Multidisciplinary International Journal of Research

Vol 1 (3), 2023, 89 - 100

Online ISSN: 2985 - 9999

Multidisciplinary International Journal of Research

Journal homepage: https://publishing.impola.co.id/index.php/MIJR

Comparison of High-Rise Building Structural Performance Using Response Spectrum Method SNI 03-1726-2019 and FEMA-154 Rapid Visual Screening (RVS)

Sudarno P Tampubolon[1]
[1]Universitas Kristen Indonesia: Department of Civil Engineering, UKI, Jakarta, Indonesia

Abstract
An earthquake is a natural disaster event that occurs suddenly but has significant impacts, making it challenging to predict. The objective of this research is to evaluate the resilience of buildings to seismic hazards using two methods: Rapid Visual Screening (RVS) and the response spectrum method. The RVS method is employed to visually assess the seismic response of buildings, referencing the guidelines of the Federal Emergency Management Agency (FEMA), while the response spectrum method adheres to the SNI 03-1726-2019 standard. This study focuses on the final score values from the RVS method and various parameters such as period, base shear force, inter-story displacement, story drift, and the coefficient of variation in the response spectrum method. The research findings indicate that the RVS method yields a safe score on Form 1 (S > 2) but experiences a decrease in vulnerability on Form 2 (S=1). Meanwhile, the response spectrum method reveals a building period of 1.809 seconds, seismic base shear forces of 812.096 kg for the X-direction and 840.275 kg for the Y-direction. The maximum inter-story displacement occurs in the X-direction at 0.007501 and the Y-direction at 0.006431, with a coefficient of variation reaching 90.7% for the X-direction and 91.5% for the Y-direction. Inter story drift limit for X-direction 0.0135-0.047 and Y-Direction 0.0129-0.0292. These values are still below the specified limit of 0.08

Keywords —Behavior; RVS (Rapid Visual Screening); Performance; FEMA-154; SNI 03-1726-2019; Response Spectrum

I. INTRODUCTION

An earthquake is a natural disaster caused by the movement of the Earth's crust and plates, resulting in vibrations from seismic waves on both land and seabed. Indonesia, positioned at the convergence of three active tectonic plates—Pacific, Ind-Australian, and Eurasian—faces a high risk of earthquake disasters,(Tampubolon et al., 2022). The primary cause of post-earthquake losses is structural failure, leading to economic disruptions and casualties due to building damage. Studies indicate that structural failure varies among building types during earthquakes, and vulnerability levels depend on the building's main vertical load,(Silaban et al., 2023)(Tampubolon et al., 2020)

To proactively address potential structural failures and mitigate earthquake-related losses, a quick and cost-effective evaluation of building vulnerability is essential. The FEMA-154 guidebook serves as a reference for the Rapid Visual Screening (RVS) method, offering a visual assessment of a building's seismic vulnerability (FEMA P-154, 2015), (Agustin et al., 2020; Dwi Pratama et al., 2021; Firdaus et al., 2016). Indonesia, prone to earthquakes, has established guidelines for earthquake-resistant planning standards (SNI 1726-2019), revising SNI 1726-2012. The response spectrum method involves dynamic analysis to assess a building's structure, (Badan Standardisasi Nasional, 2019; SNI 2847:2019, 2019)

Article info
Received (11/11/2023)
Revised (17/11/2023)
Accepted (21/11/2023)
Corresponding:sudarno.tampubolon@uki.ac.id
DOI:

This research assesses the vulnerability of the Graha William Soeryadjaya (GWS) building, located at the Indonesian Christian University (UKI) medical faculty campus. The research, conducted by (Novi Andhi Setyo Purwono et al., 2021), focuses on earthquake risk assessment using the FEMA-154 Rapid Visual Screening method and 3D response spectrum for three buildings at Wijayakusuma University, Purwokerto. The objective is to determine whether the buildings are suitable for use using the RVS FEMA-154 method and to calculate building loads using SAP-2000 software, (Harirchian et al., 2020). The results indicate that the three buildings are deemed safe through the RVS method, but modeling in SAP-2000 reveals they are unsafe under fundamental natural vibration conditions, although the loading remains within the safe range.

