Structural Performance Analysis Due To Dynamic Earthquake Loads on the Pegadaian Tower In Central Jakarta

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Abstract

The DKI Jakarta area is one of the areas that has an earthquake risk because there are several active faults that stretch around it. Rapid economic growth increases the need for building construction and renovation, so the design of high-rise buildings in Jakarta must consider the seismic risk as well as structural aspects, element integration, comfort, and safety of occupants. This study aims to determine the maximum displacement value due to dynamic earthquake loads using the response spectrum and time history methods, and determine the structural performance level based on ATC-40. The analysis was carried out on the 30-story Pegadaian Tower Building in Jakarta, with 27 floors modeling in ETABS software. The results showed the maximum displacement value of the response spectrum method in the x direction was 23.0395 mm and the y direction were 22.698 mm. For the time history method with the Hiroshima earthquake source in the x direction of 97,323 mm and the y direction of 72,419 mm, for the Kakuda earthquake source in the x direction of 66,808 mm and the y direction of 61,220 mm, while the Shinshinotsu earthquake source in the x direction of 62,832 mm and the y direction of 58,514 mm. The difference in the deviation value is influenced by the characteristics of each earthquake source, the analysis method used, as well as the different stiffness and natural period of the structure in the x and y directions. The performance level of Pegadaian Tower based on ATC-40 is included in the Immediate Occupancy (IO) category which indicates that the building structure only suffered minor damage and can still be used again immediately for activities

Keywords : Structural Performance, Drift, Spectrum Response, Time History, ATC 40.

1. INTRODUCTION

Indonesia is located on the equator, with a diverse landscape and complex geological conditions. This region lies at the confluence of three active tectonic plates: the Eurasian, Australian, and Pacific. The movement of these plates triggers the formation of earthquake zones, active volcanoes, and faults that can cause earthquakes. This makes Indonesia one of the countries with a high level of vulnerability to earthquakes and volcanic activity.

Jakarta is part of this earthquake-prone area due to the presence of active faults, one of which is the Baribis Fault, which stretches from Purwakarta to Banten. The presence of this fault places Jakarta in the M7 Earthquake Risk Zone, thus the potential for earthquakes is quite high. This condition raises concerns about the safety of infrastructure, especially the multi-story buildings that are often found in Jakarta, the center of economic activity.

Rapid economic growth is increasingly driving building construction and renovation, so structural planning must consider aspects of strength, comfort, and occupant safety. To reduce the risk of damage and loss of life due to earthquakes, building resilience analysis is crucial. Structural performance evaluation based on ATC 40 can be used as a reference to ensure building designs meet safety and feasibility standards, ensuring buildings continue to function optimally even in earthquake-prone areas.

Pegadaian Tower is a 30-story office building with a height of 119 m, measured from 0.0 m above ground level to the roof. Located at Jl. Kramat Raya No. 162, Kenari Village, Senen District, Central Jakarta. This office building is a multi-story high-rise in a densely populated area, requiring a structural performance analysis.

2. METHODS

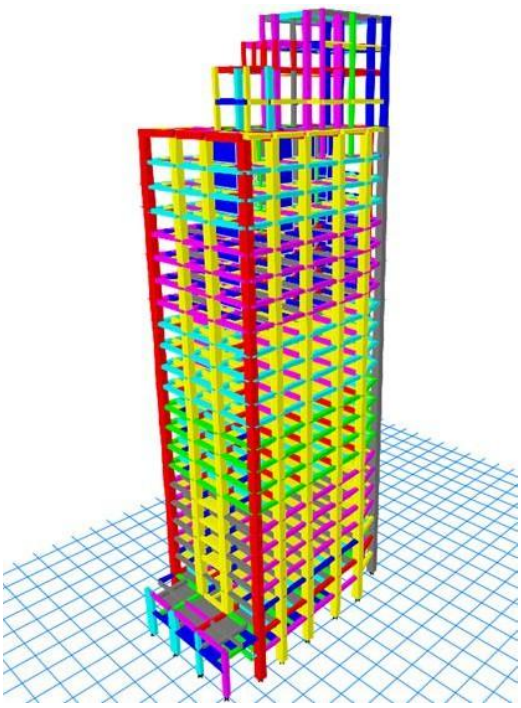
Penelitian ini menerapkan metode analisis kuantitatif melalui simulasi dengan pendekatan analisis dinamik, yaitu analisis *respons spektrum* dan analisis *time history* akibat beban gempa pada gedung Pegadaian Tower. Pemodelan struktur dilakukan dengan menggunakan perangkat lunak ETABS versi 22 untuk memperoleh hasil evaluasi kinerja bangunan terhadap pengaruh gempa.

