Asian Journal Science and Engineering
Vol. 1, No. 2, December 2022
https://attractivejournal.com/index.php/ajse

Comparison Analysis of Equivalent Static Earthquake and Spectrum Response Dynamics on Steel Structure

Diana Ningrum[1*], Albertus Nahak[2], Nawir Rasidi[3]
[1,2] Unversitas Tribhuwana Tunggadew, Indonesia
[3]Politekhnik Negeri Malang, Indonesia

diana.ningrum@unitri.ac.id*

ARTICLE INFO
Article history:
Received December 13, 2022
Revised January 24, 2023
Accepted January 26, 2023

Abstract

The purpose of this study is to compare two methods of seismic load analysis, namely the static equivalent method and the dynamic response spectrum method. The case study is the integrated service building of Tribhuwana Tunggadewi University, Malang City which has 5 levels and is located in the 4 (medium) earthquake zone with moderate soil conditions. The research method used is descriptive quantitative. Collecting data of project drawings, as well as observations and interviews. Analysis method Equivalent static and dynamic response spectrum using software Staad Pro. The results compared are the base shear force (V), the floor lateral force (F), and the displacement or displacement. The result in the form of maximum internal force is analyzed to determine the capacity or ability of the profile to withstand combined loads. The comparison of base shear and displacement does not differ much from the two seismic analysis methods used. This insignificant difference is in accordance with the SNI that for structures with a height below 40m can be analyzed using equivalent statics, while in the case study it only has a height of 30m. So that the equivalent static analysis becomes more accurate to use because the analysis process is simpler than dynamic analysis, but for structures with a height above 5 floors it is recommended to use dynamic analysis. The results of the analysis of the ability of the steel profile on the cross section of the column and beam indicate a safe condition in carrying combined loads.

Keywords: Volume Fraction, Cannabis Sativa Fibers, Fiber Composites

Published by CV. Creative Tugu Pena
ISSN 2963-6752
Website https://attractivejournal.com/index.php/ajse

INTRODUCTION

Building construction needs to consider seismic loads to avoid severe damage caused by earthquake loads [1]. Factors High building height, special geographic and environmental conditions, not surprisingly, present one of the biggest challenges for structural engineers to calculate the resistance of buildings to earthquake loads [2].

For a rational earthquake-resistant building design, an analytical method is needed that can produce adequate calculations of structural stiffness, strength, and ductility supply, as well as ductility demand, during the design earthquake. regarding the uncertainty of the input data. The generally applied methods are equivalent lateral force procedures and dynamic modal analysis based on the assumption of linear elastic structural behavior, and multi-degrees-of-freedom mathematical model (MDOF) non-linear dynamic analysis of building structures, for the time being, it is impractical to everyday design use [3].

One of the building and non-building planning standards from Badan Standarisasi Nasional (2012) is a policy of the Indonesian government. The application of SNI-1726-2012 has a positive impact in the calculation of a wider earthquake. Indonesia as an earthquake-prone area must be in the planning stage to take into account the effect of earthquake loads on structures [5]. The Indonesian National Standard provides guidelines for calculating design earthquake forces which can be analyzed using three methods, including: the equivalent static method, the dynamic response spectra method, and the dynamic time history method [6]. All of these analytical procedures or methods incorporate a performance-based concept that pays more attention to damage control [7].

The equivalent static earthquake analysis method for structures is a method in which the analysis phase is carried out using nominal static earthquake loads at earthquake loading [8]. Equivalent static analysis was carried out with the aim of understanding the standard earthquake load characteristics [1]. The purpose of equivalent static analysis is to simplify the actual earthquake load, into a horizontal force due to inertial forces acting on a mass due to the earthquake [9].

Meanwhile, dynamic analysis of time history/response spectrum is an analytical method that examines dynamic loads that affect building motion, including the direction of the earthquake motion (direction), the point of application (point of application), and the strength of the earthquake (magnitude). Several factors affect the loading of dynamic structures, namely stiffness, damping factors, structure mass and earthquake acceleration [8].