II. METHODOLOGY RESEARCH

This Researach uses the Rapid Visual Screening (RVS) approach with the FEMA-154 reference and the spectrum response method using primary and secondary data collection techniques. Primary data is data originating from original sources obtained from reviewing conditions in the field, not tangible data. In the case of this research, primary data is in the form of observations using the Rapid Visual Screening (RVS) form as well as photos of the condition of the building and the function of the building. Secondary data is data that contains information that has been collected from various sources. In this research, secondary data is in the form of plan drawings (building age, floor area and number of floors), research topographic data and soil testing, and spectral design data.

1. Rapid Visual Screening (RVS) Method


Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
MODERATELY HIGH Seismicity

Building Name: Graha William Soeryadjaya
Use: Sekolah & Kantor
Screener(s): Haryady
Date/Time: 23 - 12 - 2022
Year Built: 2011

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

EXTENT OF REVIEW

OTHER HAZARDS

ACTION REQUIRED

LEVEL 2 SCREENING PERFORMED?

Figure 1. Form Level 1 RVS FEMA-154

Rapid Visual Screening of Buildings for Potential Seismic Hazards **Level 2 (Optional)**

FEMA P-154 Data Collection Form **MODERATELY HIGH Seismicity**

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	S_{L1} = **2,3**	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =* **-1,1**	*Plan Irregularity, P_{L1} = -*
Date/Time:	**ADJUSTED BASELINE SCORE:**	$S' = (S_{L1} - V_{L1} - P_{L1})$ = **2,3 - 1,1 - 0 = 1,2**	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic		Statement *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*	Yes	Subtotals
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.3	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.3	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.6	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.3	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.3	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-1.0	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	✓
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.5	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.5	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	V_{L2} = **-0,5**
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	*(Cap at -1.3)*
Plan Irregularity, P_{L2}		Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*	-0.8	
		Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.	-0.4	
		Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.	-0.4	
		Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.	-0.3	
		C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.	-0.4	P_{L2} = **-**
		Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.	-0.8	*(Cap at -1.3)*
Redundancy		The building has at least two bays of lateral elements on each side of the building in each direction.	+0.3	✓
Pounding	Building is separated from an adjacent structure by less than 0.5% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.3)*	-1.0	
		One building is 2 or more stories taller than the other.	-1.0	
		The building is at the end of the block.	-0.5	
S2 Building		"K" bracing geometry is visible.	-1.0	
C1 Building		Flat plate serves as the beam in the moment frame.	-0.5	
PC1/RM1 Bldg		There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*	+0.3	
PC1/RM1 Bldg		The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).	+0.3	
URM		Gable walls are present.	-0.4	
MH		There is a supplemental seismic bracing system provided between the carriage and the ground.	+1.2	
Retrofit		Comprehensive seismic retrofit is visible or known from drawings.	+1.4	M = **+0,3**

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: 1,2 - 0,5 + 0 + 0,3 = 1,0 > SMIN (0,3) *(Transfer to Level 1 form)*

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	Statement *(Check "Yes" or "No")*	Yes	No	Comment
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.		✓	
	There is heavy cladding or heavy veneer.		✓	
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.	✓		
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.	✓		
	There is a sign posted on the building that indicates hazardous materials are present.		✓	
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.		✓	
	Other observed exterior nonstructural falling hazard:	✓		
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.		✓	
	Other observed interior nonstructural falling hazard:	✓		

Estimated Nonstructural Seismic Performance *(Check appropriate box and transfer to Level 1 form conclusions)*

- ☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended
- ☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required
- ☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Figure 2. Form Level 2 RVS FEMA-154