2.1. Data Structure

Tabel 1. Building Description

Building Description	Information
Bulding Name	Pegadaian Tower
Bulding Location	Jln. Kramat Raya No. 162, Kelurahan Kenari, Kecamatan Senen, Kota Administrasi Jakarta Pusat, Daerah Khusus Ibukota Jakarta 10430 Indonesia.
Building Structural System	SRPMK
Building Function	Office Building
Number of Floors	2 bassement + 27 floors
Beam Concrete Quality	*Fc' 30* Mpa
Column Concrete Quality	*Fc' 40* Mpa
Steel Reinforcement BJ 420B	*Fy* 420Mpa, *Fu* 525 Mpa
Soil Site Class	Special Soil (SF)
Earthquake Risk Category	(II)

3D modeling of the Pegadaian Tower building structure using ETABS v.22, adjusting dimensions and materials according to the building's Detailed Engineering Design (DED). The following is the 3D modeling result for the Pegadaian Tower building in Central Jakarta.



Gambar 1. 3D Structural Modeling using ETABS

2.2. Loading Input

The structural loads and load combinations are referenced in SNI 1727:2020 concerning Minimum Design Loads and Related Criteria for Other Building Structures. For the calculation and input of seismic loads, SNI 1726:2019 concerning Procedures for Earthquake Resistance Planning for Buildings and Non-Building Structures is used.

a. Dead Load

The ETABS software program can directly (automatically) calculate the dead load or self-load on a structure, including columns, beams, floor slabs, and roof slabs.

b. Super Imposed Dead Load (SIDL)

The additional dead load on this building, which refers to SNI 1727:2020, is determined as follows.

- Floor Slab

Sand Load	= 0.16 kN/m2
Specimen Load	= 0.63 kN/m2
Ceramic Load	= 0.24 kN/m2
Mechanical, Electrical, and Ceiling Load	= 0.25 kN/m2
Total	= 1.28 kN/m2

- Roof Slab

Mechanical, Electrical, and Ceiling Load	= 0.25 kN/m2
Total	= 0.25 kN/m2

c. Live Load

Live load is determined based on applicable standards regarding the functional category of each room in the building to ensure the building structure complies with the provisions.

- Walls on Floor 1	= 5.8 kN/m2
- Walls on Floor 2, 4-22, ME	= 4.2 kN/m2
- Walls on Floor 3, 23-24 MEZZ, Roof	= 5 kN/m2
Total	= 15 kN/m2

d. Rainwater Load

- Rainwater

Total = 0.5 kN/m2

e. Earthquake Load

The results of the soil investigation at the Pegadaian Tower construction site assumed a site class of SF (special soil) according to the SNI 1726:2019 classification. The building's function as an office building places it in earthquake risk category II with an earthquake severity factor (Ie) of 1. The earthquake acceleration values on the bedrock of the Central Jakarta area, based on official data from the National Seismic Information System, are SS = 0.7806 and S1 = 0.3823. With an amplification coefficient of Fa = 1.2755 and Fv = 2.4708, the spectral response parameters are obtained as SMS = 0.995 and SM1 = 0.944.

Based on these parameters, the design acceleration values are determined as SDS = 0.6638 g and SD1 = 0.6297 g. Because it meets the requirements of $0.50 < SDS$ and $0.20 < SD1$, the structure falls into Seismic Design Category D. This indicates that the building must be designed with a structural system capable of withstanding significant deformations due to strong earthquakes.

The structural system applied to this building is a Special Moment Resisting Frame System (SRPMK) with an earthquake reduction factor of R = 8, a displacement factor of Cd = 5.5, and an overstrength factor of $\Omega_0 = 3$. The characteristics of the design spectrum response curve obtained include periods T0 = 0.18 seconds, Ts = 0.94 seconds, and TL = 20 seconds, which serve as the basis for evaluating the structure's dynamic response to earthquake loads.

f. Load Combination

(1) 1,4 DL + 1,4 SIDL
(2) 1,2 DL + 1,2 SIDL + 1,6 LL + 0,5 (Lr atau R)
(2.1) 1,2 DL + 1,2 SIDL + 1,6 LL + 0,5 Lr
(2.2) 1,2 DL + 1,2 SIDL + 1,6 LL + 0,5
(3) 1,2 DL + 1,2 SIDL + 1,6 (Lr atau R) + (L atau 0,5 W)
(3.1) 1,2 DL + 1,2 SIDL + 1 LL +1,6 Lr
(3.2) 1,2 DL + 1,2 SIDL + 1 LL +1,6 R