[10] described the primary difference between static equivalent and dynamic earthquake conceptions, which lies in the behavior of the structure as an object of analysis. Conceptually the dynamic method both spectral response and time history takes into account the mass of the structure, the stiffness of the structure, and the damping, while the equivalent static earthquake calculation only considers the mass of the structure. The analysis and design of buildings for static forces is simplified due to the availability of affordable computers and special programs that can be used for analysis. On the other hand, the dynamic analysis process is time-consuming and requires additional input related to the mass structure, and an understanding of the dynamics of the structure for the interpretation of the analysis results [11].

Several studies related to static equivalent earthquakes and dynamic time history or response spectrum provide conclusions that vary according to the research object. Faizah, (2015) assesses equivalent static earthquakes to be more accurate than time history dynamic earthquakes when analyzed on a 5-storey structure. Wantalangie et al., (2016) on a 5-story, 10-story and 15-story structure, stated that equivalent static earthquakes are safer to use when compared to dynamic earthquakes. Meanwhile, Afids, (2018) concluded that dynamic analysis is better used for structures above 10 floors.

The aim of this research is to compare the static earthquake equivalent to the dynamic earthquake response spectra. Analysis was performed using Staad Pro software. The comparative research review is the base shear or often known as the notation (V), lateral force (F) per level, and displacement.

In a planning concept it is important to optimize cross-sectional dimensions by analyzing columns, beams from the forces acting including internal forces due to the design earthquake load. The structure is said to be strong if it has sufficient dimensions but is economical when applied to high-rise buildings. Dimensional calculations are based on structural columns and beams that bear the greatest load [14]. Where this is the main concept of planning to be able to ensure the stability of the structure is able or strong and sturdy to withstand earthquake loads that work as long as the life of the building plan [15].

So that the focus of the research, apart from the comparison of base shear (V) and displacement, will also consider the strength of the structure by analyzing the internal forces due to the earthquake load, the equivalent static design and the dynamic response spectrum.

METHOD

The research method is a comparison of static earthquake analysis equivalent to dynamic response spectrum on steel structures, the research object is the Tribhuwana Tunggadewi University integrated building located in Malang City. Data collection is in the form of shop drawings. The method of analysis was carried out using Staad Pro Software. Data analysis consists of equivalent static earthquake load, dynamic earthquake response spectrum, and analysis of the capacity or strength of the steel profile which is the main material for the portal structure, and profile strength analysis using Microsoft Excel.

Stages of Equivalent Static Analysis

a) Structural Modeling in 3D
b) Input Dead load (property weight + floor slab weight and wall weight) and live load
c) Determine the total weight of the structure
d) Determine the design earthquake parameters
e) Equivalent static earthquake analysis using ASCE-7-10 (Staad Pro analytical procedure)

The results of the static earthquake analysis are; base shear force (V), lateral force (Fx) per story and displacement (displacement) per story. The results of the

Staad Pro analysis need to be validated by manual calculations using the SNI-1726-2012 procedure with the following steps;

Determining the Weight of the Structure (Wt)

(SNI 1726, 2012) regulates the effective structural weight for design seismic load analysis by determining the dead load which covers the entire load of the structure, as well as the reduced live load.

Determine the parameters of the planned earthquake load

The determined using the web from Kementrian PUPR, (2011) which is accessed on the following site;
http://puskim.pu.go.id/aplikasi/desain_spektra_indonesia_2011/

Table 1. Design Seismic Parameters

Variable	Value	Variable	Value
PGA (g)	0,392	PSA(g)	0,434
Ss (g)	0,767	SMS (g)	0,915
S1 (g)	0,324	SM1 (g)	0,568
Fa	1,193	SDs (g)	0,610
Fv	1,752	SD1	0,378
		To (sec)	0,124
		Ts (sec)	0,620

Source: Indonesian spectra design

Determining the structural response modification factor (R)

The structural response modification factor (R) can be determined based on the reference standards for earthquake resistant building planning according to Indonesian national standards in SNI-1726-2012.

