privietlab.
RESEARCH & PUBLISHING

Priviet Social Sciences Journal

Volume 6
Issue 2 February, 2026

Article 57

27-02-2026

Comparative analysis of the behavior of reinforced concrete buildings using static equivalent, response spectrum, and time history methods

Made Hendra Prayoga, Ida Bagus Prastha Bhisama, P. Adi Yasa

To cite this article: Prayoga, M. H., Bhisama, I. B. P., & Yasa, P. A. (2026). Comparative analysis of the behavior of reinforced concrete buildings using static equivalent, response spectrum, and time history methods. *Privief Social Sciences Journal, 6*(2), 615-626.
https://doi.org/10.55942/pssj.v6i2.1616

To link to this article: https://doi.org/10.55942/pssj.v6i2.1616

Private Social Sciences Journal
E-ISSN 2798-6314
P-ISSN 2798-866X
https://doi.org/10.55942/pssj.v6i2.1616

Volume 6
Issue 2
February Edition 2026

Comparative analysis of the behavior of reinforced concrete buildings using static equivalent, response spectrum, and time history methods

Made Hendra Prayoga*, Ida Bagus Prastha Bhisama, P. Adi Yasa

Undergraduate Program in Civil Engineering, Faculty of Engineering, Udayana University, Badung, Bali, Indonesia
*e-mail: hendra.prayoga@unud.ac.id

Received 14 January 2026
Revised 01 February 2026
Accepted 27 February 2026

ABSTRACT

In structural analysis, earthquake loads are generally calculated using either equivalent static or dynamic approaches (response spectrum and time history), as specified in the SNI 1726:2019. This study aims to evaluate and compare the behavior of the Collins Boulevard Apartment building structure under earthquake loads using these three methods. The analysis was conducted using the structural modeling of a high-rise building with a dual system. For the time history method, three real earthquake records were used: Chi-Chi, Ibaraki Off, and Tohoku, which represent shallow crustal, Benioff, and megathrust earthquake sources, respectively. The results indicate that the equivalent static method produced the highest base shear of 51,761 kN, followed by the response spectrum method with ratios of 0.55 and 0.51 for the X and Y directions, respectively, relative to the static value, and the time history method with ratios of 0.48 and 0.42 for the X and Y directions, respectively. The maximum inter-story drift occurred in the equivalent static method, exceeding the allowable limit specified in SNI 1726:2019, while the two dynamic methods remained within safe limits. The internal forces in the beams and columns ranged from 0.3–0.9 times those produced by the static method, with the time history method exhibiting more fluctuating yet realistic structural responses.

Keywords: earthquake load analysis; equivalent static; response spectrum; time history.

1. INTRODUCTION

Indonesia is one of the countries with the highest seismic activity in the world because it is located at the meeting point of three major tectonic plates: the Pacific, Eurasian, and Indo-Australian plates. The interaction between these tectonic plates causes tectonic and volcanic earthquakes, which often damage buildings and infrastructure. Several major earthquakes have occurred in Indonesia, such as the 2004 Aceh, 2006 Yogyakarta, 2009 West Sumatra, and 2018 Lombok and Palu earthquakes, which demonstrate the high seismic threat faced by Indonesia. This condition requires the design of building structures that can effectively withstand seismic forces to minimize the risk of damage and casualties. Therefore, the analysis of structural behavior owing to seismic loads is an important aspect of planning, especially for multi-story buildings with large masses and complex geometries.

In earthquake-resistant structural design, the influence of seismic loads is generally analyzed using two main approaches: the equivalent static method and the dynamic method (response spectrum and time history) (Suntoko, 2019). The equivalent static method works by simplifying the effects of earthquakes as horizontal forces acting at the center of the building's mass (Nurkhusnaedi, 2025). This method is quite effective for regular buildings with low heights but is less accurate for high-rise buildings, irregular geometries, or those on soft ground conditions. SNI 1726:2019 states that the equivalent static method is only applicable to regular buildings with a maximum height of 40 m or 12 floors (National Standardization Agency, 2019). Dynamic analysis must be performed beyond these criteria.