(6) 1,2 DL +Ev +Eh + L
(6.1) 1,33 DL + 1,33 SIDL + 1 LL + 1,3 Ex + 0,39 Ey
(6.2) 1,33 DL + 1,33 SIDL + 1 LL + 1,3 Ex - 0,39 Ey
(6.3) 1,33 DL + 1,33 SIDL + 1 LL - 1,3 Ex + 0,39 Ey
(6.4) 1,33 DL + 1,33 SIDL + 1 LL - 1,3 Ex - 0,39 Ey
(6.5) 1,33 DL + 1,33 SIDL + 1 LL + 0,39 Ex + 1,3 Ey
(6.6) 1,33 DL + 1,33 SIDL + 1 LL + 0,39 Ex - 1,3 Ey
(6.7) 1,33 DL + 1,33 SIDL + 1 LL - 0,39 Ex + 1,3 Ey
(6.8) 1,33 DL + 1,33 SIDL + 1 LL - 0,39 Ex - 1,3 Ey
(7.1) 0,64 DL + 0,64 SIDL + 1,3 Ex + 0,39 Ey
(7.2) 0,64 DL + 0,64 SIDL + 1,3 Ex - 0,39 Ey
(7.3) 0,64 DL + 0,64 SIDL - 1,3 Ex + 0,39 Ey
(7.4) 0,64 DL + 0,64 SIDL - 1,3 Ex - 0,39 Ey
(7.5) 0,64 DL + 0,64 SIDL + 0,39 Ex + 1,3 Ey
(7.6) 0,64 DL + 0,64 SIDL + 0,39 Ex - 1,3 Ey
(7.7) 0,64 DL + 0,64 SIDL - 0,39 Ex + 1,3 Ey
(7.8) 0,64 DL + 0,64 SIDL - 0,39 Ex - 1,3 Ey
(Service) 1 DL + 1 SIDL + 1 LL
(Service Atap) 1 DL + 1 SIDL + 1 Lr + 1 R

2.3. Structural Performance Level

The level of structural damage and response of a building after an earthquake is analyzed based on performance-based design. The structural performance level can be determined by the maximum total drift value based on the Applied Technology Council (ATC-40), which classifies it into four categories.

$$\text{Maximum Total Drift} = \frac{\Delta}{H}$$

$$\text{Maximum Inelastic Drift} = \frac{\Delta t - \Delta 1}{H}$$

Keterangan:
Δ = Maximum deflection
H = Height of the portal structure

Tabel 2. Structural Performance Levels based on ATC-40

	Structural Performance Levels			
Inter-Story Deviation Limits	Immediate Occupancy	Damage Control	Life Safety	Structural Stability
Maximum Total Deviation	0.01	0.01 - 0.02	0.02	$0.33 \frac{Vi}{Pi}$
Maximum Inelastic Deviation	0.005	0.005 - 0.15	No Limit	No Limit

3. Result and Discussion

3.1. Effective Seismic Weight

The effective seismic weight of a structure (W) is regulated based on SNI 1726:2019, including all dead loads (DL) and additional dead loads (SIDL).

Tabel 3. Effective Seismic Weight

Floor	**Mass (kg)**
Roof	481378.4
ME Floor	449386.66
24th Mezz Floor	380849.49
24th Floor	622753.53

Floor	Mass
	(kg)
23th Floor	1476200.8
22th Floor	1485179.1
21th Floor	1435972.5
20th Floor	1446681.7
19th Floor	1402781.9
18th Floor	1402781.9
17th Floor	1402781.9
16th Floor	1402781.9
15th Floor	1389167.1
14th Floor	1389167.1
13th Floor	1389167.1
12th Floor	1389167.1
11th Floor	1403323.8
10th Floor	1403323.8
9th Floor	1403323.8
8th Floor	1403323.8
7th Floor	1360366.7
6th Floor	1360366.7
5th Floor	1360366.7
4th Floor	1360366.7
3rd Floor	1406509.8
2nd Floor	1575653.2
Ground Floor (Longue Room)	1411224.5

3.2. Response Spectrum Analysis

Response spectrum analysis is a dynamic method for calculating the maximum response of a structure to an earthquake by utilizing the acceleration spectrum curve. According to SNI 1726:2019, this method is mandatory for buildings with medium to high seismic design categories. The results are used to determine seismic forces, displacements, and the design of structural elements to ensure safety against earthquake loads.

Shape and Number of Varieties

Tabel. 4 Modal Participating Mass Ratio

Case	Mode	Period	UX	UY	RZ	SumUX	SumUY
		sec					
Modal	1	4.362	0.6302	0.0855	2.12E-05	0.6302	0.0855
Modal	2	3.721	0.0929	0.5766	0.0024	0.723	0.6621
Modal	3	3.584	0.0003	0.0011	0.6948	0.7233	0.6632
Modal	4	1.203	0.1089	0.0021	2.70E-05	0.8323	0.6653
Modal	5	0.965	0.0006	0.0396	0.0083	0.8329	0.7049
Modal	6	0.944	0.0001	0.0007	0.1101	0.8329	0.7056
Modal	7	0.827	0.0361	0.002	0.0001	0.869	0.7076
Modal	8	0.723	0.0022	0.088	0.0148	0.8712	0.7956
Modal	9	0.596	0.0007	0.0585	0.0283	0.8719	0.8541
Modal	10	0.509	0.0001	0	0	0.872	0.8541
Modal	11	0.466	0.042	0.0008	1.87E-06	0.914	0.8549
Modal	12	0.44	0	7.86E-06	3.41E-06	0.914	0.855
Modal	13	0.369	0.0001	0.0091	0.0342	0.9141	0.864
Modal	14	0.356	0.0001	0.0008	0.0215	0.9142	0.8648
Modal	15	0.335	0.001	9.21E-06	0.0001	0.9152	0.8648
Modal	16	0.301	0.0131	0.0004	5.45E-06	0.9282	0.8652
Modal	17	0.275	0.0009	0.0524	0.0006	0.9291	0.9176
Modal	18	0.251	0.0075	0.0003	0.0007	0.9367	0.9179
Modal	19	0.248	0.0085	0.0005	0.0001	0.9451	0.9184
Modal	20	0.227	0.0001	4.25E-05	0.0303	0.9452	0.9184

