

# Structural Performance Analysis Due to Dynamic Earthquake Loads on the Pasar Baru Heritage Building Bandung

Tio Chandra Muharram<sup>1\*</sup>, Budi Kudwadi<sup>1</sup>, Istiqomah<sup>1</sup>

<sup>1</sup>Civil Engineering Study Program, Indonesia University of Education

\*Corresponding Author: Tio Chandra Muharram. Email: [tiochandramuharram10@upi.edu](mailto:tiochandramuharram10@upi.edu)

## Abstract

The Pasar Baru Heritage Building is located in the city of Bandung. The city of Bandung is one of the earthquake-prone areas in Indonesia, so it is necessary to plan a structure that is able to withstand earthquake loads. The building has 17 floors and 1 basement floor with a total height of 61.9 meters. The analysis method carried out was analysis with the spectrum response method and the time history method. The analysis was carried out using ETABS software with reference to SNI 1726:2019 for earthquake loading. The purpose of this study is to determine the maximum deviation value that occurs and to determine the level of structural performance that occurs based on ATC-40. The results of the study showed that the maximum drift that occurred due to the shock load of the spectrum response earthquake was 57.7 mm for the X direction and 55.64 mm for the Y direction. The Tohoku earthquake was 51.90 mm in the X direction and 45.88 mm in the Y direction. The structural performance level that occurred based on the ATC-40 was at the Immediate Occupancy (*IO*) performance level which indicates that the Pasar Baru Heritage Building remains functional and safe to occupy immediately, or can be reused in a very short time with minimal repairs and does not interfere with the main functionality of the building.

Keywords: earthquake, spectrum response, time history, ATC-40.

## 1. INTRODUCTION

As a country located in the Pacific Ring of Fire Region, Indonesia is one of the countries that has high seismic activity. This condition makes Indonesia prone to earthquakes which can cause significant damage to infrastructure. As a center of economic and social activity, buildings designed especially in urban areas must be able to withstand earthquake loads to minimize the impact of losses both in terms of material and life safety.

The city of Bandung is one of the areas in Indonesia that has a fairly high risk of earthquakes. This is because in the Bandung City area there are active faults, including the Lembang Fault, Cimandiri Fault, Garsela Fault. Given the large number of earthquake activities, the development of earthquake analysis on structures continues to increase. This building has 17 floors and 1 basement floor with a total height of 61.9 meters above the ground. This building is located on Jl. Otto Iskandar Dinata No.84, Andir District, Bandung City. Performance analysis due to earthquake loading is necessary to create safety and comfort for users and visitors to the building.

The load of earthquakes on structures is divided into two, namely static analysis and dynamic analysis. In the analysis with dynamic earthquakes, the analysis of the spectrum response method and the time history method (time history) was used. The spectrum response method is an analysis of the dynamic response of building structures to soil movement, while the time history method is an analysis based on earthquake acceleration recordings. In the analysis of the spectrum response, soil acceleration data in the reviewed location was used, while in the time history analysis, earthquake data from different locations was used that could represent earthquakes that occurred in time with the location of the building being reviewed. In analyzing the performance of the structure, the things reviewed are the impact that occurs on the structure due to the earthquake and to determine whether the structure can perform its function properly after experiencing an earthquake. One of the standard concepts that is a reference in making earthquake building structure planning is ATC-40. There are 6 categories of structural performance levels according to ATC-40 with several considerations of damage conditions.

Based on the above background, the author will examine the performance of the Pasar Baru Heritage Building with the title of the final project "Structural Performance Analysis Due to Dynamic Earthquake Loads on the Pasar Baru Heritage Building Bandung". The author will analyze the behavior of the building structure to dynamic earthquake loads with spectrum response and time history with the help of ETABS18 software to obtain the maximum deviation value that occurs and also to determine the level of structural performance based on ATC-

40. This study aims to evaluate the performance of the building structure of the Pasar Baru Heritage Building on earthquake load by analyzing the behavior of base *shear*, *displacement*, and the influence of the P-Delta effect. The evaluation was carried out through simulation using ETABS structure analysis software version 21, with a dynamic analysis approach in the form of spectrum response and time *history analysis*.

### 1.1 Earthquake

Earthquakes are a natural phenomenon that is difficult to predict when and where they will occur. The impact of an earthquake can be very detrimental even if it occurs in a short time. Earthquakes can be interpreted as vibrations that occur on the earth's surface due to a sudden release of energy from within that creates a seismic wave (Sholeh, 2022).