According to Chopra (2012), a response spectrum is a graph that shows the relationship between the natural period of a structure and its maximum response, such as the displacement, relative velocity, or total acceleration. This spectrum is used to estimate the maximum response of a single-degree-of-freedom (SDOF) structural system at various natural periods in terms of displacement, velocity, or acceleration. Of these three parameters, spectral acceleration (Sa) is generally used as the main reference because the earthquake forces acting on a building structure are calculated based on horizontal inertia forces ($F = m \times a$), which depend on the building mass(m) and surface acceleration (a).

Time history analysis is a dynamic method that directly calculates the structural response to ground acceleration caused by past earthquakes. This method utilizes numerical integration of the dynamic motion equation of the structure to obtain the displacement, velocity, and relative acceleration of each structural element, over time (Yang et al., 2022). SNI 1726:2019 requires the use of at least three pairs of orthogonal earthquake records adjusted to the design response spectrum using spectral matching or amplitude scaling techniques. The selection of earthquake records refers to the results of earthquake hazard deaggregation (PusGeN, 2022) so that the seismic input characteristics match the site conditions and dominant earthquake sources at the structure location.

Nurkhusnaedi (2025) analyzed a 12-story apartment building in Yogyakarta using the equivalent static method, response spectrum, and time history. They found that the equivalent static method produced the largest structural response for the base shear and inter-story drift. Laila et al. (2017) discussed linear response spectrum analysis. In this study, linear response spectrum analysis was compared with linear time history analysis. The results showed differences between the two methods. The base shear obtained from the response spectrum analysis was greater than that from the linear time history analysis.

2. METHOD

This research began with the collection of primary data in the form of structural layouts, dimensions, and reinforcement details of the main elements obtained from the owner, contractor, and structural design consultant of Collins Boulevard Apartment. Soil investigation data was also used to determine the site class and seismic parameters in accordance with SNI 1726:2019 (National Standardization Agency, 2019). Structural modeling was performed using ETABS v21 software, employing reinforced concrete as the primary material, with concrete and reinforcing steel quality specifications based on the building design specifications.

2.1. Structural Loading

The loads applied to the model include gravity loads and earthquake loads determined based on SNI 1727:2020 and SNI 1726:2019. Gravity loads include dead loads, additional dead loads, and live loads. Dead and additional loads are calculated from the weight of structural elements and permanent non-structural elements such as floor finishes, fixed partitions, ceilings, ducting, and MEP installations. Meanwhile, live loads are determined based on room functions, with values taken from the SNI 1727:2020 loading table. A summary of the superimposed dead load (SDL) and live load (LL) values for each room function is shown in Table 1.

Table 1. Room Functions and Floor Slab Load Calculations

Room Function	SDL (kN/m^2)				LL (kN/m^2)
	Finishing + Screed	Ceiling + Ducting	Partation	Total SDL	
Corridor Housing	1.1	0.3	0.72	2.12	1.92
Apartment	1.1	0.3	0.72	2.12	1.92
Stairs	1.1	0.3		1.4	4.79
F.O.R Corridor	1.1	0.3	0.72	2.12	3.83
F.O.R. Lower Deck	1.1	0.6	0.72	2.42	3.83
F.O.R Upper	1.1	0.6	0.72	2.42	1.92
Landscape	0.5	0.3		0.8	6
Gym	1.1	0.3		1.4	4.79
Parking Corridor	0.5	0.3		0.8	3.83
Parking	0.5	0.3		0.8	1.92
First Floor Store	1.1	0.3	0.72	2.12	4.79
First Floor Corridor	1.1	0.3	0.72	2.12	4.79

Table 2. Seismic Design Parameters

Indicator	Data
Location	Serpong, Tangerang
Building risk category	II (Residential)
Site class	SE (Soft soil)
Earthquake importance factor (Ie)	1.0
Mapped spectral acceleration (Ss)	0.837
Mapped spectral acceleration (S1)	0.41
Site class coefficient (Fa)	1.231
Site class coefficient (Fv)	2.381
Spectral response acceleration (Sds)	0.686
Acceleration spectral response (Sd1)	0.650
Seismic design category (KDS)	D

Earthquake loads are calculated in accordance with SNI 1726:2019, taking into account the building risk category, site class, and design spectral acceleration parameters obtained from the RSA Cipta Karya website. The seismic parameters used for this case study are shown in Table 2.