Based on the results of the evaluation that has been carried out by filling in forms at level 1 and level 2 (Wahyuni et al., 2017), the final scores of SL1 and SL2 are obtained, namely at SL1 the final score is 2.3 ($>S_{min}$ = 0.3) while in further evaluations carried out on the level form 2 obtained a final score of 1 ($>S_{min}$ = 0.3). With this final score, the vulnerability value can be obtained based on this equation. If we enter the final score on SL1 into equation, we obtain the building vulnerability value as follows.

$$P = \left(\frac{1}{10}\right)^{s}$$
$$P = \left(\frac{1}{10}\right)^{2,3}$$
$$P = (0,1)^{2,3}$$
$$P = 0,005$$

Meanwhile, if you use the final score SL2, you will get a vulnerability value as in equation as follows.

$$P = \left(\frac{1}{10}\right)^{s}$$
$$P = \left(\frac{1}{10}\right)^{1}$$
$$P = (0,1)^{1}$$
$$P = 0,1$$

In calculating the vulnerability value for SL1, the P value is 0.005, which means the chance of the building experiencing structural failure during an earthquake is 0.5%, and for SL2, the value is 0.1, which means the chance of the building experiencing structural failure during an earthquake. by 10%.

2. Spectrum Response Method SNI 03-1726-2019

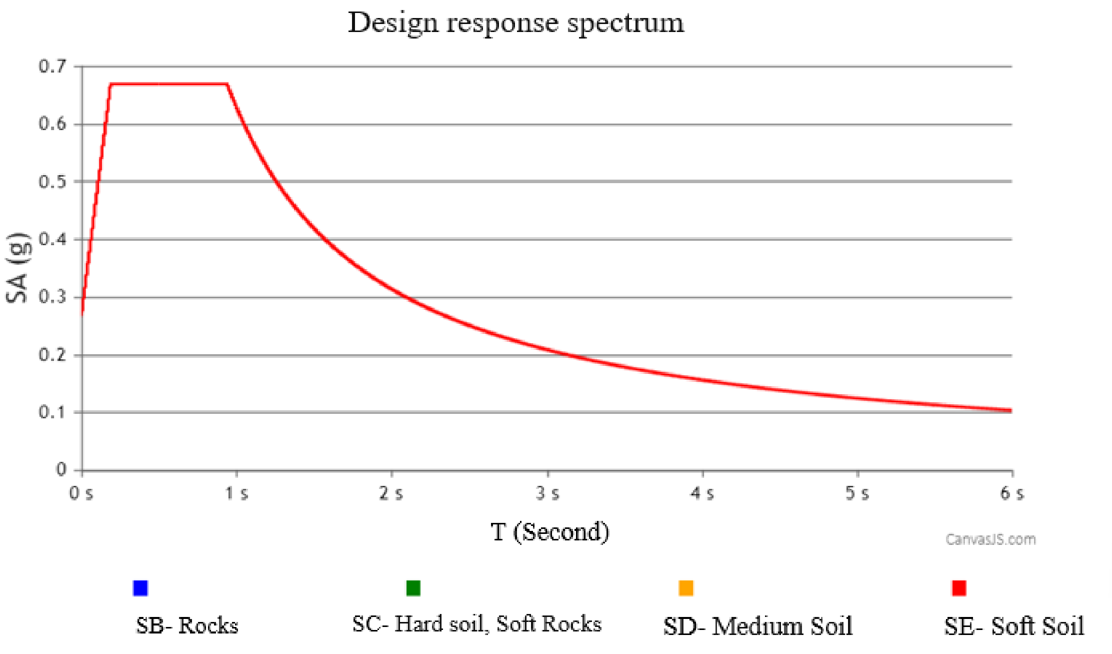

Figure 3. Design Response Spectrum

Spectrum response is an analysis used in solving dynamic equations due to earthquake loads, especially for linear systems. Furthermore (Mallisa, Zet., 2008) stated that spectrum analysis is a simple analysis and only requires a short time, . Based on SNI 03-1726-2019, it is stated that the spectrum response is a plot of the peak response (displacement, speed and acceleration) of a series of oscillators that have various natural frequency variations and are driven by vibrations.