### 1.2 Effects of Earthquake Force on Buildings

The force of the earthquake occurs due to the influence of vibrations that occur on the earth's surface due to the sudden release of energy from the inside. The tremors cause seismic waves and cause damage to the buildings above. This earthquake gives rise to irregular/random forces in all directions in the building. The force produced is a dynamic force called an earthquake force. The force of the earthquake is directly proportional to the mass of the building and the acceleration of the earthquake on the ground level. (Simanjuntak, 2020).

$$F = m \cdot a \dots \dots \dots (1)$$

### 1.3 Earthquake Resistant Buildings

Based on SNI 1726-2019 concerning Earthquake Resilience Planning Procedures for Building and Non-Building Structures, the requirements for earthquake-resistant building planning for buildings and non-buildings, namely the structure must have a lateral or vertical force bearing system, rigidity, strength and ability to absorb sufficient energy to withstand seismic ground design styles.

### 1.4 Spectrum Response Analysis

Spectrum response analysis is a way of analyzing the relationship between the period of the building structure and the value of the building's acceleration when exposed to an earthquake (Zhafira et al., 2023). The spectrum response can be interpreted as the acceleration of the ground that affects a system with a degree of freedom (SDOF). Through this analysis, the aspect of earthquake movement which is the main parameter in calculating the response of a system can be determined directly (Nasution, 2016)

### 1.5 Time History Analysis

Historical dynamic analysis is a method used to determine the acceleration of the ground level in an area based on multiple earthquake recordings. This method can be applied to building structures with linear and non-linear behavior to earthquakes. Because this analysis evaluates structural responses based on earthquake records over time, it is considered more comprehensive than other methods (Arga Rumbyarso, 2024).

### 1.6 ATC-40 Structure Performance

ATC-40 (Applied Technology Council Report 40) is a guide used in the evaluation and improvement of building structures against earthquake loads with a performance-based approach (Performance-Based Seismic Design). This document provides a method for assessing the capacity of structures in dealing with earthquakes as well as determining the expected level of performance. According to ATC-40 (Applied Technology Council 40), the performance of structures in the face of earthquakes is classified into several levels based on the response of the structure to earthquake loads. There are several levels of structural performance, namely Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP).

## 2. METHOD

### 2.1. Analysis Methods and Techniques

The research method applied in this study is a quantitative descriptive method. This method will describe an event that occurs in the form of numbers and data interpretation. Analysis of the performance of the structure to the earthquake load was carried out using the spectrum response method and the time history method using ETABS software version 18. The structure of the Heritage Baru Market Building is modeled in three dimensions by incorporating material quality and structural elements such as plates, columns, and beams. The concrete slab in this model is assumed to be a rigid diaphragm that functions to channel the load to other structural elements and is perfectly clamped to the beam. After the modeling is completed, an analysis of *the drift* and displacement that occurs is carried out and then continues to analyze the level of structure performance based on ATC-40.

### 2.2. Project Data

The data used in this study is secondary data in the form of DED (detail engineering design) drawings as a reference in structural modeling in ETABS v.18.0.2 software.

Table 1: Building Description

Building Description	Information
Building Name	Pasar Baru Heritage Building
Building Location	Jalan Otto Iskandar Dinata No.84, Andir District, Bandung City, West Java.
Building Structure System	SRPMK + Shear Wall
Building Function	Shops and Hotels
Number of Floors	17 Floors + 1 Basement
Concrete Quality	$F_c' 33.2$ Mpa and $F_c' 37.35$ Mpa
BJ 420B Steel Reinforcement	$F_Y 420$ Mpa, $F_U 525$ Mpa
Soil Site Class	Soft Soil (SE)
Category Earthquake Risk	(II)