2.2. Load Combination

The load combinations used are compiled based on the provisions in SNI 1726:2019, which include dead load, additional dead load and live load, as well as earthquake load.

3. RESULT AND DISCUSSION

3.1. Building Structure Modeling

The structural modeling of Collins Boulevard Apartment as shown in Figure 1 was performed using ETABS v21 software. This building is a high-rise structure with horizontal irregularity and uses a dual system for resisting earthquake loads. It is very important to examine how static and dynamic earthquake loads affect this type of structural system. The structure was modeled as a dual system combining a special moment-resisting frame (SRPMK) and special reinforced concrete shear walls in accordance with SNI 1726:2019. Beams and slabs use concrete strength fc' 40 MPa on the ground floor to the 13th floor, and fc' 30 MPa on the 14th floor to the roof. Meanwhile, the columns and shear walls use higher concrete quality, namely fc' 50 MPa in the basement to the 13th floor, fc' 40 MPa on the 14th to 20th floors, and fc' 30 MPa on the 21st floor to the roof.

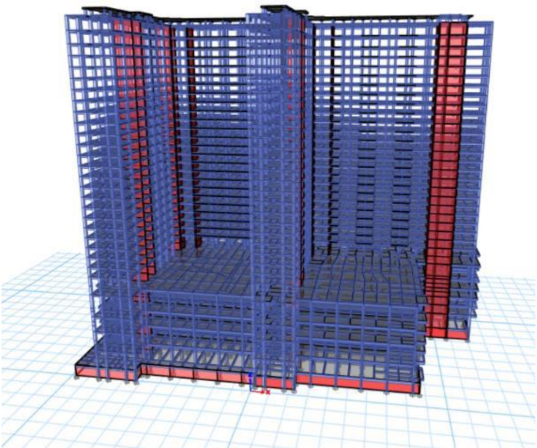

Figure 1. 3D Model of Collins Boulevard Apartment

3.2. Equivalent Static Analysis

Based on SNI 1726:2019, the equivalent static earthquake load can be used for buildings with a maximum height of 40 m or 12 stories. For buildings exceeding that height, dynamic earthquake loading must be used. However, in this study, the static earthquake load is still applied to determine the comparison of structural responses due to static and dynamic earthquake loads for buildings with heights exceeding 40 m or 12 stories. The determination of the equivalent static earthquake load for the Collins Boulevard Apartment was based on the provisions of SNI 1726:2019. This building is categorized as risk II (residential) with aseismic importance factor of$Ie = 1$. Based on the SE site class and spectral acceleration data mapped from the RSA Cipta Karya website, the design spectral acceleration was obtained from$SDS = 0{,}686$ and$SD1 = 0{,}650$, placing the building in seismic design category D.

The seismic weight and natural vibration period obtained from ETABS were then reprocessed in accordance with SNI 1726:2019 to obtain the base shear value $V = Cs.\ w = 51.760{,}85$ kN. Using the equation $Fx = Cvx \times V$, the lateral seismic force per floor is obtained as shown in Table 3.