Determine the period of vibration of the structure (T)

The natural vibration period of the structure can be determined using the Staad Pro program by adding modal analysis commands to obtain the natural frequency (*f*) and the natural vibration period of the structure (T). The natural vibration period of the structure is influenced by the mass of the structure and the stiffness of the structure. Where this is in accordance with the following equation;

$$\omega = \sqrt{\frac{k}{m}}$$

$$T = \frac{2x\pi}{\omega}$$

$$f = \frac{1}{T}$$

Information;

f is the natural frequency, K is the stiffness, and (m) is the mass of the structure, and ω is the angular frequency. The modal analysis used is the Eigenvector, which then the vibration period obtained is notated (Tc). The period of analysis vibration (Tc) is not allowed to exceed the upper limit period of multiplication (Cu*Ta) with (Ta) is the approximate period of vibration known by the following equation;

T_a = $C_t.h^x$ (SNI-1726:2012)

The determination of the next period of vibration is determined by considering the following equation;

Tc > Cu.Ta used T = Cu.Ta

Ta < Tc < Cu.Ta used T = Tc

Tc < Ta used T = Ta

Determining the Earthquake Response Coefficient (Cs)

Cs is the earthquake response coefficient, and Wt is the effective earthquake weight (dead load, reduced live load). The value of the earthquake response coefficient (Cs) can be calculated using the following equation;

$$Cs = \frac{SD_S}{\left(\frac{R}{Ie}\right)}$$

The Cs value from the above equation is not allowed to exceed Cs with the following equation;

$$Cs_{max} = \frac{SD_S}{T\left(\frac{R}{Ie}\right)}$$

The value of Cs from the above equation is not allowed to be smaller than Cs with the following equation;

$$Cs_{min} = 0{,}044 * SD_s * I_e \geq 0{,}01$$

Information:

- **SDs** is a parameter of the acceleration response spectrum of the short period design range (Puskim.pu.go.id)
- **SD_1** is a design response acceleration parameter within a period of 1 second (Puskim.pu.go.id)
- **R** is a response modification factor, it can be found in the provisions (SNI 1726-2012)
- **Ie** is the priority factor for earthquakes, the value of Ie can be found in the provisions (SNI-1726-2012)

Calculating the base shear force (V)

Based on the planning standards for buildings and non-building in SNI-1726-2012, the design earthquake load and base shear V are obtained using the equation:

$$V = C_s * W_t$$

Calculate the lateral force (F) distributed on each story

In SNI 1726-2012 the distribution of the lateral force that appears at each story is determined by the following equation;

$$F = C_{vx}.V$$

$$Cv = \frac{W_x(h_x)^k}{\sum_i^n = 1^{wi(hi)^k}}$$

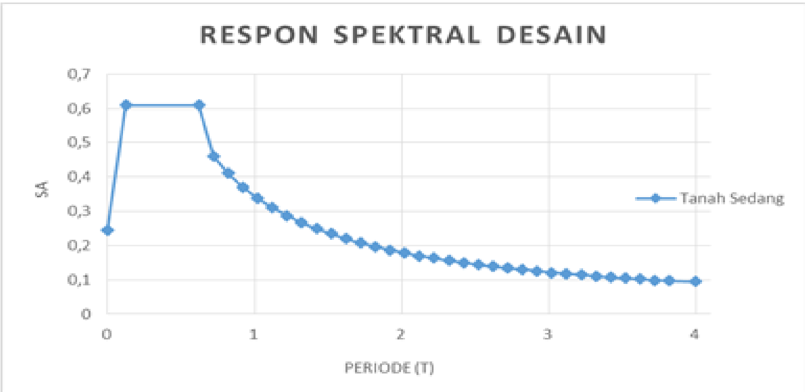
Spectrum Response Dynamic Method

The dynamic response spectrum analysis in this study is an advanced stage developed from modal analysis in determining the vibration period in the previous static equivalent analysis. Because the main principle of dynamic response spectrum analysis is to review the response of the vibration range that occurs due to the design earthquake load.

Variety Response Parameters

The spectrum response is generally in the form of a graph or plot based on the period of vibration of the structure (T), compared to the maximum responses based on the ratio of the earthquake damping.