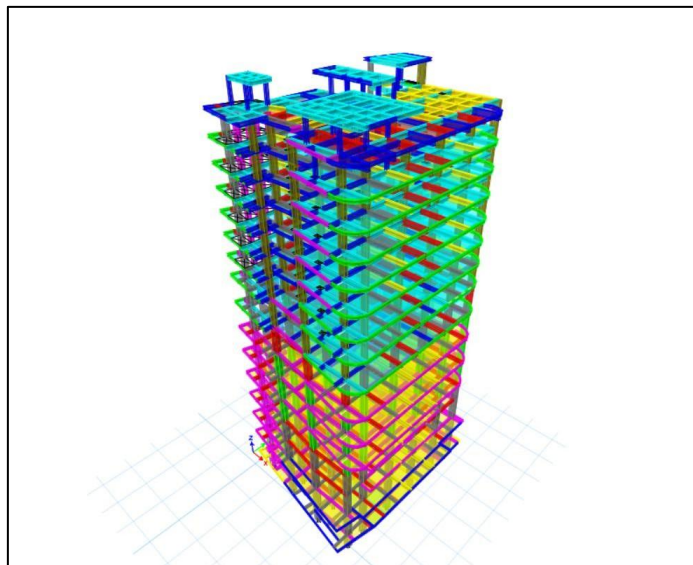


Fig 1. 3D modeling of the structure of the Pasar Baru Heritage Building using Etabs 21

## 2.2. Flowchart

The stages of the research carried out can be seen in the flowchart. The flowchart is presented in Figure 2.

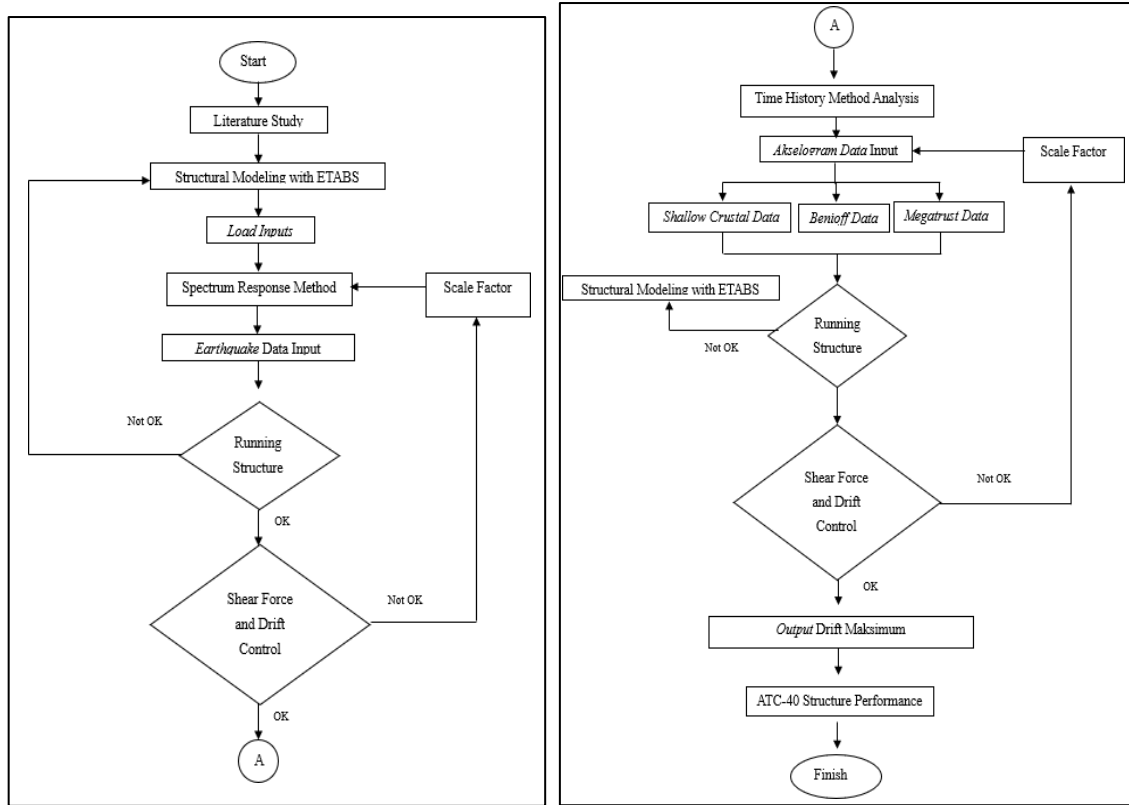


Fig 2. Research Flow Diagram

### 3. RESULT AND DISCUSSION

#### 3.1 Response Spectrum Method Dynamic Analysis

Spectrum Response Method analysis requires several stages such as determining the period of structure and structure variety, checking for irregularities, checking the seismic base shear force, scaling forces, checking the deviation between levels and checking the influence of P-Delta. There are several parameters required, namely:  $SS = 1.1209$ ,  $S1 = 0.4928$  g,  $SDS = 0.7497$ g,  $SD1 = 0.7525$  g, risk category I, classification of SE sites (soft soils),

The structure of the Pasar Baru Heritage Building uses a dual system with a special moment bearer capable of withstanding at least 25% of the set seismic force. The earthquake parameters used were, earthquake priority factor ( $i_e$ ) = 1, response modification coefficient ( $r$ ) = 7, system strength factor ( $\Omega_0$ ) = 2.5, deflection enlargement factor ( $C_d$ ) = 5.5.