Table 3. Equivalent Static Lateral Forces

Story	Static Equivalent Analysis	
	Lateral Force	
	Fix (kN)	Fiy (kN)
R	4441.7	4441.7
30	3975.3	3975.3
29	3622.9	3622.9
28	3356.7	3356.7
27	3182.8	3182.8
26	3012.7	3012.7
25	2821.1	2821.1
24	2635.6	2635.6
23	2456.2	2456.2
22	2282.9	2282.9
21	2115.8	2115.8
20	1975.8	1975.8
19	1839.9	1839.9

18	1688.0	1688.0
17	1542.4	1542.4
16	1403.1	1403.1
15	1270.2	1270.2
14	1143.6	1143.6
13	1028.5	1028.5
12	920.8	920.8
11	812.4	812.4
10	710.5	710.5
9	615.3	615.3
Story	**Static Equivalent Analysis**	
	Lateral Force	
	Fix (kN)	**Fiy (kN)**
8	526.7	526.7
7	443.0	443.0
6M	122.6	122.6
6	755.2	755.2
L5M	96.6	96.6
P5B	255.4	255.4
L5	100.7	100.7
P5A	191.3	191.3
3M	39.3	39.3
P3A–L3	178.8	178.8
P2B–L2M	104.9	104.9
P2A–L2	75.5	75.5
L1	16.3	16.3

3.3. Response Spectrum Analysis

Based on the Serpong seismic design parameters obtained from the RSA Cipta Karya website and the short-period design acceleration calculation (SDS) and the 1-second design acceleration ($SD1$), then $T0$ and Ts can be calculated using the equation.

$$T_0 = 0{,}2\frac{S_{D1}}{S_{DS}} = 0{,}2\frac{0{,}6864}{0{,}6500} = 0{,}19\ detik$$

$$T_S = \frac{S_{D1}}{S_{DS}} = \frac{0{,}6864}{0{,}6500} = 0{,}94\ detik$$

The design acceleration response spectrum value (Sa) is then calculated by considering the following three conditions:

For T < T_0

$$S_a = S_{Ds}(0{,}4 + 0{,}6\frac{T}{T_0})$$

For T_0 ≤ T ≤ T_s

$$S_a = S_{Ds}$$

For T > T_s

$$S_a = \frac{S_{D1}}{T}$$

Thus, the response spectrum curve for the Serpong, Tangerang region is obtained as shown in Figure 2.

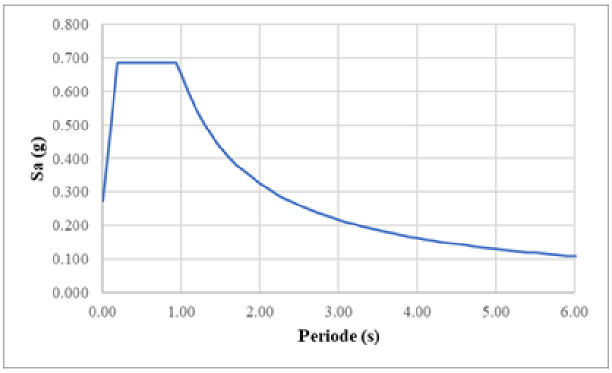

Figure 2. Serpong Response Spectrum Graph

3.4. Time History Analysis

Linear time history analysis must use at least three pairs of earthquake records Lombardi & De Luca, 2020) The selection of earthquake records refers to the results of earthquake hazard deagregation from the book "Indonesian Earthquake Hazard Deagregation Map for Earthquake-Resistant Infrastructure Planning and Evaluation" (PusGeN, 2022). The spectral data for this study was planned for a 2500-year return period, located in Serpong, Tangerang, with a soft soil site classification (SE), and a spectral velocity (Vs) < 175 m/s. Deagregation was performed with a vibration period of 0.3 seconds because T > Ts, resulting in the selected ground motion spectral data asshown in Table 4.

Table 4. Selected Spectral Data of Earthquake Recordings

Source	Magnitude	Distance (km)
Shallow Crustal	6–6.2	30–40
Benioff	7.4–7.6	120–150
Megathrust	8.6–8.8	150–200

In accordance with the requirements of SNI 1726:2019, this study used three earthquake records representing shallow crustal, Benioff, and megathrust earthquakes. The earthquake records were obtained from the NGA-West2 database for shallow crustal earthquake sources and from the NGA Sub/NHR3 database for Benioff and megathrust earthquakes. Each earthquake shown in Table 5.

