1726:2019;

$$\mathbf{Cs} = \frac{S_{DS}}{\left(\frac{R}{Ie}\right)} = \frac{0{,}7608}{\left(\frac{8}{1{,}5}\right)} = 0{,}1426$$

The value of Cs calculated in the above equation does not need to be exceeded;

Untuk $T \leq T_L$

$$\mathbf{Cs} = \frac{S_{D1}}{T\left(\frac{R}{Ie}\right)} = \frac{0.5754}{0{,}946\left(\frac{8}{1{,}5}\right)} = 0{,}1140$$

Cs should not be less than,

$$Cs = 0.044 S_{DS} I_e \geq 0.01$$

$$Cs = 0.044\,(0{,}7608)(1{,}5) = 0{,}0502 \geq 0.01(ok)$$

So that the value of the seismic base shear force is obtained;

$V = 0{,}1426 \times 39480{,}3811$ kN = **5631,9336 kN**

4. Basic Shear Force Result Control.

Table 1. Base Shear Force Control (SNI-1726:2012)

Seismic Type		Base Shear Fx (kN)	Base Shear Fy (kN)	Control (V/Vt)*85%	
Statics (V)	EQ X	**3594,3087**	0	85,00	OK
	EQ AND	0	**3594,3087**		
Dynamic (Vt)	RSP X	**3595,5304**	533,374		
	RSP AND	559,374	**3595,5304**		

Based on *SNI 1726-2012*, the final value of the dynamic response of the building structure to the nominal seismic load due to the influence of the planned earthquake in a certain direction, should not be taken less than 85% of the first variety response value (*Vdynamic ≥ 0.85Vstatic*).

Table 2. Base Shear Force Control (SNI-1726:2019)

Seismic Type		Base Shear Fx (kN)	Base Shear Fy (kN)	Control (V/Vt)*100%	
Statics (V)	EQ X	**5631,9336**	0	100,00	OK
	EQ Y	0	**5631,9336**		
Dynamic (Vt)	RSP X	**5631,9336**	840,5113		
	RSP Y	886,439	**5631,9336**		

Based on *SNI 1726-2019*, the final value of the dynamic response of the building structure to nominal seismic load due to the influence of the planned earthquake in a certain direction, should not be taken less than 100% of the first variety response value (*Vdynamic ≥ Vstatik*).

5. Comparison of Base Shear Results from *SNI 1726:2012* and *SNI 1726:2019*.

Table 3. Comparison of Base Shear Force Values According to SNI 1726-2019 and SNI 1726-2019

Type Seismic	Direction	Base Shear SNI 1726-2012 (kN)	Base Shear SNI 1726-2019 (kN)	Difference (%)
Statics (V)	EQ X	3594,3087	5631,9336	56,690
	EQ Y	3594,3087	5631,9336	
Dynamic (Vt)	RSP X	3595,5304	5631,9336	56,637
	RSP Y	3595,5304	5631,9336	

The shear force of the seismic base is then distributed vertically to the floor above it in accordance with *SNI 1726:2012* and *2019 Article 7.8.3*. The story shear at each floor is the cumulative sum of all lateral story forces applied to the floors above it.

Table 4. Comparison of Story Shear Forces in SNI 1726:2012 and SNI 1726:2019

Floor	Story (m)	SNI 1726:2012 Fx (kN)	SNI 1726:2012 Fy (kN)	SNI 1726:2012 Story Shear (kN)	SNI 1726:2019 Fx (kN)	SNI 1726:2019 Fy (kN)	SNI 1726:2019 Story Shear (kN)
6	+19,5	1275,2119		1275,2119	1998,1336		1998,1336
5	+15,5	997,9314		2273,1433	1563,6618		3561,7954
4	+11,5	712,7105		2985,8538	1116,7484		4678,5438
3	+7,5	438,4474		3424,3012	687,0046		5365,5484
2	+3,5	170,0074		3594,3086	266,3852		5631,9336
1	0	0		3594,3086	0		5631,9336
Σ		3594,3086			5631,9336		

Shown in *figures 8* and *9*, respectively are presented a comparison graph of the lateral force story and the story shear force of the two different seismic code *(SNI 1726:2012* and *SNI 1726:2019* .