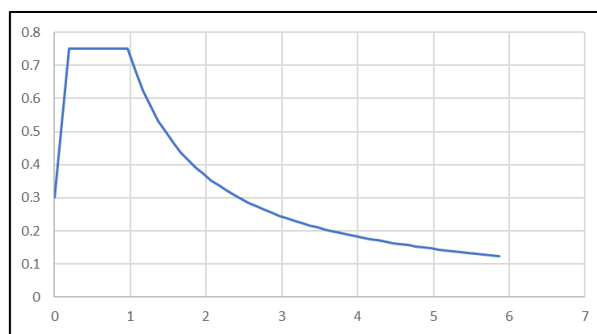


Fig 3. Spectrum Response Graph

The seismic base shear force is the structural response of a building that generates a shear force at the bottom or bottom during an earthquake. The shear coefficient of the seismic base ( $V$ ) in the set direction should be determined according to the following formulation:

$$V = C_s \cdot W \dots\dots\dots (2)$$

Information:

$C_s$  = Specified Seismic Response Coefficient  
 $I_n$  = Effective Seismic Weight

The value of the base shear force obtained must be greater than or equal to the value of the static base shear force. If it is not yet met, it is necessary to magnify the scale factor (Damara & Handayani, 2024). Thus the value of the dynamic basic shear force ( $V_{dynamic}$ ) is qualified as in Table 2.

Table 2: Dynamic Base Shear Force (Impact of Earthquake Load Response Spectrum)

Earthquake	Axis	Unscaled (kN)		FS	SF (mm/s <sup>2</sup> )	Scaled (kN)	
		V static	V dynamic			V static	V dynamic
Spectrum Response	X	3825.266	2557.597	1.495649	2095.33	3825.266	3825.286
	Y	3129.141	2012.853	1.55458	2177.89	3129.141	3129.157

### 3.2. Time History

In the analysis of the time history method, data on land movement recordings derived from real events that have occurred are needed. The data used must represent the soil movements that occur at the research site. The data used is earthquake data that has similar characteristics such as similarity in magnitude (M) and distance (R). Based on SNI 1726:2019, the soil acceleration history data used for analysis was no less than three pairs of orthogonal components.

Table 3: Time History Data

RSN	Event	Location	Year	M	R (km)	Vs30 (m/s)
3934	Tottori, Japan	Japan	2000	6,61	16,61	138,76
4030913	Miyagi-Eq	Japan	2005	7.22	120,45	137.3
4000715	Tohoku	Japan	2011	9,12	180,82	135,5

Based on SNI 1726:2019, each component of the soil acceleration history data used must be spectral matched in the range of 0.8 Tlower to 1.2 Tupper.

Tlower = 0.238 seconds      0.8 Tlower = 0.1904 seconds  
Tupper = 3.059 seconds      1.2 Tupper = 3.6708 seconds

Scaling of the seismic base shear force should be performed if the value of the dynamic base shear force is smaller than the static seismic base shear force value (Purba, 2014). The following is the recapitulation value of force scaling in earthquake time history analysis, which can be seen in Table 4 as follows.

Table 4. Dynamic Basic Shear Force (Due to Earthquake Load Time History)

Earthquake	Axis	Unscaled (kN)		FS	SF (mm/s <sup>2</sup> )	Scaled (kN)	
		V static	V dynamic			V static	V dynamic
Tottori	X	3825.266	2584.8485	1.47988	2073.24	3825.266	3825.2879
	Y	3129.1408	2083.4197	1.501925	2104.12	3129.141	3129.1523
Miyagi	X	3825.266	2898.8668	1.319573	1848.66	3825.266	3825.2957
	Y	3129.1408	1879.9907	1.664445	2331.80	3129.141	3129.1488
Tohoku	X	3825.266	2507.0611	1.525797	2137.57	3825.266	3825.2926
	Y	3129.1408	2200.8537	1.421785	1991.85	3129.141	3129.1572

### 3.3. Displacement

Displacement occurs if there is a degree of freedom experienced by the building structure (Pranata, Bunyamin, & Hady, 2023). Displacement in the structure is caused by beams that experience deflection which if the value

exceeds the permit limit, it can cause instability in the building structure. The transfer value is obtained directly from the ETAB program. The following is a recapitulation of the value of the displacement of the X direction that occurs due to dynamic earthquakes presented in Table 5.