3. Seismic Base Shear (V)

The calculation of the seismic bed shear force, V, in the specified direction should be determined according to the following equation:

$V = Cs\,W$

4. Vertical and Horizontal Earthquake Force Distribution

The distribution of vertical seismic forces as stated in SNI 03-1726-2019 must be determined using the following equation:

Fx = Cvx. V, dimana

Cvx $= \frac{w_x h_x^k}{\Sigma_{i=1}^{n} w_i h_i^k}$

k = exponent related to the structure period as follows:

Buildings with a period (T) ≤ 0.5 seconds, then k = 1

Buildings with a period (T) ≥ 2.5 seconds, then k = 2

Buildings with a period of 0.5 seconds < T < 2.5 seconds, then k must be greater than 2 or a linear interpolation between 1 and 2 is carried out. Because the building structure has values of Tx and Ty = 1.808608, a liner interpolation is carried out to get the values K of the structure is like equations as follows:

Kx = $(\frac{Tx-0,5}{(2,5-0,5)/(2-1)})$+1

Kx = $(\frac{1,8086608-0,5}{(2,5-0,5)/(2-1)})$+1

Kx = 1,6543304

Ky = $(\frac{Tx-0,5}{(2,5-0,5)/(2-1)})$+1

Ky = $(\frac{1,8086608-0,5}{(2,5-0,5)/(2-1)})$+1

Ky = 1,6543304

Horizontal earthquake force distribution of seismic loads as stated in SNI 03-1726-2019 must be found through equation as follows:

Vx = $\Sigma_{i=x}^{n} Fi$

Information:

Fi = seismic base shear (V) at level i

III. RESULT AND DISCUSSION

1. Fundamental Value of Structure

The calculation of the fundamental period of a structure (T) has minimum and maximum limits determined based on SNI 03-1726-2019. The value of the natural vibration time coefficient (T) is not permitted to exceed the upper limit of the calculated period (Cu). From the results of the sap analysis, building period data was obtained as in Table 1.

Table 1. Building Period

Mode	Period
1	1.808608
2	1.632236
3	1.561282

4	0.686746
5	0.556653
6	0.528477
7	0.491924
8	0.472324
9	0.453959
10	0.440303
11	0.41423
12	0.362096

with the output results obtained through SAP2000 software, the data can be analyzed by calculating the period limit coefficient:

Cu = 1,4
Ct = 0,0466
x = 0,9
hn = 44
T_{amin} = Ct x hn^x
= 0,0466 x $44^{0,9}$
= 1,4044 detik
T_{amax} = Cu x T_{amin}
= 1,4 x 1,4044
= 1,966 detik
T_c (Sap2000) = 1.808608

2. Seismic Basic Shear Force Value (V)

Based on the results of analytical calculations, the static and dynamic earthquake shear forces (base reaction) are as follows.

Wtotal = 6646160 kg
Cs = 0,09
V = Cs. W
V = 0,09 x 6646160
V = 598154,4 kg

3. Vertical and horizontal earthquake force distribution values

Analysis of vertical and horizontal earthquake force distribution is described in Table 2.

Table 2. Distribution of Lateral Earthquake Force and Building Shear Force

Earthquake Force Distribution								
Lantai	Wi	hi	Wi.hi	$Wi.hi^{kx}$	Fx	Fy	Vx	Vy
(m)		(m)						
roof	303130	42	12731460	567304215801	88651	88651	88651	88651
11	410410	38.2	15677662	800520736683	125095	125095	213746	213746
10	418520	34.4	14397088	695266621670	108647	108647	322394	322394
9	438520	30.6	13418712	618854725701	96707	96707	419100	419100
8	459500	26.8	12314600	536905517738	83901	83901	503001	503001
7	509550	23	11719650	494675483779	77302	77302	580303	580303
6	550670	19.2	10572864	417191478984	65193	65193	645496	645496
5	780190	15.4	12014926	515463406828	80550	80550	726046	726046
4	804190	11.6	9328604	339140439891	52997	52997	779043	779043