Fundamental Period and Seismic Base Shear

Seismic Response Coefficient, C_s $= S_{DS}/(R/I_e)$
$= 0.083$
Upper Boundary, $C_{s,\,max} = S_{DS}/(T.(R/I_e))$
$C_{s,\,max}$, x = 0.018
$C_{s,\,max}$, y = 0.0212
Lower Boundary, $C_{s,\,min} = 0.44 \times S_{DS} \times I_e \geq 0.01$
$C_{s,\,min}$, 1 = 0.0292
Used Seismic Response Coefficient, $C_s > C_{smax}$, maka $C_s = C_{smax}$
$C_{s\,pakai}$, x= 0.0292
$C_{s\,pakai}$, y= 0.0292
Effective Seismic Weight, W = 337293 kN
Seismic Base Shear Force V $= C_s \times W$
V_x = 9851.11 kN
V_y = 9851.11 kN
Seismic Base Shear Force (ETABS) V_x = 10040.17 kN
V_y = 10040.17 kN
Initial Scale Factor SF = g/(R/I)
$= 1225.83$ mm/s^2
Static Base Shear Force V_x = 10040.17 kN
V_y = 10040.17 kN
Basic Shear Force of various combinations $V_{i,\,x}$ = 4108.382 kN
$V_{i,\,y}$ = 5132.081 kN
Earthquake Force Scaling f $= V/V_i$
f_x = 1.962
f_y = 1.57
New Scale Factor S_{fx} = SF awal x f_x
$= 2404.65$ mm/s^2
S_{fy} = SF awal x f_y
$= 1924.99$ mm/s^2

Tabel. 5 Base Reaction before and after scaling of Response Spectrum Method

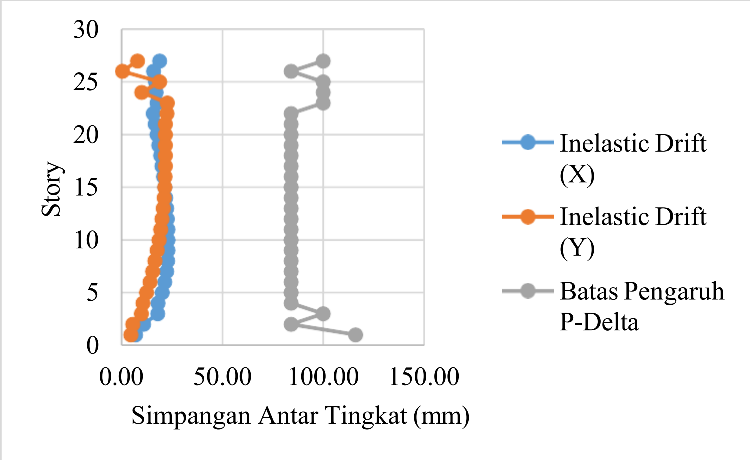
Output Case	***Step Type***	**Vx**	**Vy**
Statik Ex	1	-10040.1701	1.89E-05
Statik Ex	2	-10040.1701	1.77E-05
Statik Ex	3	-10040.1701	2.00E-05
Statik Ey	1	1.20E-05	-10040.17
Statik Ey	2	1.20E-05	-10040.17
Statik Ey	3	1.21E-05	-10040.17
Scale X		10040.1859	3766.4383
Scale Y		3015.1422	10040.1776
Unscaled X		4108.3816	1541.2031
Unscaled Y		1541.2031	5132.0808

Inter-Story Drift Using the Response Spectrum Method

According to SNI 1726:2019, the design inter-story drift (Δ) must not exceed the permissible inter-story drift limit (Δa). The Pegadaian Tower building structure uses a dual system consisting of SRPMK and shear walls and is classified as a risk category II office building.