Figure 1. Spectral Response Graph



Source: Indonesian spectra design

Stages of Response Spectrum Analysis

1. Capital structure analysis will obtain output in the form of (shape mode, frequency, and structure mass participation factor mode)
2. The mass source of the structure is used to obtain a response similar to the maximum response in each mode of vibration using the acceleration response spectrum of the earthquake.
3. Combination of the maximum modal vibrations using one of the following two methods; namely the square root sum of squares method (SRSS) or the complete square combination method (CQC) refers to SNI-1726-2012.

Style Scale

Based on the provisions of SNI-1726-2012 the response combination that produces a base shear force (Vt) must be greater than 85% of the equivalent static shear force (V) which is the vibration mode in the first mode. Conversely, if (Vt) is less than 85% Vstatic equivalent, a force scale is needed using the equation (0.85*V/Vt)

Seismic Load Combination

The combined loads due to the influence of seismic loads according to SNI-1726-2012 are;

E = Eh+Ev

Information;

E = Seismic Load

Eh = Horizontal Earthquake (SNI 2012 Article 7.4.2.1)

Ev = Vertical Earthquake (SNI 2012 Article 7.4.2.2)

Influence of Horizontal seimic Loads

Eh = ρQe

Information;

Qe = Horizontal seismic effect V or Fp (SNI-2012 article 7.5.3)

P = Redundancy Factor, (SNI-2012 article 7.3.4)

Furthermore, the combination of base loading and static earthquake loads and dynamic earthquake loads is formulated as follows

- 1,4D
- 1,2D + 1,6L
- (1,2D + 0,2 SDs) + 1L + ρ.1Ex + ρ.0,3Ez
- (1,2D + 0,2 SDs) + 1L + ρ.0,3Ex + ρ.1Ez
- (0,9 – 0,2 SDs) + (0,9-0,2 SDs) + ρ.1Ex + ρ.0,3Ez
- (0,9 – 0,2 SDs) + (0,9-0,2 SDs) + ρ.0,3Ex + ρ.1Ez

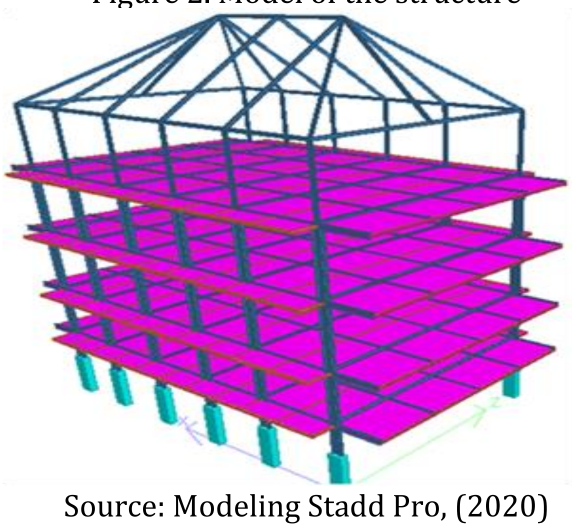
Research Flow

a. Structural Modeling, Material input / structure properties
b. Load inputs
c. Equivalent static analysis
d. Spectrum response dynamic analysis
e. Comparative analysis (base shear force (V), lateral force (Fx), and displacement)
f. Calculation of profile strength (main material Steel)
g. Conclusion, advice

RESULT AND DISCUSSION

Modeling of Structure

Figure 2. Model of the structure



Source: Modeling Stadd Pro, (2020)

The structure of the research building is modeled in 3D (space frame system) so that it can provide behavior that is in accordance with the real conditions in the field.

Equivalent Static Analysis

Table 2. Lateral Force (F) and Base Shear Force (V).

Floor Level	**Staad Pro Analysis**		**Manual calculation**	
	X	**Z**	**X**	**Z**
4	130,82	130,82	131,01	131,01
3	92,83	92,83	92,44	92,44
2	56,78	56,78	56,84	56,84
1	27,92	27,92	27,94	27,94
∑V	**308,36**	**308,36**	**308,23**	**308,23**

Source: Analysis, 2020

Based on the table above, it is known that the results of the equivalent static analysis in the x and z directions analyzed using Staad Pro are the same as or close to manual calculations, so that the input of structural weight data and earthquake parameters in Staad Pro is correct.