Table 5. Selected Modified Ground Motion

Source	RSN	Event	Location	Year	M	R (km)	Vs30 (m/s)
Shallow Crustal	2715	Chi-Chi	Taiwan	1999	6.2	38.62	169.52
Benioff	4040722	IbarakiOff	Japan	2011	7.92	131.4226	137.6
Megathrust	4000628	Tohoku	Japan	2011	9.12	192.8215	158.3

Each earthquake recording must be spectrally matched to adjust the response spectrum shape of each recording to match the target design spectrum based on the seismic parameters of the Serpong, Tangerang region. The adjustment is carried out in the period range of 0,8 $Tlower$ = 0,207s to1,2 $Tlower$ = 5,209s, as required by SNI 1726:2019 Article 7.9.2.3 (National Standardization Agency, 2019).

In the spectral matching process using ETABS software, the maximum error in the X and Y directions was 4.68% and the average error was 1.70%. In the book Earthquake Spectra and Design (Newmark & Hall, 1982), the target spectrum for the vertical component uses an approach of 2/3 of the horizontal response spectrum. The matching results for the Z direction yielded a maximum error of 9.84% and an average error of 3.33%. Therefore, it can be concluded that the modified earthquake record is valid for use in three-dimensional time history analysis.

3.5. Base Shear

Table 6. Equivalent Static Base Shear Values and Response Spectrum

Output Case	Case Type	Fx kN	Fy kN
QX	LinStatic	51761	0.00
QY	LinStatic	0.00	51761
RSQX-	LinResp Spec	28587	4184
Unscale	LinResp	4184	26643
RSQY-	Spec	51771	7578
Unscale	LinResp	8142	51847

Based on the analysis results obtained using ETABS v21 software, the base shear value of the response spectrum method is less than 100% of the equivalent static analysis base shear. Therefore, to meet this requirement, the response spectrum base shear will be increased by a scaling factor

$$\frac{VX}{Vt} = \frac{28587{,}2}{51760{,}82} = 1{,}811$$

$$\frac{VY}{Vt} = \frac{26642{,}6}{51760{,}82} = 1{,}946$$

A summary of the equivalent static base shear, base shear response spectrum before and after scaling is shown in Table 6

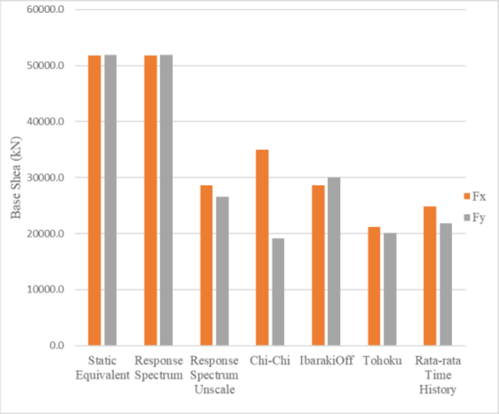

Figure 3. Comparison of Base Shear Values

Figure 3 compares the base shear values obtained from the analysis results of the three earthquake loading methods. From the figure, it can be seen that the response spectrum base shear shows the largest value, slightly above the equivalent static base shear value. However, it should be noted that the base shear values of this method have already been scaled to meet the requirements of SNI 1726:2019. Meanwhile, the smallest value is caused by the time history method, where the average base shear value of the s less than half of the base shear caused by the equivalent static method.

3.6. Inter-Story Drift

In determining inter-floor deflection, SNI 1726:2019 (National Standardization Agency, 2019) explains that the deflection value must be calculated based on the difference in horizontal displacement of the center of mass at the level above and below. Inter-floor deflection is calculated using the equation:

$$\Delta x = \frac{(\delta ex_{(i)} - \delta ex_{(i-1)}) \times C_d}{I_e}$$

The displacement values for each floor from the ETABS analysis are processed to obtain the inter-floor deflection according to the above equation for all levels, from floor 1 to the roof. Based on the analysis results, the largest X-direction deflection occurred in the equivalent static method with a value of 276.83 mm on the 6th mezzanine floor. Meanwhile, for the Y-direction, the maximum deflection was also produced by the equivalent static method, namely 265.60 mm, which occurred on the roof floor.