Permissible Inter-Story Drift Δ_a = 0.02 h
Redundancy Factor ρ = 1
Story Drift Inelastic Permissible $\Delta_{max} = \Delta/\rho$
= 0.02 h
Deflection Magnification Factor C_d = 5.5
Earthquake Priority Factor I_e = 1

Story Drift Inelastic $\Delta = \frac{Cd \cdot \delta}{I_e}$



Gambar 2. Inter-Level Deviation Graph of Response Spectrum Analysis Method

Tabel 6. Inter-Level Deviation Analysis of Response Spectrum Method

Story	***Displacement***		***Elastic Drift***		***h***	***Inelastic Drift***		***Drift Limit***	***Cek***
	δeX	***δeY***	***δeX***	***δeY***		***ΔX***	***ΔY***		
	(mm)	**(mm)**	**(mm)**	**(mm)**	**(mm)**	**(mm)**	**(mm)**	**(mm)**	
27	93.224	80.017	3.430	1.448	5000	18.865	7.964	100.0	OK
26	89.794	78.569	2.869	0.065	4200	15.780	0.357	84.0	OK
25	86.925	78.504	3.060	3.424	5000	16.830	18.832	100.0	OK
24	83.865	75.08	3.110	1.805	5000	17.105	9.927	100.0	OK
23	80.755	73.275	3.187	4.127	5000	17.529	22.699	100.0	OK
22	77.568	69.148	2.852	4.089	4200	15.686	22.490	84.0	OK
21	74.716	65.059	3.024	3.953	4200	16.632	21.742	84.0	OK
20	71.692	61.106	3.194	3.943	4200	17.567	21.687	84.0	OK
19	68.498	57.163	3.354	3.959	4200	18.447	21.775	84.0	OK
18	65.144	53.204	3.505	3.962	4200	19.278	21.791	84.0	OK
17	61.639	49.242	3.644	3.951	4200	20.042	21.731	84.0	OK
16	57.995	45.291	3.774	3.926	4200	20.757	21.593	84.0	OK
15	54.221	41.365	3.891	3.884	4200	21.401	21.362	84.0	OK
14	50.33	37.481	3.990	3.823	4200	21.945	21.027	84.0	OK
13	46.34	33.658	4.069	3.743	4200	22.380	20.587	84.0	OK
12	42.271	29.915	4.130	3.643	4200	22.715	20.037	84.0	OK
11	38.141	26.272	4.169	3.519	4200	22.930	19.355	84.0	OK
10	33.972	22.753	4.189	3.378	4200	23.040	18.579	84.0	OK
9	29.783	19.375	4.183	3.211	4200	23.007	17.661	84.0	OK
8	25.6	16.164	4.153	3.004	4200	22.842	16.522	84.0	OK
7	21.447	13.16	4.069	2.804	4200	22.380	15.422	84.0	OK
6	17.378	10.356	3.906	2.551	4200	21.483	14.031	84.0	OK
5	13.472	7.805	3.656	2.260	4200	20.108	12.430	84.0	OK
4	9.816	5.545	3.299	1.937	4200	18.145	10.654	84.0	OK
3	6.517	3.608	3.267	1.789	5000	17.969	9.840	100.0	OK
2	3.25	1.819	1.985	0.996	4200	10.918	5.478	84.0	OK
1	1.265	0.823	1.265	0.823	5800	6.958	4.527	116.0	OK

3.3. Time History Analysis

Time history analysis is a dynamic analysis method that utilizes earthquake load data based on historical ground acceleration (accelerograms) recorded from earthquake events at locations with characteristics similar to the building site under review. Referring to SNI 1726:2019, this analysis requires at least three pairs of accelerograms from three different earthquake events to minimize uncertainty in site conditions. Given the limited historical ground acceleration data in Indonesia, accelerograms with characteristics that approximate the conditions at the design site are used.

Ground Motion Recording Selection

$T < T0$ = PGA
$T0 < T < T_S$ = 0.2 s
$T > T_S$ = 3 s

The vibration period used is as follows:
T_{C}, X = 4.362 s
T_{C}, Y = 3.721 s
T0 = 0.1897 s
T_S = 0.9487 s

Since the T value is > TS, a 3-second return period is used. At the DKI Jakarta location, the return period is 1000 years and the response spectrum acceleration are 3 seconds.

Tabel 7. Earthquake Summary Data Parameters

Source	Magnitude	Distance (km)
	3 second	3 second
Shallow Crustal	5.2-5.4	40-50
Benioff	7.2-7.4	120-150
Megathrust	8.2-8.4	150-200

The site class used is SE (Soft Soil), so the VS30 value used, based on SNI 1726:2019, is 0–175 m/s. The following data is obtained from the earthquake website.

Tabel 8. Earthquake Recording Data

RSN	Earthquake Name	Station	Year	Magnitude (SR)	R (km)	Vs30 (m/s)
4027638	Geiyo	Hiroshima	2001	5.2	56.56	129.3
4030913	Miyagi	Kakuda	2005	7.22	120.44	137.3
4022861	Tokachi	Shinshinotsu	2003	8.29	171.96	127.7

Spectral Matching

According to SNI 1726:2019 article 7.9.2.3.1, matching is performed in the range of 0.8 Tlower to 1.2 Tupper, with 5% damping. The average acceleration value of the adjusted recordings must not differ by more than 10% from the target spectrum. This process aims to ensure that the structure's response to the modeled earthquake represents the design earthquake conditions while reducing uncertainty due to differences in earthquake source characteristics and ground conditions.