Table 5. X Directional Displacement

Floor	H(mm)	Directional Displacement X (mm)			
		Spectrum Response	Tottori	Miyagi	Tohoku
17	3000	118.775	110.37	97.581	101.514
16	3000	112.37	107.838	94.392	98.842
15	3000	108.157	104.806	91.868	96.108
14	3000	103.785	100.507	88.938	92.469
13	3000	98.399	95.061	85.107	87.908
12	3000	92.113	88.55	80.31	82.475
11	3000	84.831	81.098	74.421	76.197
10	3000	76.947	73.49	67.86	69.626
9	4250	69.498	66.274	61.173	62.77
8	4250	59.007	56.404	51.84	53.371
7	4250	48.604	46.5	42.529	43.935
6	4250	38.266	36.651	33.309	34.57
5	4250	28.419	27.224	24.56	25.621
4	4250	19.349	18.657	16.655	17.551
3	4250	11.604	11.211	9.91	10.528
2	5000	5.498	5.244	4.605	4.893
1	3150	0.961	0.917	0.792	0.852

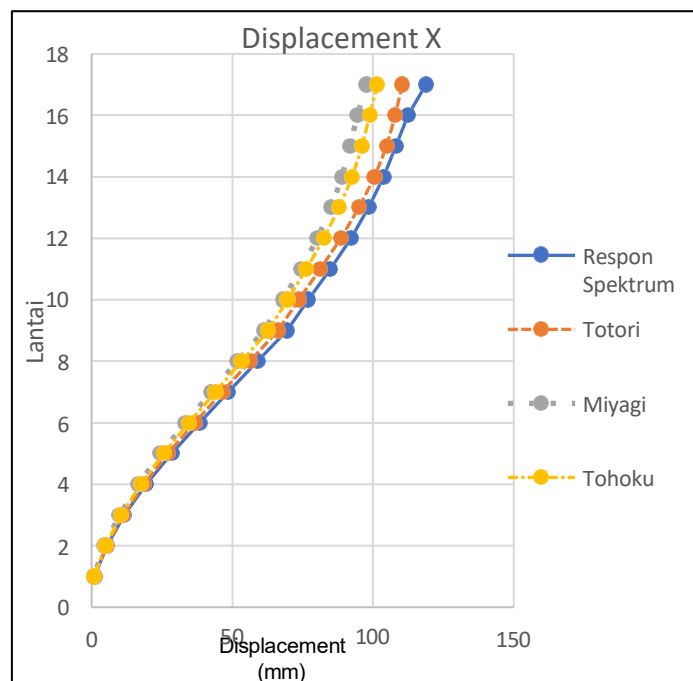


Fig 4. X Directional Displacement

In Figure 4. it can be seen that the maximum displacement in the X direction occurs on the 17th floor. The maximum displacement value due to the spectrum response earthquake was 118.775 mm, the Totori earthquake was 110.37 mm, the Miyagi earthquake was 97,581 mm, and the Tohoku earthquake was 101,514 mm.

Table 6. Y Directional Displacement

Floor	H(mm)	Directional Displacement Y (mm)			
		Spectrum Response	Tottori	Miyagi	Tohoku
17	3000	101.008	95.134	77.445	101.901
16	3000	101.839	94.487	77.238	100.467
15	3000	97.731	90.168	73.431	96.55
14	3000	93.943	84.78	68.918	90.991
13	3000	88.802	77.523	62.841	83.472
12	3000	83.527	69.693	56.412	75.131
11	3000	77.758	61.905	52.289	67.222
10	3000	71.836	56.974	49.396	60.489
9	4250	63.683	50.404	43.498	53.305
8	4250	55.074	43.815	37.311	46.104
7	4250	47.156	37.918	31.892	39.678
6	4250	39.074	31.778	26.681	33.02
5	4250	30.484	24.979	20.981	25.915
4	4250	20.368	16.451	13.887	17.705
3	4250	12.638	10.19	8.663	11.062
2	5000	6.704	5.489	4.659	5.798
1	3150	1.18	0.937	0.822	1.046