Spectrum Response Dynamics

Table 3. Shape Mode and Mass Participation

Mass Participation (%)				
Mode	**X**	**Z**	**SumX**	**SumZ**
1	0	75,42	0	75,42
2	0	0	0	75,42
3	77,58	0	77,75	75,42
4	0	14,49	77,75	**89,90**
5	0	3,95	77,75	93,85

6	0	0	77,75	93,85
7	15,26	0	**92,84**	93,85

Source: Analysis, 2020

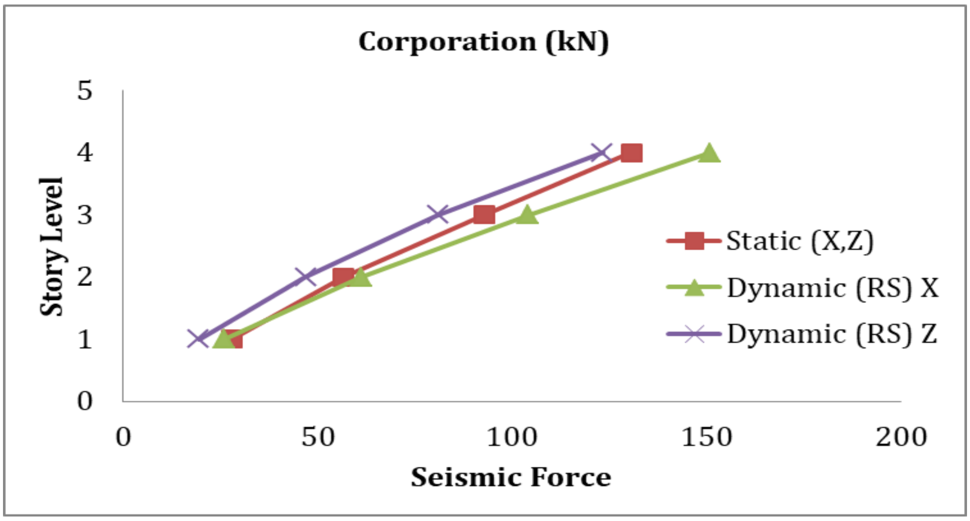
Based on the provisions of SNI-1726 where the variation/pattern of structural shaking must include a sufficient number of variations, in order to obtain a combined mass participation of at least 90% of the actual mass for each direction of earthquake loading. From the results of the analysis in the table above, in the 7th mode, the mass participation factor on the two main axes of the x and z loading directions has reached ≥ 90%.

Table 4. Lateral Force (F) and Base Shear

Floor Level	**Comparison (kN)**			
	Equivalent Static		**Dynamic(RS)**	
	X	**Z**	**X**	**Z**
4	130,82	130,82	151	123,32
3	92,83	92,83	104,3	80,98
2	56,78	56,78	61,42	47,05
1	27,92	27,92	26,02	19,59
∑ (V)	**308,36**	**308,36**	**342,9**	**270,94**