The following are the T_{lower} and T_{upper} values
T_{lower} = 0.275 detik
T_{upper} = 4.362 detik
0.8 T_{lower} = 0.22 detik
1.2 T_{upper} = 5.2344 detik

Notes:
T_{lower} : The period of vibration of the structure when 90% mass participation in both orthogonal directions is achieved.
T_{upper} : The initial period of vibration that is greater than the two orthogonal direction period values.

Tabel 9. Percentage of Spectral Matching Results for Earthquakes

Source	Spectral Matching	
	Mean	Max
Shallow Crustal	2.1%	6.5%
Benioff	2.5%	8.5%
Megathrust	2.1%	7.7%

Base Shear Force Scaling

Tabel 10. Shear Value Input in ETABS

TH Arah X	U1	100% × g (m/s^2)	9.8	9800	mm/s^2
	U2	30% × g (m/s^2)	2.94	2940	mm/s^2
TH Arah y	U1	30% × g (m/s^2)	2.94	2940	mm/s^2
	U2	100% × g (m/s^2)	9.8	9800	mm/s^2

Earning ETABS Output for Shear at Each Seismic Source.

Tabel 11. ETABS Output for Static Shear

Output Case	Case Type	Step Type	FX	FY
			kN	kN
Hiroshima X	LinModHist	Max	47938.51	19690.32
Hiroshima Y	LinModHist	Max	17373.73	37137.58
Kakuda X	LinModHist	Max	36143.41	17634.34
Kakuda Y	LinModHist	Max	107826.4	56351.33
Shinshinotsu X	LinModHist	Max	39393.87	16399.38
Shinshinotsu Y	LinModHist	Max	19855.34	35080.59

Referring to SNI 1726:2019 Article 7.9.2.5.1, after obtaining the elastic shear value, the next step is to calculate the inelastic shear value

$$V_{IX,\,IY} = \frac{V_E \; x \; I_e}{R}$$

Notes:

$V_{IX,\,IY}$ = Inelastic shear force in the x and y directions
V_E = Elastic shear force in the x and y directions
R = Response modification coefficient
I_e = Earthquake priority factor

The inelastic shear force in the x and y directions is

$$V_{IX} = \frac{47938.5143 \text{ x } 1}{8} = 5992.31 \text{ kN}$$

$$V_{IY} = \frac{37137.5822 \text{ x } 1}{8} = 4642.20 \text{ kN}$$

The inelastic shear force value is known to be smaller than the equivalent static shear force calculated in sub-chapter 4, which is 9851.11 kN. Therefore, a new scale factor is required, referring to the formula listed in SNI 1726:2019, article 7.9.2.5.2.

$$\eta_x = \frac{V_x}{V_{IX}} \geq 1.0$$

So, the new scale factor is obtained as follows.

$\eta_x = \frac{V_x}{V_{IX}} \geq 1.0$

$\eta_x = \frac{9851.11}{5992.31} \geq 1.0$

$\eta_x = 1.644$ m/s^2

$\eta_y = 2.122$ m/s^2

Tabel 12. New Scale Factors in ETABS

Hiroshima X	U1	(100% × g (m/s2)) × ηX	2.01E+00	2013.85	mm/s2
	U2	((30% × g (m/s2)) × ηY	7.80E-01	779.864	mm/s2
Hisroshima Y	U1	((30% × g (m/s2)) × ηX	6.04E-01	604.154	mm/s2
	U2	(100% × g (m/s2)) × ηY	2.60E+00	2599.55	mm/s2
Kakuda X	U1	(100% × g (m/s2)) × ηX	2.67E+00	2671.05	mm/s2
	U2	((30% × g (m/s2)) × ηY	5.14E-01	513.959	mm/s2
Kakuda Y	U1	((30% × g (m/s2)) × ηX	8.01E-01	801.315	mm/s2
	U2	(100% × g (m/s2)) × ηY	1.71E+00	1713.2	mm/s2
Shinshinotsu X	U1	(100% × g (m/s2)) × ηX	2.45E+00	2450.66	mm/s2
	U2	((30% × g (m/s2)) × ηY	8.26E-01	825.592	mm/s2
Shinshinotsu Y	U1	((30% × g (m/s2)) × ηX	7.35E-01	735.197	mm/s2
	U2	(100% × g (m/s2)) × ηY	2.75E+00	2751.97	mm/s2

Then the results of the inelastic shear values are obtained at each earthquake source.