3	980820	7.8	7650396	244279805612	38173	38173	817216	817216
2	990660	4	3962640	82270954150	12856	12856	830072	830072
Total	**6646160**	**76,53**	**123788602**	**24432484419271**			**5925068**	**5925068**

4. Base Shear Force

In SNI 1726:2019 article 7.9.1.4.1, the dynamic base shear force of the response spectrum must be equal to 100% of the equivalent static base shear force. If the combined response for the basic shear force resulting from analysis of variance (Vt) is less than 100% of the shear force (V) calculated using the equivalent static method, then the force must be multiplied by V/Vt, where. V is the equivalent static basic shear force, and Vt is the basic shear force obtained from the results of the variance combination analysis. In Table 3, it is known that the VD values in the So after scaling, Table 4 is obtained.

Table 3. Base Shear

Earthquake Load	**Base Shear (kg)**	
	X-Direction	Y-Direction
Static Base Shear (Vs)	915387	915387
Dynamic Base Shear ($V_{d)}$	812096	840275
Scale Factor V_s/V_D	1.12719063	1.08939
Control (V_D)≥ 100% V_S	Not Ok	Not Ok

Table 4. Base Shear Modification

Earthquake Load	**Base Shear (kg)**	
	X-Direction	Y-Direction
Static Base Shear (Vs)	915387	915387
Dynamic Base Shear ($V_{d)}$	915387	915387
Scale Factor V_s/V_D	1	1
Control (V_D)≥ 100% V_S	Ok	Ok

5. Inter Story Drift

Acording SNI 03-1726-2019, structural serviceability limit requirements are calculated from the deviation between levels of the building structure which must not exceed 0.03/R x story height in the X or Y direction.

S permit = 0.03/6.5 x 44 = 0.0203 m

Below in Table 5. you can see the deviation between floors in each structure which was carried out using equivalent static analysis and dynamic analysis.

Table 5. Inter Story Drift

Floor	**High (hx)**	**Story Drift**			**Inter Story Drift Levels**		**S permit**
		Δhi	**X-direction**	**Y- direction**	**X-direction**	**Y- direction**	

	m				m	m	m
ROOF FLOOR	44						
		4	0.000944	0.00298	0.002983	0.002854	0.0203
11FL	40						
		4	0.001022	0.001069	0.00571	0.003458	0.0203
10FL	36						
		4	0.001365	0.001299	0.004583	0.004332	0.0203
9FL	32						
		4	0.001685	0.001528	0.005799	0.005202	0.0203
8FL	28						
		4	0.001935	0.001682	0.006749	0.005788	0.0203
7FL	24						
		4	0.002133	0.001812	0.007501	0.006282	0.0203
6FL	20						
		4	0.002209	0.00391	0.01022	0.006388	0.0203
5FL	16						
		4	0.002251	0.001854	0.01038	0.006431	0.0203
4FL	12						
		4	0.002159	0.001779	0.01003	0.006156	0.0203
3FL	8						
		4	0.001189	0.001578	0.006536	0.005278	0.0203
2FL	4						
		4	0.001228	0.000939	0.004262	0.003106	0.0203
BASE	0						