Source: Analysis, 2020

Figure 3. Seismic force



Base Shear (V) Control

85% V_{static} = 0,85 x 308,36 Kn

= 262,109 Kn

$V_{dynamic\ (X)}$ = 342,90 ≥ 262,109 **....Ok**

$V_{dynamic}$ (z) = 279,94 ≥ 262,109 **....Ok**

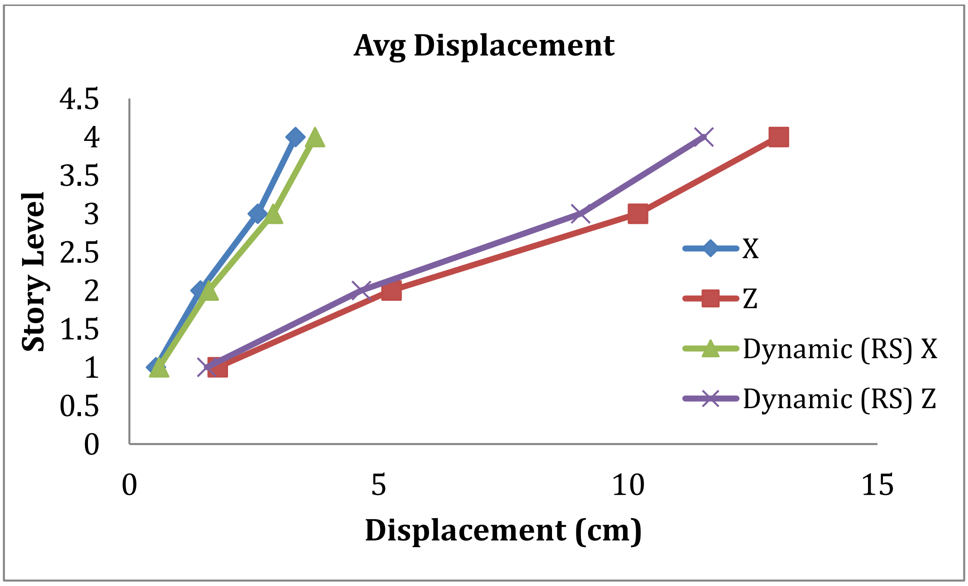
Check displacement

Table 4. Displacement

Average Displacement (cm)				
Floor Level	**Static**		**Dynamic (RS)**	
	X	Z	X	Z
4	3,3323	13,022	3,7238	11,518
3	2,5725	10,196	2,8788	9,0494
2	1,4219	5,2549	1,5899	4,6508
1	0,5332	1,768	0,5942	1,5535

Source: Analysis, 2020

Figure 4. Displacement



Source: Analysis, 2020

Check Strength Profile

Table 5. Output of internal forces acting on the column (WF.350.175.7.11)

Load Combination	Axial force	Shear force	Moment (kN.m)	
	Nu (kN)	Vu (kN)	Muy	Muz
K1	807,9	3,2	70,7	4,9
K2	792,6	2,8	70,9	4,3
K3	797,1	21,8	85,2	60,8
K4	857,0	12,4	119,8	19,7
K5	547,0	37,3	58,8	60,6
K6	543,1	11,5	93,5	18,5
K7	933,5	46,1	87,0	75,0
K8	902,1	14,9	115,9	23,2
K9	619,5	46,0	60,1	74,8
K10	588,2	14,4	89,1	22,6

Source: Analysis, 2020

Maximum force data used for profile strength analysis (WF.350.175.7.11)

Nu max = 933.5 kN

Vu max = 46.1 kN

Muy max = 119.8 kN

Max muz = 74.8 kN

Based on the results of the calculation of the profile strength check, the results are obtained;

- The value of the interaction of axial compression and bending moment, the conditions that must be met using the following equation;

$$\frac{N_u}{(2xf_n xN_n)} + \left[\frac{M_{ux}}{f_b xM_{nx}} + \frac{M_{uy}}{f_b xM_{ny}}\right] < 1$$

= 0,8389 < 1 …. **Safe (OK)**

- Shear resistance must comply with the following equation; Vu< f_f*Vn
  = 46098,4 < 264600 N …. **Safe (OK)**
- Shearing and Flexing Interaction requirements that must be met are based on equations;

$$\left[\frac{M_{ux}}{(f_b x M_{nx})} + \frac{M_{uy}}{(f_b x y)} + 0{,}625x \frac{V_u}{(f_f x V_n)}\right] < 1{,}375$$

= 0,9469 < 1,375 ….. **Safe (OK)**

Table 6. Output of Forces on Castella Main Beam from Acyl Profile (WF.350.175.7.11)

Load Combination	**Shear force**	**Moment**
	Vu (kN)	Mu (Kn.m)
K1	73,66	83,146
K2	78,19	89,746
K3	76,94	115,12
K4	73,30	173,05
K5	48,54	78,109
K6	44,85	140,268
K7	83,60	114,331
K8	93,98	164,838
K9	55,01	81,549
K10	65,39	132,055