Tabel 13. Inelastic Shear Force in ETABS

Output Case	Case Type	Step Type	FX	FY	FX, FY ≥ Vstatik
			kN	kN	
Hiroshima X	LinModHist	Max	9866.512	4529.8392	OKE
Hiroshima Y	LinModHist	Max	4388.8923	9879.0323	OKE
Kakuda X	LinModHist	Max	10018.3854	3783.1263	OKE
Kakuda Y	LinModHist	Max	3787.7236	10088.4255	OKE
Shinshinotsu X	LinModHist	Max	9929.0252	4165.5123	OKE
Shinshinotsu Y	LinModHist	Max	5242.2737	9912.4436	OKE

Inter-Story Drift

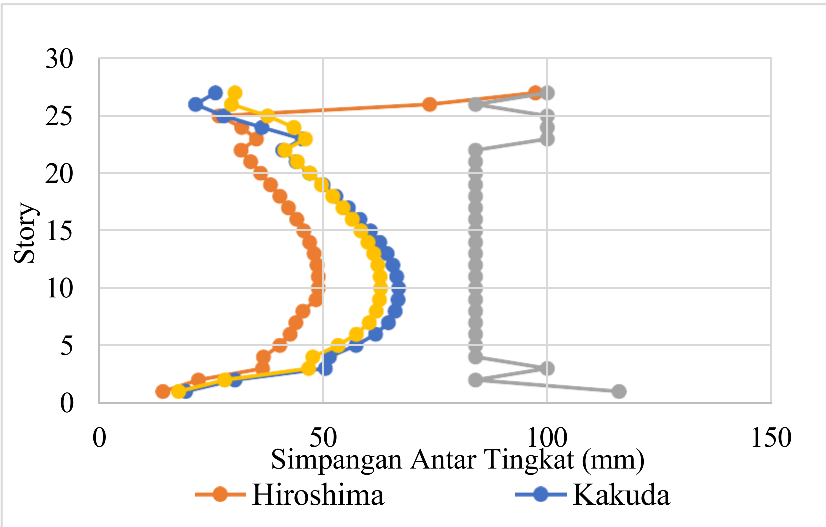
Displacement values are obtained from the analysis using ETABS software. The following are the parameters for calculating inter-story drift.

Allowable Inter-Story Drift	Δ_a	= 0.02 h
Redundancy Factor	ρ	= 1
Deflection Magnification Factor	C_d	= 5.5
Earthquake Priority Factor I_e		= 1
Inelastic Story Drift, Allowable Story Drift Inelastic	Δ_{max} Δ	= Δ_a/ ρ = $\frac{Cd\ S}{Ie}$

Tabel 14. Inter-Story Deviation in X Direction Time History Method

Story	h	Inter-Story Deviation X (mm)			Drift Limit	Check
	(mm)	Hiroshima	Kakuda	Shinshinotsu	(mm)	
Roof	5000	97.3225	25.927	30.3435	100.00	OK
ME	4200	73.7715	21.4885	29.5515	84.00	OK
24 Mezz	5000	26.752	27.8355	37.5705	100.00	OK
24	5000	31.8175	36.2945	43.45	100.00	OK
23	5000	35.134	45.331	46.057	100.00	OK
22	4200	31.669	40.9475	41.481	84.00	OK

Story	*h*	Inter-Story Deviation X (mm)			Drift Limit	Check
	(mm)	Hiroshima	Kakuda	Shinshinotsu	(mm)	
21	4200	33.836	43.956	44.253	84.00	OK
20	4200	36.058	46.9865	47.003	84.00	OK
19	4200	38.236	49.94	49.6155	84.00	OK
18	4200	40.315	52.833	52.074	84.00	OK
17	4200	42.273	55.5885	54.362	84.00	OK
16	4200	44.077	58.1955	56.4905	84.00	OK
15	4200	45.672	60.5605	58.41	84.00	OK
14	4200	46.97	62.5955	59.9995	84.00	OK
13	4200	47.9655	64.284	61.27	84.00	OK
12	4200	48.609	65.571	62.1555	84.00	OK
11	4200	48.906	66.3905	62.6725	84.00	OK
10	4200	48.862	66.8085	62.832	84.00	OK
9	4200	48.411	66.6875	62.5405	84.00	OK
8	4200	45.4795	66.077	61.798	84.00	OK
7	4200	43.8955	64.5425	60.225	84.00	OK
6	4200	42.6305	61.6495	57.4255	84.00	OK
5	4200	40.3205	57.354	53.317	84.00	OK
4	4200	36.663	51.3975	47.696	84.00	OK
3	5000	36.4925	50.468	46.7445	100.00	OK
2	4200	22.198	30.294	28.061	84.00	OK
GF (LR)	5800	14.2615	19.2885	17.7485	116.00	OK