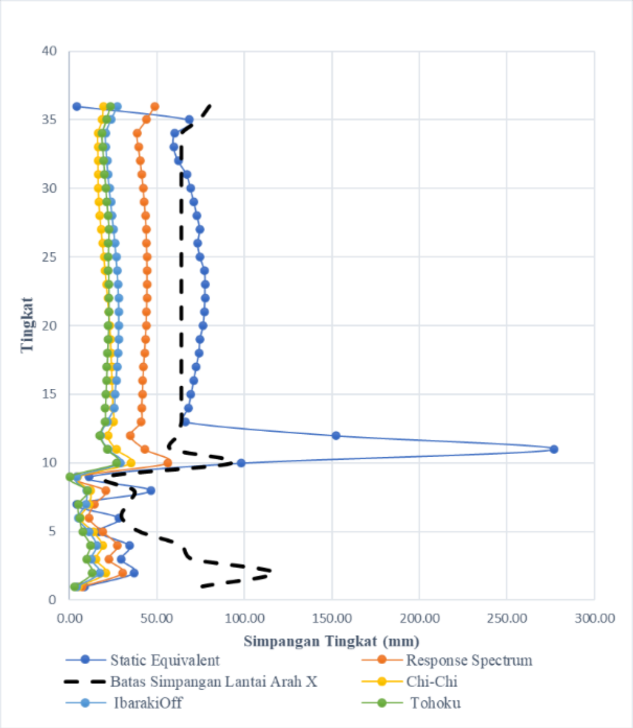

Figure 4. Graph of Inter-Floor Deflection in the X Direction

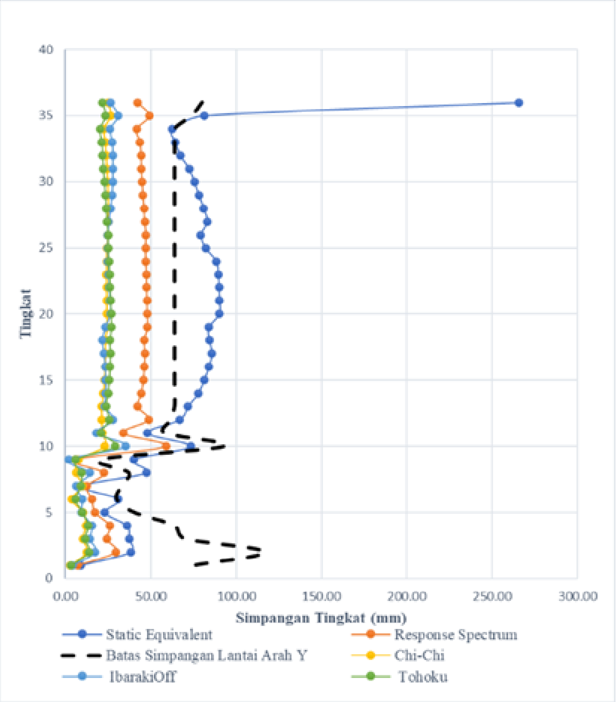

Figure 5. Graph of Inter-Floor Deviation in the Y Direction

From Figure 4 and Figure 5, it can be seen that the distribution pattern of inter-floor deflection in the three methods shows an irregular trend up to the 6th mezzanine floor, then relatively uniform from the 7th to the 30th floor. The irregularity on the lower floors up to the 6th mezzanine is caused by changes in floor plan configuration and height between floors, as well as differences in building functions from the facility and retail areas to the residential area. Meanwhile, in the tower segment (floors 7– 30), which has a uniform floor plan and function, the structural response to lateral loads becomes more consistent.