Source: Analysis, 2020

Checking

Vu max = 93.98 kN

Mu max = 173.05 kN

Bending Moment Resistance

Requirements that must be met; Mn < fb x Mn

= 173050000 < 254406241 N … **Safe (OK)**

Shear Resistance

Requirements that must be met; Vu < ff x Vn

= 93980 < 396900 N …. **Safe (OK)**

Flex Sliding Interaction

Requirements that must be met;

$$\left[\frac{M_u}{f_b x M_n} + 0{,}625\frac{V_u}{f_f x V_n}\right] < 1{,}375$$

= 0,8282 < 1,375 **….Safe (OK)**

Table 7. Output of Forces on Castella Main Beam from Acyl Profile (WF.400.200.8.13)

Load Combination	Shear Force	Moment
	Vu (kN)	**Mu (Kn.m)**
K1	156,33	128,356
K2	155,11	128,458
K3	158,30	161,141
K4	154,50	228,207
K5	97,82	111,266
K6	94,02	178,332
K7	167,14	162,398
K8	178,09	219,328
K9	106,40	112,523
K10	117,35	169,281

Source: Analysis, 2020

Checking

Vu max = 178.09 kN

Mu max = 228.208 kN

Bending Moment Resistance

Requirements that must be met; Mn < fb x Mn

= 228207000 < 385414283 N ...**Safe (OK)**

Shear Resistance

Requirements that must be met; Vu < ff x Vn

= 178090 < 518400 N ....**Safe (OK)**

Flex Sliding Interaction

Requirements that must be met;

$$\left[\frac{M_u}{f_b x M_n} + 0,625\frac{V_u}{f_f x V_n}\right] < 1,375$$

= 0,8068 < 1,375 **.....Safe (OK)**

Table 8. Output of Forces on Main Beam (WF.250.125.6.9)

Load Combination	Shear Force	Moment
	Vu (kN)	**Mu (Kn.m)**
K1	34,10	29,097
K2	30,68	31,728
K3	22,03	30,923
K4	29,50	32,286
K5	14,19	19,616
K6	16,50	20,98
K7	80,60	33,393
K8	44,50	32,927
K9	69,46	21,935
K10	33,36	21,696

Source: Analysis, 2020

Checking

Vu max = 80.60 kN

Mu max = 33.93 kN

Bending Moment Resistance

Requirements that must be met; Mn < fb x Mn

= 33393000 < 48418035 N ...**Safe (OK)**

Shear Resistance

Requirements that must be met; Vu < ff x Vn

= 80600 < 162000 N ....**Safe (OK)**

Flex Sliding Interaction

Requirements that must be met;

$$\left[\frac{M_u}{f_b x M_n} + 0{,}625 \frac{V_u}{f_f x V_n}\right] < 1{,}375$$

= 1 < 1,375 **.....Safe (OK)**

Table 9. Output of Forces on Main Beam (WF.200.100.5,5.8)

Load Combination	Shear Force	Moment
	Vu (kN)	**Mu (Kn.m)**
K1	16,75	20,8
K2	18,73	22,813
K3	18,98	23,665
K4	18,71	23,029
K5	12,43	15,647
K6	12,16	14,947
K7	19,02	23,772
K8	18,72	23,061
K9	12,47	15,787

K10	12,17	14,979

Source: Analysis, 2020

Checking

Vu max = 19.02 kN

Mu max = 23.772 kN

Bending Moment Resistance

Requirements that must be met; Mn < fb x Mn

= 23772000 < 25225884 N ...**Safe (OK)**

Shear Resistance

Requirements that must be met; Vu < ff x Vn

= 19200 < 118800 N ....**Safe (OK)**

Flex Sliding Interaction

Requirements that must be met;

$$\left[\frac{M_u}{f_b x M_n} + 0{,}625\frac{V_u}{f_f x V_n}\right] < 1{,}375$$

= 1,04 < 1,375 **.....Safe (OK)**

CONCLUSION

Analysis results of the equivalent static base shear of 308.38 kN. While the dynamic base shear in the x direction is 342.9 kN and for the z direction it is 270.94 kN. The maximum deviation of the equivalent static earthquake in the Z direction is 13 cm while the dynamic earthquake response spectrum is 11.5 cm. These results indicate that the comparison of the loading of the two methods does not differ significantly, so that the equivalent static method is more accurate and can be used on a 5-story structure, because the calculation is simpler than dynamic analysis.After the c alculation process has been carried out, it is known that all the Existing Portal Beams of the Tribhuwana Tunggadewi University Malang Integrated Building are categorized as safe to withstand the working forces. There are three methods of calculating earthquake loads, namely static equivalent, dynamic response spectrum and also time history. In this study, two methods of analysis were used, so that the research could be further developed using a comparative analysis of dynamic time history.