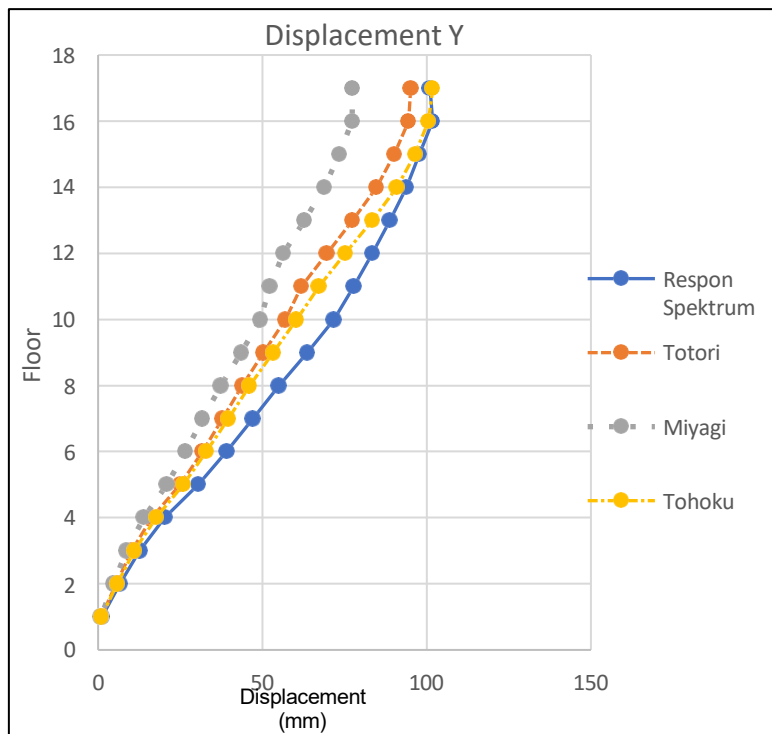


Fig. 5. Y Directional Displacement

In Figure 5. it can be seen that the maximum displacement in the Y direction occurs on the 17th floor (roof floor 2). The maximum displacement value due to the spectrum response earthquake was 101,839 mm, the Totori earthquake was 95,134 mm, the Miyagi earthquake was 77,445 mm, and the Tohoku earthquake was 101,901 mm.

### 3.4. Story Drift

The Story Drift can be obtained from the displacement value obtained from the output of the ETAB program. The calculated drift value should not exceed the permit deviation value (Anam, Sutriyono, & Trimutiningrum, 2020).

The following are the parameters used in the calculation.

$$D_{max} = D/r \dots\dots\dots (3)$$

$$\Delta a = 0.02 h \dots\dots\dots (4)$$

$$\delta = D_{\text{floor } i} - D_{\text{floor } i-1} \dots\dots\dots (5)$$

$$D = \delta * cd / ie \dots\dots\dots (6)$$

Information:

$\Delta_{max}$  = deviation between permission levels

$\rho$  = reduction factor

$\delta$  = elastic drift

The results of the recapitulation of the calculation of the Story Drift value of x can be seen in table 7.

Table 7. Directional Displacement X Response Spectrum, and Time History

Story	H(mm)	Drift X (mm)				Drift Limit	Cheque
		Spectrum Response	Tottori	Miyagi	Tohoku		
17	3000	35.23	13.93	17.54	14.70	46.15	OK
16	3000	23.17	16.68	13.88	15.04	46.15	OK
15	3000	24.05	23.64	16.12	20.01	46.15	OK
14	3000	29.62	29.95	21.07	25.09	46.15	OK
13	3000	34.57	35.81	26.38	29.88	46.15	OK
12	3000	40.05	40.99	32.39	34.53	46.15	OK
11	3000	43.36	41.84	36.09	36.14	46.15	OK
10	3000	40.97	39.69	36.78	37.71	46.15	OK
9	4250	57.70	54.29	51.33	51.69	65.38	OK
8	4250	57.22	54.47	51.21	51.90	65.38	OK
7	4250	56.86	54.17	50.71	51.51	65.38	OK
6	4250	54.16	51.85	48.12	49.22	65.38	OK
5	4250	49.89	47.12	43.48	44.39	65.38	OK
4	4250	42.60	40.95	37.10	38.63	65.38	OK
3	4250	33.58	32.82	29.18	30.99	65.38	OK
2	5000	24.95	23.80	20.97	22.23	76.92	OK
1	3150	5.29	5.04	4.36	4.69	48.46	OK