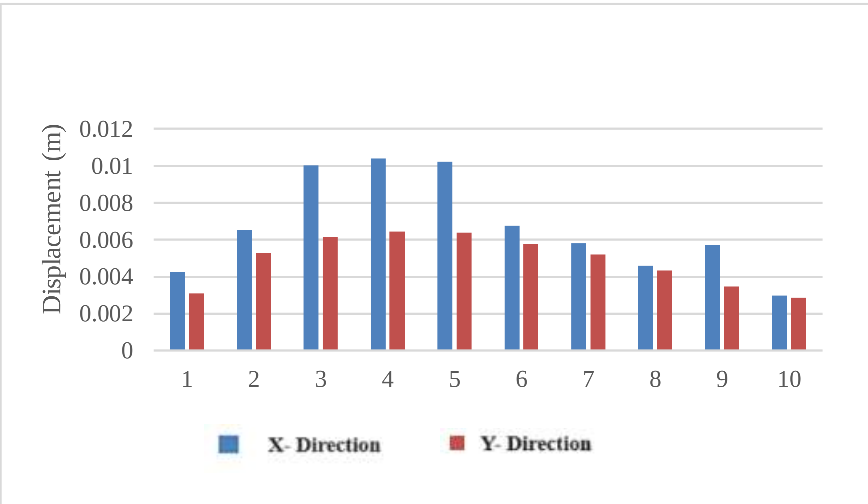

Figure 4. Inter Story Drift

Inter Story Drift Ultimate

Table 6. show the story drift ultimate floors in each structure which was carried out using equivalent static analysis and dynamic analysis.

Table 6. Inter Story Drift Ultimate

Floor	High (hx)			Inter Story Drift Levels		S_{permit} ultimate	Condition
			Δhi	**X-Direction**	**Y-Direction**		
	m			**m**	**m**	**m**	
ROOF FLOOR		44					
			4	0.01357265	0.0129857	0,08	OK
11FL		40					
			4	0.0259805	0.0157339	0,08	OK
10FL		36					
			4	0.02085265	0.0197106	0,08	OK
9FL		32					
			4	0.02638545	0.0236691	0,08	OK
8FL		28					
			4	0.03070795	0.0263354	0,08	OK
7FL		24					
			4	0.03412955	0.0285831	0,08	OK
6FL		20					
			4	0.046501	0.0290654	0,08	OK
5FL		16					
			4	0.047229	0.02926105	0,08	OK
4FL		12					
			4	0.0456365	0.0280098	0,08	OK
3FL		8					
			4	0.0297388	0.0240149	0,08	OK
2FL		4					
			4	0.0193921	0.0141323	0,08	OK

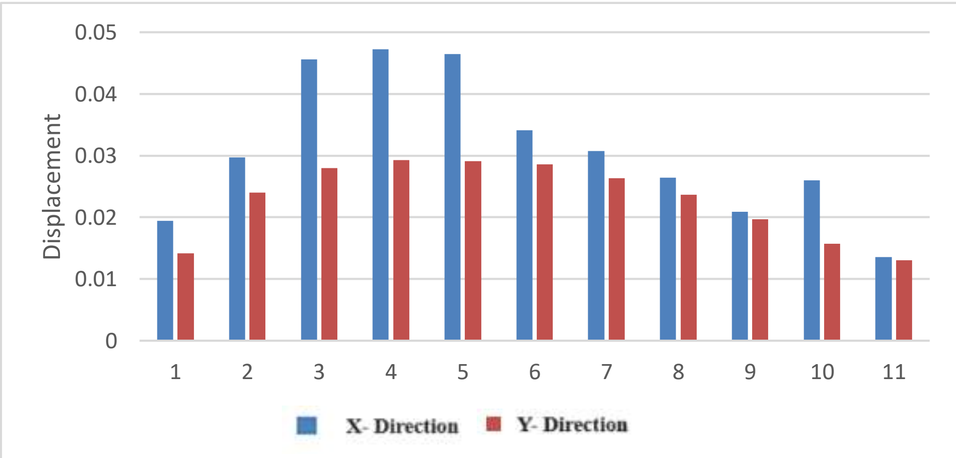

Figure 5. Inter Story Drift Ultimate

6. Number of Variety

Based on SNI 03-1726-2019, the number of variations in combined mass participation is 100% of the structure mass, however there is an alternative by including a minimum combined number of variations of 90%.