In addition, structural dynamics analysis can be performed manually and compared with the analysis of certain supporting programs, such as Staad Pro, SAP 2000 or Etabs and other analysis programs

REFERENCES

[1] J. L. Cui, M.-H. Chey, and S.-I. Kim, "Seismic performance of urban structures with various horizontal irregularities using equivalent static analysis," *J. Converg. Soc. SMB*, vol. 6, no. 1, pp. 25–32, 2016.

[2] H. Fan, Q. S. Li, A. Y. Tuan, and L. Xu, "Seismic analysis of the world's tallest building," *J. Constr. Steel Res.*, vol. 65, no. 5, pp. 1206–1215, 2009.

[3] P. Fajfar and M. Fischinger, "N2-A method for non-linear seismic analysis of regular buildings," in *Proceedings of the ninth world conference in earthquake engineering*, 1988, vol. 5, pp. 111–116.

[4] Badan Standarisasi Nasional (BSN), *SNI Badan Standarisasi Nasional*. Jakarta: Badan Standarisasi Nasional (BSN), 2012.

[5] R. R. Latuheru and R. Prasojo, "Static and Dynamic Analysis of an 8-Floor Building," J. Kaji. Tech. Civil, vol. 2, no. 2, pp. 130–141, 2017.

[6] M. Tarigan and D. R. Teruna, "Comparison of Responses to Regular Structures and Horizontal Irregular Angles Due to Earthquakes Using Equivalent Static Analysis and," J. Tech. USU Civil, vol. 3, no. 1, 2014.

[7] M. Causevic and S. Mitrovic, "Comparison between non-linear dynamic and static seismic analysis of structures according to European and US provisions," *Bull. Earthq. Eng.*, vol. 9, no. 2, pp. 467–489, 2011.

[8] H. M. Fadilah and E. Walujodjati, "Comparison of Earthquake Loading of Multi-storey Buildings Using Static Equivalent Analysis and Dynamic Time History Analysis in Kab. Garut," J. construction. vol. 18, no. 1, pp. 20–30, 2020.

[9] I. Rifandi, "Earthquake Load Analysis Using the Equivalent Static Method Based on SNI 1726-2019 on the WWTP Building," J. Constr., vol. 18, no. 2, pp. 72–82, 2020.

[10] I. Widodo and P. D. MSCE, "Dynamic Response of Elastic Structures." Jogjakarta: UII Press, 2001.

[11] A. Gottala, K. S. N. Kishore, and S. Yajdhani, "Comparative study of static and dynamic seismic analysis of a multistoried building," *IJSTE-International J. Sci. Technol. Eng.*, vol. 2, no. 01, 2015.

[12] R. Faizah, "Comparative Study of Equivalent Static Earthquake Loading and Time History Dynamics on High-rise Buildings in Yogyakarta," Semesta Tek., vol. 18, no. 2, pp. 190–199, 2015.

[13] R. O. F. Wantalangie, J. D. Pangouw, and R. S. Windah, "Static and Dynamic Analysis of Multi-Storied Buildings Due to Earthquakes based on SNI 1726-2012 with Variations in the Number of Levels," J. Civil Static, vol. 4, no. 8, 2016.

[14] I. K. Arianta, "Analysis of Multilevel Steel Portal Structures for the Ummah

Muhammadiyah Sumbawa Besar Health Center Building," 2018.
[15] Y. Lende, N. Rasidi, and D. Ningrum, "Planning of the Upper Structure of the UNITRI Campus 2 Building." University Faculty of Engineering Tribhuwana Tunggadewi Malang, 2022.
[16] Kementrian PUPR, "Desain Spektra Indonesia," 2011. rsa.ciptakarya.pu.go.id/2010/ (accessed Jun. 18, 2019).