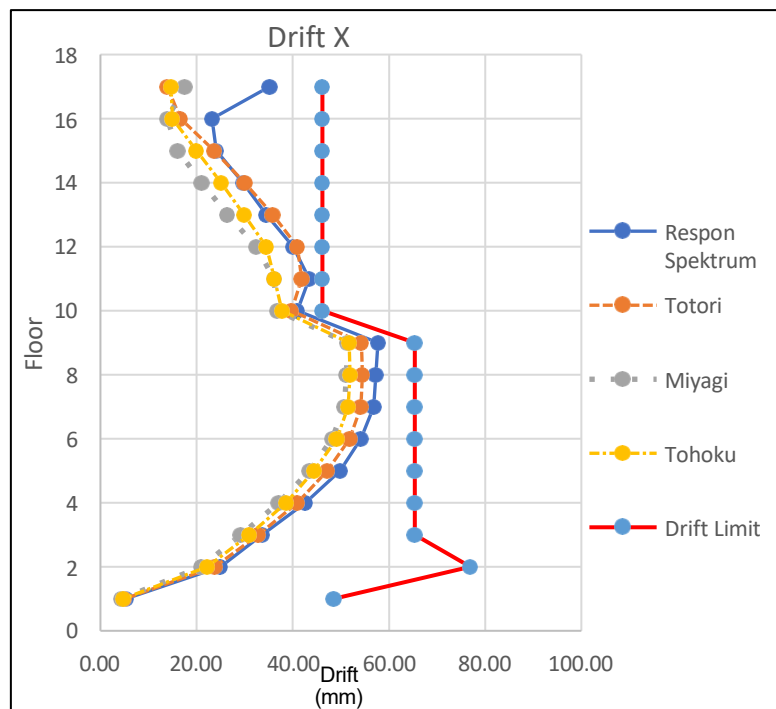


Fig 6. Drift X

The results obtained showed that the maximum drift value that occurred in the X direction occurred due to the earthquake load of the spectrum response, which was 57.7 mm. The maximum drift value that occurs in each earthquake still meets the requirements so that it can be declared safe.

The results of the recapitulation of the calculation of the story drift value of Y can be seen in table 8

Table 8. Directional Displacement Y Response Spectrums and Time History

Story	H(mm)	Drift Y (mm)				Drift Limit	Cheque
		Spectrum Response	Tottori	Miyagi	Tohoku		
17	3000	4.57	3.56	1.14	7.89	46.15	OK
16	3000	22.59	23.75	20.94	21.54	46.15	OK
15	3000	20.83	29.63	24.82	30.57	46.15	OK
14	3000	28.28	39.91	33.42	41.35	46.15	OK
13	3000	29.01	43.07	35.36	45.88	46.15	OK
12	3000	31.73	42.83	22.68	43.50	46.15	OK
11	3000	32.57	27.12	15.91	37.03	46.15	OK
10	3000	44.84	36.14	32.44	39.51	46.15	OK
9	4250	47.35	36.24	34.03	39.61	65.38	OK
8	4250	43.55	32.43	29.80	35.34	65.38	OK
7	4250	44.45	33.77	28.66	36.62	65.38	OK
6	4250	47.25	37.39	31.35	39.08	65.38	OK
5	4250	55.64	46.90	39.02	45.16	65.38	OK
4	4250	42.52	34.44	28.73	36.54	65.38	OK
3	4250	32.64	25.86	22.02	28.95	65.38	OK
2	5000	30.38	25.04	21.10	26.14	76.92	OK
1	3150	6.49	5.15	4.52	5.75	48.46	OK