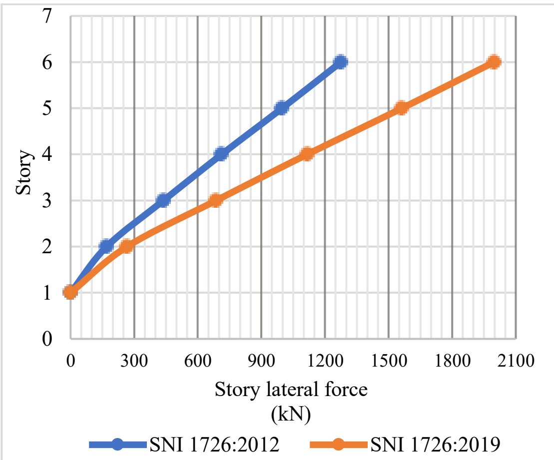

Figure 8. Comparison of Lateral Forces Shear

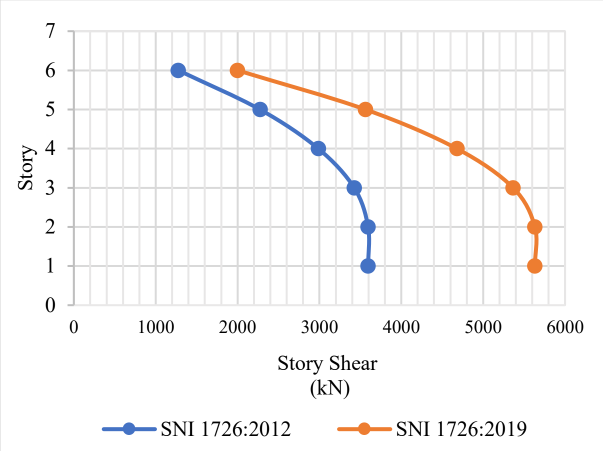

Figure 9. Comparison of Story Shear Forces

6. Results of Displacement and Inter-Story Drift Analysis.

Based on *SNI-1726:2012* and *SNI-1726-2019 article 7.12.1.1*, for seismic design category *(SDC)* D, the design inter-story drift (Δ) shall not exceed the allowable inter-story drift, Δa/ρ, for all stories, where Δa is taken as $0.010 \cdot h_{sx}$ according to the structural type and building risk category IV, as specified in *SNI 1726*, Article 7.3.4.2. For structures in *SDC* 'D', the redundancy factor (ρ) shall be 1.3.

Table 5. Displacement in X & Y Directions with Redundancy Factor (SNI 1726:2012)

Story	*Displacement*		*Elastic Drift*		*h*	*Inelastic Drift*		*Drift Limit*	Cek
	δex	*δeY*	*δex*	*δeY*		*Δx*	*ΔY*	*Δmax*	
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	
6	29,681	33,044	3,525	5,743	4000	12,925	21,058	30,769	OK
5	26,156	27,301	5,697	7,210	4000	20,889	26,437	30,769	OK
4	20,459	20,091	8,330	8,271	4000	30,543	30,327	30,769	OK
3	12,129	11,82	8,081	8,096	4000	29,630	29,685	30,769	OK
2	4,048	3,724	4,048	3,724	3500	14,843	13,655	26,923	OK

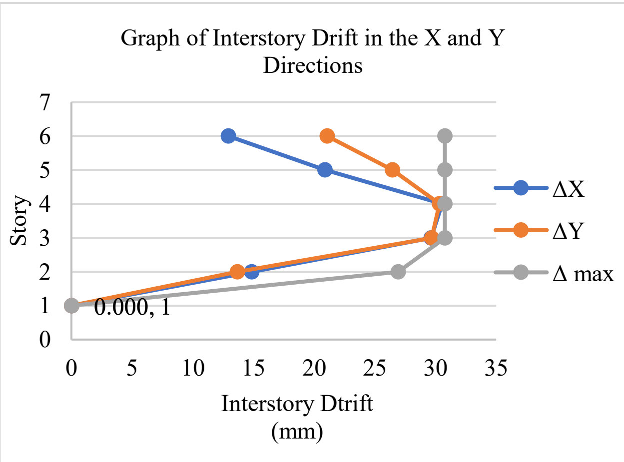

Figure 10. Graph of Interstory Drift in the X and Y Directions, according to SNI 1726:2012

Table 5 shows that the Interstory Dtrift of the building has met and does not exceed the maximum deviation limit allowed by *SNI-1726:2012*.

Table 6. Displacement in X & Y Directions with Redundancy Factor (SNI-1726:2019)

Story	*Displacement*		*Elastic Drift*		*h*	*Inelastic Drift*		*Drift Limit*	*Cek*
	δex	*δeY*	*δex*	*δeY*		*Δx*	*ΔY*	*Δmax*	
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	
6	31,194	34,736	3,701	6,036	4000	13,570	22,132	30,769	OK
5	27,493	28,7	5,991	7,586	4000	21,967	27,815	30,769	OK
4	21,502	21,114	8,760	8,697	4000	32,120	31,889	30,769	NOT OK
3	12,742	12,417	8,497	8,510	4000	31,156	31,203	30,769	NOT OK
2	4,245	3,907	4,245	3,907	3500	15,565	14,326	26,923	OK