3.7. Internal Force

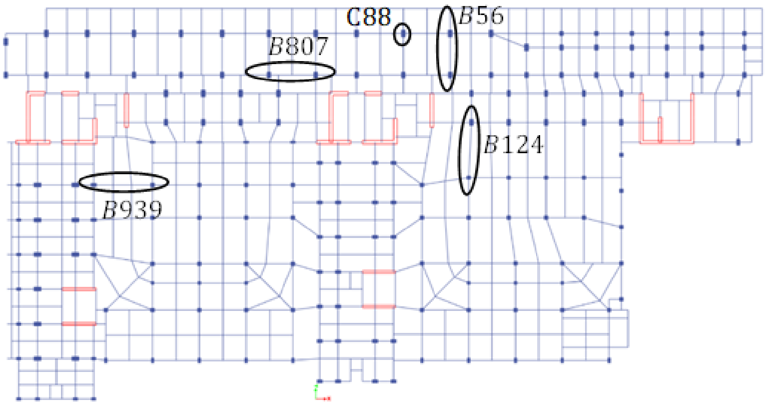

Figure 6. Floor Plan of Compared Structural Components

Table 7. Comparison of Internal Forces in Beams

Floor	Eelemnt	Method	Internal Force (kN)			
			M Absolute	M Ratio	V Absolute	V Ratio
6	B939	Static	1376.8	1.0	611.6	1.00
		RSA	1234.2	0.90	576.6	0.94
		Chi-Chi	980.8	0.71	526.0	0.86
		IbarakiOff	980.2	0.71	526.0	0.86
		Tohoku	1008.3	0.73	526.0	0.86
6	B124	Static	1151.2	1.00	445.9	1.00
		RSA	906.8	0.79	386.1	0.87
		Chi-Chi	645.5	0.56	309.6	0.69
		IbarakiOff	676.5	0.59	317.2	0.71
		Tohoku	656.3	0.57	312.1	0.70
20	B807	Static	755.7	1.00	306.7	1.00
		RSA	579.7	0.77	259.9	0.85
		Chi-Chi	408.3	0.54	205.3	0.67
		IbarakiOff	415.4	0.55	207.2	0.68
		Tohoku	401.1	0.53	203.4	0.66
R	B56	Static	806.4	1.00	440.4	1.00
		RSA	673.7	0.84	394.5	0.90
		Chi-Chi	459.6	0.57	295.2	0.67
		IbarakiOff	480.3	0.60	309.5	0.70
		Tohoku	452.3	0.56	293.6	0.67

Table 8. Comparison of Internal Forces in Columns (C88)

Floor	Method			Internal Force (kN)			
		P (kN)	P Ratio	V (kN)	V Ratio	M (kNm)	M Ratio
30	Static	1599.7	1.00	118.8	1.00	192.4	1.00
	RSA	1508.5	0.94	84.7	0.71	132.7	0.69
	Chi-Chi	1366.7	0.85	45.9	0.39	71.4	0.37
	IbarakiOff	1366.7	0.85	50.9	0.43	79.0	0.41
	Tohoku	1366.7	0.85	35.4	0.30	55.1	0.29
15	Static	10779.0	1.00	205.6	1.00	270.1	1.00
	RSA	10119.4	0.94	125.9	0.61	177.1	0.66

	Chi-Chi	9428.9	0.87	62.2	0.30	89.2	0.33
	IbarakiOff	9428.9	0.87	76.5	0.37	111.4	0.41
	Tohoku	9428.9	0.87	63.1	0.31	92.9	0.34
L1	Static	22137.4	1.00	150.9	1.00	880.3	1.00
	RSA	20813.8	0.94	151.1	1.00	744.2	0.85
	Chi-Chi	19860.8	0.90	98.5	0.65	371.0	0.42
	IbarakiOff	19860.8	0.90	104.1	0.69	403.2	0.46
	Tohoku	19860.8	0.90	97.2	0.64	348.9	0.40

Based on Table 7, Table 8, and Figure 6, it is known that the internal forces generated by each earthquake loading method are different. The equivalent static method produces the largest output for both beam and column elements, followed by the response spectrum and time history methods. The time history method itself shows a significant difference in values when compared to the equivalent static method, indicating that the structure's response is greatly influenced by the characteristics of the earthquake input, such as duration, frequency content, and peak acceleration amplitude.