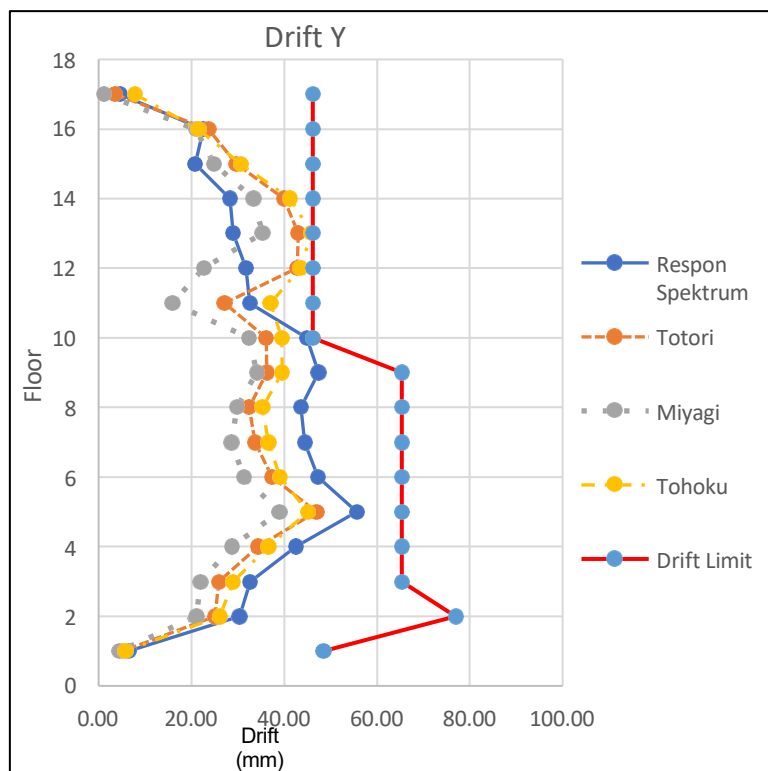


Fig 7. Drift Y

The results obtained showed that the maximum drift value that occurred in the Y direction occurred due to the earthquake load of the spectrum response, which was 55.63 mm. The maximum drift value that occurs in each earthquake still meets the requirements so that it can be declared safe.

### 3.4. Structural Performance

The level of performance of the structure is obtained based on the values of the maximum total displacement and the maximum inelastic displacement. The assessment of the structure performance level is used to determine the category of structures in the Pasar Baru Heritage Building. The following is a recapitulation of the results of the calculation of the performance of the structure that occurred.

Table 9. X Directional Structure Performance Level

Earthquake	Displacement Target (m) [DT]	First Displacement (m) [D1]	Maximum Total Displacement	Structural Performance Level	Maximum Inelastic Displacement	Structural Performance Level
Spectrum Response	0.118775	0.000961	0.001918821	IO	0.0019033	IO
Tottori	0.11037	0.000917	0.001783037	IO	0.00176822	IO
Miyagi	0.097581	0.000792	0.00157643	IO	0.00156363	IO
Tohoku	0.101514	0.000852	0.001639968	IO	0.0016262	IO

Table 10. Y Directional Structure Performance Level

Earthquake	Displacement Target (m) [DT]	First Displacement (m) [D1]	Maximum Total Displacement	Structural Performance Level	Maximum Inelastic Displacement	Structural Performance Level
Spectrum Response	0.101839	0.00118	0.001645218	IO	0.00162616	IO
Tottori	0.095134	0.000937	0.001536898	IO	0.00152176	IO
Miyagi	0.077445	0.000822	0.001251131	IO	0.00123785	IO
Tohoku	0.101901	0.001046	0.00164622	IO	0.00162932	IO

Based on Table 9 and Table 10, the calculation of the maximum total displacement value that occurred was still below 0.01 and the maximum inelastic displacement value that occurred was still below the value of 0.005. Thus, the structure of the Pasar Baru Heritage Building is included in the Immediate Occupancy (IO) level of the structure performance for all earthquakes in the X and Y directions.

## 4. CONCLUSION

The maximum displacement value due to the load of the spectrum response earthquake in the Pasar Baru Heritage Building was 118.775 mm for the X direction and 101.008 mm for the Y direction. The maximum drift value that occurred was 57.7 mm for the X direction and 55.64 mm for the Y direction. The maximum displacement value based on the analysis of the time history method due to the Tottori earthquake at the Pasar Baru Heritage Building was 110.37 mm for the X direction and 95.134 mm for the direction Y with the maximum drift that occurred was 54.47 mm for the X direction and 46.90 mm for the Y direction. The maximum displacement that occurred due to the Miyagi earthquake was 97,581 mm for the X direction and 77,445 mm for the Y direction with the maximum drift that occurred was 51.33 mm for the X direction and 39.02 mm for the Y direction. direction X and 101,901 mm for the Y direction with the maximum deviation between levels (drift) that occurs is 51.90 mm for the X direction and 45.88 mm for the Y direction.

The performance level of the structure was analyzed using ATC-40. In the analysis using the spectrum response method, the performance level value of the Immediate Occupancy (IO) structure was obtained. The results of the analysis using the time history method also show that. The Pasar Baru Heritage Building is at the Immediate Occupancy (IO) performance level.

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