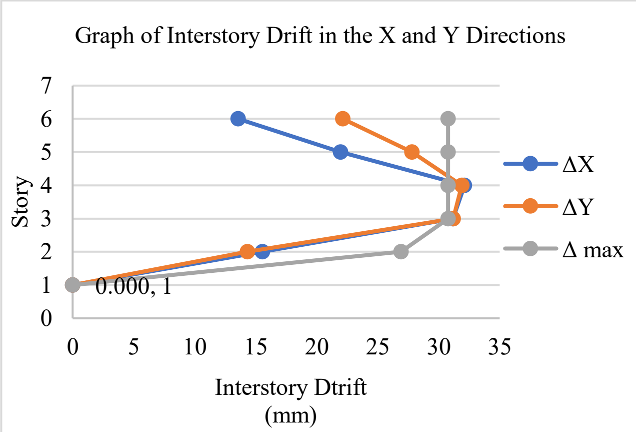

Figure 11. Graph of Interstory Drift in the X and Y Directions, according to SNI 1726:2019

From the results of the Interstory Drift of the building that has been analyzed in accordance with *SNI 1726:2019*, there is an increase as shown in *table 6*, which shows that the Interstory Drift of the building on the 4th and 3rd story exceeds the maximum permissible limit.

5 CONCLUSIONS

Based on the results of the analysis reviewed from the influence of changes in design earthquake loads in accordance with *SNI 1726-2012* and *SNI 1726-2019* on the structure of the 6-story lecture building of the Civil Engineering Department of Unsrat, which is geographically located at 1°45'80" LS-124°82'60" BT, in the city of Manado, Indonesia, the following are the main conclusions:

1. There is an increase in several response spectrum parameters from *SNI 1726-2012* to *SNI 1726-2019*. Specifically, Ss and S1 increased by 2.41% and 6.79%, respectively, which led to corresponding increases in S_{DS} and S_{D1} by 1.47% and 25.33%. These changes result in differences in the design spectrum and higher peak Sa values in the design response spectrum based on *SNI 1726-2019*.

2. The seismic base shear values showed a significant increase in *SNI 1726-2019*, with an increment of 56.7% in both X and Y directions under equivalent static analysis, and 56.6% in both directions under dynamic analysis using the response spectrum modal method.
3. Displacement values in the X and Y directions increased by 4.91%–5.12% from *SNI 1726-2012* to *SNI 1726-2019*
4. The inter-story drift (inelastic drift) values obtained from *SNI 1726-2012* and *SNI 1726-2019* increased by 4.87%–4.99% in the X direction and 4.91%–5.10% in the Y direction under *SNI 1726-2019*. This caused the analyzed structure to exhibit unsafe performance, as the inter-story drift at the 3rd and 4th floors exceeded the allowable drift limit.

REFERENCES

1. American Society of Civil Engineer, 2016. *Minimum Design Load for Buildings And Other Structures*. ASCE 7-16.
2. Badan Standarisasi Nasional. 2012. *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Nongedung*, SNI 1726:2012. Jakarta : Departemen Pekerjaan Umum.
3. Badan Standarisasi Nasional. 2019. *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Nongedung*, SNI 1726:2019. Jakarta : Departemen Pekerjaan Umum.
4. Badan Standarisasi Nasional. 2020. *Beban Desain Minimum dan Kriteria Terkait untuk Bangunan Gedung dan Struktur Lain*, SNI 1727:2020. Jakarta.
5. Badan Standarisasi Nasional. 2019. *Tata Cara Perencanaan Struktur Beton untuk Bangunan Gedung dan Penjelasan*, SNI 2847:2019. Jakarta.
6. HAKI (Himpunan Ahli Konstruksi Indonesia). (2018). Shortcourse HAKI 2018 : Perancangan Struktur Tahan Gempa. Jakarta: HAKI (Himpunan Ahli Konstruksi Indonesia).
7. Faizah, Restu & Rahma Amaliah. (2021). Comparative Study of Indonesia Spectra Response Parameters for Buildings According to 2012 and 2019 Seismic Codes. International Journal of Integrated Engineering, 168-175.
8. Michael Timbu Dona1, Sudirman Indra, & Ester Priskasari. (2022). Beban Gempa Dan Base Shear Menurut SNI 1726-2012 Dan SNI 1726-2019 Pada Gedung Fakultas Ilmu Keolahragaan (FIK) Universitas Negeri Malang. Seminar Nasional. Malang: ITN-Malang.
9. Suradjin Sutjipto & Indrawati Sumeru. (2018). Spektrum Respons Desain RSNI 1726:2018 Berdasarkan Peta Gempa Indonesia 2017. Seminar HAKI 2018. Jakarta.
10. Agustinus Agus Setiawan. (2014). Studi Perbandingan Gaya Geser Dasar Seismik Berdasarkan SNI-03-1726-2002 dan SNI-03-1726-2012 Studi Kasus Struktur Gedung Grand Edge Semarang. Jurnal Teknik Sipil & Perencanaan, 95-104.