Table 7. Number of Variety

Case	Mode	Sum UX	Sum UY
Modal	1	0.00436	0.715
Modal	2	0.368	0.77
Modal	3	0.789	0.788
Modal	4	0.792	0.788
Modal	5	0.797	0.788
Modal	6	0.797	0.894
Modal	7	0.797	0.911
Modal	8	0.82	0.913
Modal	9	0.904	0.913
Modal	10	0.907	0.913
Modal	11	0.907	0.913
Modal	12	0.907	0.915

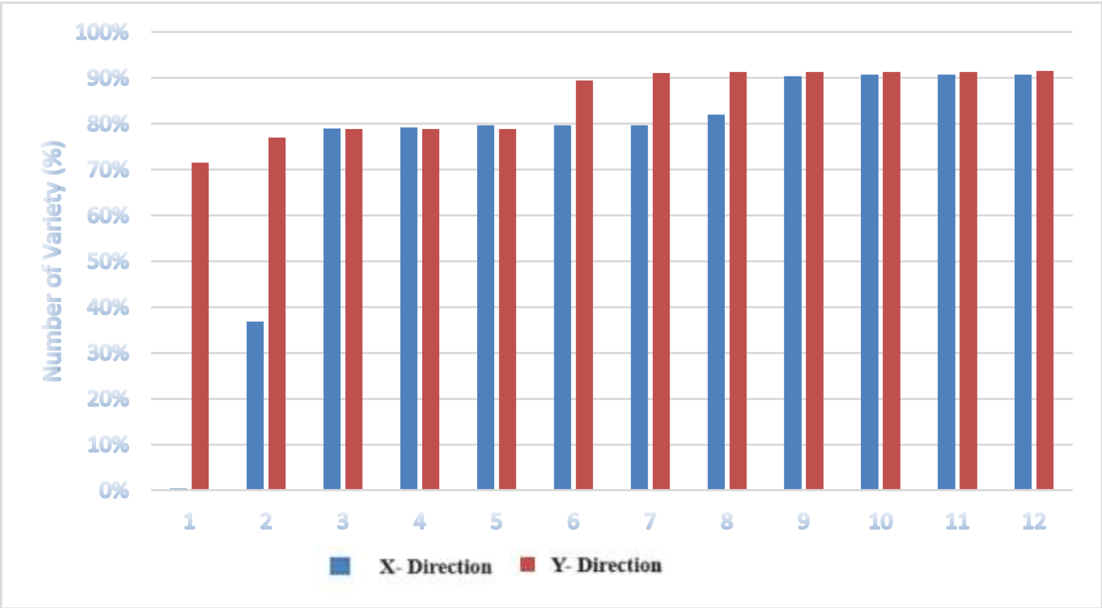

Figure 6. Number of Variety

In the analysis of the number of variations, the participating mass ratio in mode 12 still reached 90.7% in the X direction and 9.15% in the Y direction. In the analysis results it was found that the participating mass ratio reached 100% in the 31st mode in the X direction and reached 100% in 29th mode in Y direction.

7. Comparison of FEMA-154 Vulnerability Values and Spectrum Response SNI 03-1726-2019

The results of the evaluation conducted through the application of both the Rapid Visual Screening (RVS) method, as outlined in FEMA-154, and the Spectrum Response method specified in SNI 03-1726-2019, allow for a comparison of findings, as presented in Table 7.

Table 7. Comparison of FEMA-154 and Spectrum Response

FEMA-154		SNI 03-1726-2019
Level 1	Level 2	
Ok	Not Ok	Ok

In the table it can be concluded that there is a difference in vulnerability values between the FEMA-154 method at level 2, namely in the evaluation using the FEMA level 2 form it was found that the structure of the building did not meet the standards provided by FEMA so that there was a need for a detailed evaluation using SAP2000 software.

In the evaluation using SAP2000 software, based on the results of the analysis carried out using SAP2000 v22 software, the building meets the aspects of natural vibration time (period), base shear, deviation between floors, story drift and number of variations, according to the analysis.