The difference in internal force values between analysis methods affects the reinforcement requirements for structural elements. Because it produces the largest internal force, the equivalent static method requires greater flexural and shear reinforcement in beam elements, as well as more longitudinal reinforcement in column elements. Conversely, the response spectrum and time history methods produce smaller internal forces, resulting in lower reinforcement requirements and a more material-efficient structural design.

4. CONCLUSION

Based on the structural analysis results of the Collins Boulevard Apartment using three earthquake loading methods (static equivalent, response spectrum, and time history), it was found that the static equivalent method is more conservative, producing the largest response in base shear, inter-story drift, and internal forces in structural elements. The response spectrum and time history methods show lower results, with base shear ratios to equivalent static of approximately 0.55–0.51 and 0.48–0.42, respectively. The axial force of the structural elements is relatively stable with a ratio to the equivalent static load in the range of 0.8–0.9. Meanwhile, the bending moment and shear force show greater variation, particularly in the time history method, with a ratio to the equivalent static load in the range of 0.3–0.8.

Based on SNI 1726:2019, for buildings exceeding 40 m or 12 stories in height and classified as irregular structures, the equivalent static earthquake load method cannot be used. The analysis must employ dynamic earthquake loading because it is considered to produce more significant effects. However, in this study, the static earthquake load actually resulted in greater effects. Therefore, in structural analysis and design, it is recommended that the static earthquake load still be considered and compared with the dynamic earthquake load to obtain a safe structural design.

Ethical Approval

Not Applicable

Informed Consent Statement

Not Applicable

Authors' Contributions

MHP conceptualized the study, conducted structural modeling and analysis, and drafted the manuscript. IBPB and PAY contributed to research supervision, validation of analytical results, and manuscript revision. All authors have read and approved the final manuscript.

Disclosure Statement

The Authors declare that they have no conflict of interest

Data Availability Statement

The data presented in this study are available upon request from the corresponding author for privacy.

Funding

This research received no external funding.

Notes on Contributors

Made Hendra Prayoga

Made Hendra Prayoga is affiliated with Udayana University

Ida Bagus Prastha Bhisama

Ida Bagus Prastha Bhisama is affiliated with Udayana University

P. Adi Yasa

P. Adi Yasa is affiliated with Udayana University

REFERENCES

National Standardization Agency. (2019). *SNI 1726:2019 Procedures for earthquake resistance planning for building and non-building structures*.1–248.

Chopra, A. K. (2012). Dynamics of Structures. In *Dynamics of Structures 4th Edition*. https://doi.org/10.1002/9781118599792

Lombardi, L., & De Luca, F. (2020).Derivation of fragility curves at designstage through linear time-history analysis. *Engineering Structures*, *219* (September). https://doi.org/10.1016/j.engstruct.202 0.110900

Newmark, N. M., & Hall, W. J. (1982). Earthquake spectra and design. *Engineering Monographs on Earthquake Criteria*.

Nurkhusnaedi, R. A. (2025). *Comparison of Structural Response with the Application of Equivalent StaticEarthquake Load, Spectrum Response, and Time History*. Final Thesis Universitas Islam Indonesia.

PusGeN. (2022). *Indonesian EarthquakeHazard Degradation Map Book for Earthquake-Resistant Infrastructure Planning and Evaluation*.

Laila, D.A., Bayyinah, N. & Faimun. (2017). Comparative Study of Response Spectrum Analysis and Time History Analysis for Building Design. *Jurnal Teknik ITS*, 6(1), 33–38.

Suntoko, H. (2019). Spectrum Response Analysis of RDE Reactor Building Design Using SAP2000. *Journal of Nuclear Energy Development*, *21*(1), 1–7.

Yang, L., Fu, Z., & Wang, D. (2022). Groundmotion time history simulation for seismic respons history analysis. *Frontiers in Earth Science*, *10*, 908498. Zhafira, T., Taufiqy, I., & KusumaAnggraini, N. (2023). Dynamic Analysis of Spectrum Response and Static Equivalent of The Semarang University College Building. *JCEBT (Journal of Civil Engineering, Building and Transportation)*.