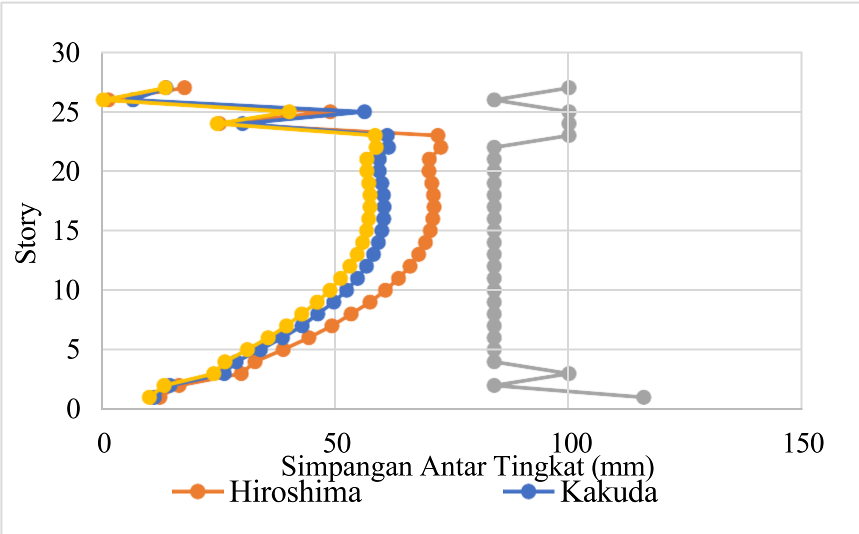
Gambar 3. Inter-Level Deviation Graph in X Direction Time History Method

Based on the graph 3, the deviation value between levels in the x direction at Pegadaian Tower using the time history method does not exceed the permitted deviation value, so the building structure is declared safe.

Tabel. 15. Inter-level Deviation in the Y Direction Time History Method

Story	*h*	Inter-Story Deviation Y (mm)			Drift Limit	Check
	(mm)	Hiroshima	Kakuda	Shinshinotsu	(mm)	
27	5000	17.512	13.5135	13.3925	100.00	OK
26	4200	1.1275	6.435	0.055	84.00	OK
25	5000	48.6915	56.023	39.9135	100.00	OK

Story	*h*	Inter-Story Deviation Y (mm)			Drift Limit	Check
	(mm)	Hiroshima	Kakuda	Shinshinotsu	(mm)	
24	5000	24.959	29.931	24.475	100.00	OK
23	5000	71.7805	60.929	58.3165	100.00	OK
22	4200	72.4185	61.2205	58.5145	84.00	OK
21	4200	69.894	59.191	56.5345	84.00	OK
20	4200	69.8775	59.224	56.5235	84.00	OK
19	4200	70.455	59.741	56.936	84.00	OK
18	4200	70.84	60.0985	57.1945	84.00	OK
17	4200	70.9225	60.236	57.2055	84.00	OK
16	4200	70.6805	60.137	56.9745	84.00	OK
15	4200	70.092	59.763	56.4795	84.00	OK
14	4200	69.0965	59.0315	55.627	84.00	OK
13	4200	67.6775	57.948	54.45	84.00	OK
12	4200	65.791	56.4685	52.8935	84.00	OK
11	4200	63.3435	54.5105	50.9135	84.00	OK
10	4200	60.5275	52.2115	48.6145	84.00	OK
9	4200	57.1945	49.467	45.903	84.00	OK
8	4200	53.1355	46.0405	42.5975	84.00	OK
7	4200	49.0765	42.669	39.336	84.00	OK
6	4200	44.1155	38.456	35.3595	84.00	OK
5	4200	38.61	33.737	30.9265	84.00	OK
4	4200	32.593	28.556	26.1085	84.00	OK
3	5000	29.656	26.0095	23.7325	100.00	OK
2	4200	16.3185	14.3275	13.09	84.00	OK
1	5800	12.1825	10.9725	9.9385	116.00	OK



Gambar 4. Inter-Level Deviation Graph Y Direction Time History Method

Based on graph 4, the deviation value between levels in the y direction at Pegadaian Tower using the time history method does not exceed the permitted deviation value, so the building structure is declared safe.

4. CONCLUSION

Based on the results of the final project research entitled "Analysis of Structural Performance Due to Dynamic Earthquake Loads at Pegadaian Tower in Central Jakarta," the following conclusions were obtained:

1. The maximum drift between stories in Pegadaian Tower due to dynamic earthquake loads, based on the response spectrum method, was 23.0395 mm in the X direction and 22.6985 mm in the Y direction. Meanwhile, the maximum displacement between stories in the X direction was 93.224 mm and, in the Y, direction was 80.017 mm.
2. The maximum drift between stories in Pegadaian Tower due to dynamic earthquake loads, based on the time history method, indicated that the Hiroshima earthquake produced 97.323 mm in the X direction and 72.419 mm in the Y direction. The maximum displacement between stories in the X direction was 208.836 mm and, in the Y, direction was 252.057 mm. The Kakuda earthquake source produced a maximum inter-story drift of 66.8085 mm in the X direction and 61.2205 mm in the Y direction, while the maximum inter-story displacement in the X direction was 247.144 mm and, in the Y, direction was 218.905 mm. Meanwhile, the Shinshinotsu earthquake source produced a maximum inter-story drift of 62.832 mm in the X direction and 58.5145 mm in the Y direction, while the maximum inter-story displacement in the X direction was 242.754 mm and, in the Y, direction was 203.981 mm.
3. The performance level of the Pegadaian Tower structure, based on ATC-40, indicates that when subjected to response spectrum, equivalent static, and all three-time history earthquake loads, the structure falls into the Immediate Occupancy (IO) performance category.

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