IV. CONCLUSION

Based on the research and analysis that has been carried out get conclusion:

1. Rapid Visual Screening (RVS) method using FEMA-154 as an evaluation reference, it was found that the building studied had met the cut-off ($s > 2$) on the level 1 form but experienced a decrease in value. S on form level 2 ($s = 1$) but is still in safe condition, because the minimum value of s is at level 2 or $S_{min} = 0.3$.
2. In the analysis results it was found that the participating mass ratio reached 100% in the 31st mode in the X direction and reached 100% in 29th mode in Y direction.
3. Value of inter story drift limit for X-direction 0.0135-0.047 and Y-Direction 0.0129-0.0292. These values are still below the specified limit of 0.08

V. REFERENCE

Agustin, S., Djauhari, Z., & Suryanita, R. (2020). Aplikasi Metode Rapid Visual Screening (RVS) Dalam Monitoring Kerentanan Bangunan Pemerintahan di Indragiri Hulu. *Jurnal Rekayasa Sipil (JRS-Unand)*, *16*(1). https://doi.org/10.25077/jrs.16.1.38-48.2020

Badan Standardisasi Nasional. (2019). SNI 1726:2019. Tata Cara Perencanaan Ketahanan Gempa Untuk Struktur Bangunan Gedung Dan Non Gedung.

Dwi Pratama, A. R., Soetjipto, J. W., & Krisnamurti, K. (2021). Evaluation of Building Vulnerability to Earthquake Using Rapid Visual Screening (RVS) Method. Jurnal Teknik Sipil Dan Perencanaan, 23(2). https://doi.org/10.15294/jtsp.v23i2.31399

Firdaus, R., Kurniawandy, A., Djauhari, Z., Jurusan, M., Sipil, T., & Jurusan, D. (2016). Evaluasi Kerentanan Bangunan Gedung Terhadap Gempa Bumi Dengan Rapid Visual Screening (RVS) Berdasarkan Fema 154. Jom FTEKNIK, 3(2).

Harirchian, E., Lahmer, T., Buddhiraju, S., Mohammad, K., & Mosavi, A. (2020). Earthquake safety assessment of buildings through rapid visual screening. Buildings, 10(3). https://doi.org/10.3390/buildings10030051

Novi Andhi Setyo Purwono, Iwan Rustendi, Roesly Sakban, & Ajeng Purba Kencana. (2021). KAJIAN RESIKO GEMPA DENGAN PENDEKATAN METODE RAPID VISUAL SCREENING (RVS) FEMA 154 DAN 3D RESPONSE SPEKTRUM TERHADAP GEDUNG UNIVERSITAS WIJAYAKUSUMA PURWOKERTO. PADURAKSA: Jurnal Teknik Sipil Universitas Warmadewa, 10(2). https://doi.org/10.22225/pd.10.2.2745.211-223

Silaban, G. T. N., Tampubolon, S. P., Sri Mulyani, A., & Felestin. (2023). Performance Evaluation of High-rise Buildings with Respons Spectrum Analysis and Time History Analysis. Science Tech: Jurnal Ilmu Pengetahuan Dan Teknologi, 9(1), 84–95. https://doi.org/10.30738/st.vol9.no1.a14295

SNI 2847:2019. (2019). Persyaratan Beton Struktural untuk Bangunan Gedung dan Penjelasan (SNI 2847:2019). Badan Standardisasi Nasional.

Tampubolon, S. P., Sarassantika, I. P. E., & Suarjana, I. W. G. (2022). Analisis Kerusakan Struktur Bangunan dan Manajemen Bencana Akibat Gempa Bumi, Tsunami, dan Likuifaksi di Palu. Bentang : Jurnal Teoritis Dan Terapan Bidang Rekayasa Sipil, 10(2). https://doi.org/10.33558/bentang.v10i2.3263

Tampubolon, S. P., Wang, C. Y., & Wang, R. Z. (2020). Numerical simulations of the bond stress-slip effect of reinforced concrete on the push over behavior of interior beam-column joint. IOP Conference Series: Materials Science and Engineering. https://doi.org/10.1088/1757-899X/725/1/012028

Wahyuni, E., Aji, P., & Budi, F. (2017). Study of Rapid Visual Screening of Buildings for High Potential Seismic Hazard According to Indonesian Standard. IPTEK Journal of Proceedings Series, 0(2). https://doi.org/10.12962/j23546026.y2017i2.2273.