Syntax Literate: Jurnal Ilmiah Indonesia p–ISSN: 2541-0849
e-ISSN: 2548-1398
Vol. 9, No. 4, April 2024

EVALUATION ON EFFECTIVE DIMENSIONS OF BASE ISOLATORS APPLIED AT EXISTING RC BUILDING DUE TO EARTHQUAKES

Jaka Suranto[1], Muhammad Aswin[2*], Nursyamsi[3]
Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia[1,2,3]
Email: muhammad.aswin@usu.ac.id[*]

Abstract

This study investigates the structural performance of High Damper Rubber Bearings (HDRB) as base isolators in reinforced concrete (RC) buildings subjected to seismic loads. Given the potential for damage or collapse in RC buildings during earthquakes, the utilization of base isolators offers a promising solution to mitigate seismic risks. Finite element analysis was employed to assess the displacement efficiency of different HDRB configurations, focusing on the SMP 5 Muhammadiyah building in Surabaya as a case study. Results indicate that HDRB type HH090X6R exhibits superior performance, achieving displacement efficiencies of 90.56% in the x-direction and 95.87% in the y-direction. These findings underscore the importance of selecting optimal base isolator configurations to enhance the seismic resilience of RC structures. The study's implications extend to seismic retrofitting and structural design practices, offering valuable insights for improving the seismic performance of existing buildings and bolstering community resilience to earthquakes.

Keyword: Earthquakes, Response Spectra, Pushover Analysis, Performance Level Structure, Base Isolator

Introduction

Indonesia is a country prone to earthquakes. The cause is the meeting of several tectonic plates that stretch almost throughout the territory of Indonesia. Several earthquakes that have occurred in Indonesia have caused many casualties and major damage to buildings.

The construction of reinforced concrete buildings although designed to be earthquake-resistant, but if exposed to earthquake loads, the building still has the potential to experience damage. Building damage caused by horizontal earthquake loads is more dominant than vertical earthquake loads, so a mechanical device is needed that can dissipate energy from the earthquake. Building damage that occurs due to earthquake force in Indonesia because planning and implementation have not been in accordance with the rules and standards of planning earthquake-resistant buildings (Simanjuntak, 2020). With base isolator can reduce the displacement of reinforced concrete structures by 26% (Wijaya et al., 2020). Using base isolator on reinforced concrete structures, achieving faster performance levels of Immediate Occupancy structures (Wijaya et al., 2019). Using a base insulator on reinforced concrete structure can reduce the base shear force by 12.56% (Syahnandito et al., 2020). Using a base insulator on reinforced concrete structure can reduce displacement by 66% (Cahyani et al., 2021). Flexibility of the base of the building increases by using base isolators (Ravi et al., 2021). Base isolator will

How to cite:	Suranto, J., Aswin, M., & Nursyamsi, N. (2024). Evaluation on Effective Dimensions of Base Isolators Applied at Existing RC Building due to Earthquakes. *Syntax Literate. (9)4.* http://dx.doi.org/10.36418/syntax-literate.v9i4
E-ISSN:	2548-1398
Published by:	Ridwan Institute

make the displacement of the structure will be lower (Gunawan et al., 2020). The level of structural performance in controlling damage due to earthquake loads has arranged in FEMA 440 and ATC-40 (Masrilayanti et al., 2023), and also considered by ASCE 14-13 (Enggartiasto et al., 2023).

To assess the horizontal displacement capacity of several types of base isolators based on the results of analysis of existing building structures due to earthquake loads, the appropriate type of base isolator can be applied in existing buildings. This study investigates the structural performance of High Damper Rubber Bearings (HDRB) as base isolators in reinforced concrete (RC) buildings subjected to seismic loads.

Research Method

Before conducting a study of the base isolator to be used in the existing building, it must first check the structural model, and whether the reliability of the existing building structure has been met. At the stage of checking the existing structure model, namely checking the natural vibration time of the structure, checking shear forces, checking mass participation, checking the deviation limit between levels, checking the influence of P-Delta, checking horizontal irregularities and vertical irregularities, checking the Strong Coloumn-Weak Beam (SC-WB) concept and conducting pushover analysis to determine the level of performance of the structure.

Data from the analysis due to earthquake load was obtained from the results of the running program ETABS V.18.0.2. The regulations used in this analysis refer to the applicable standards in Indonesia, refer to (SNI 1726, 2019), (SNI 1727, 2020) and (SNI 2847, 2019).

Results and Discussion

Before conducting a study of the base isolator to be used, firstly it was evaluated the reliability of structural model of the SMP Muhammadiyah 5 building that located in Surabaya. The building was constructed by a reinforced concrete that having 15 floors, as shown in Fig. 1.

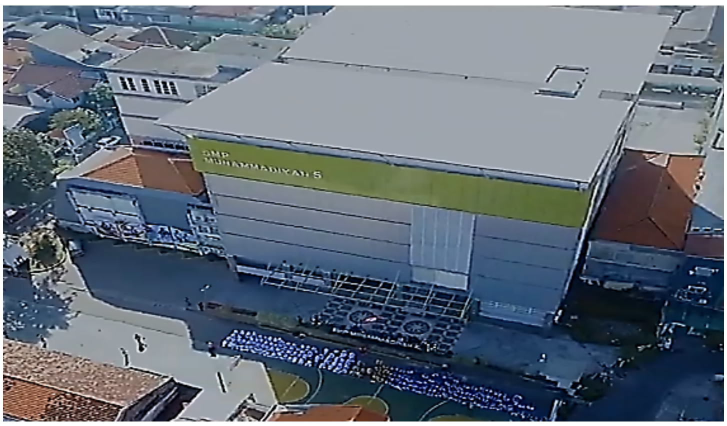

Figure 1. Building of SMP Muhammadiyah 5, Surabaya.
(*Source: google.com*, *2024*)

Structural Models

By using ETABS V.18.0.2, structural analysis was conducted, that involve the fixed base portals for x and y directions without the base isolator, as shown in Fig. 2 and Fig. 3.

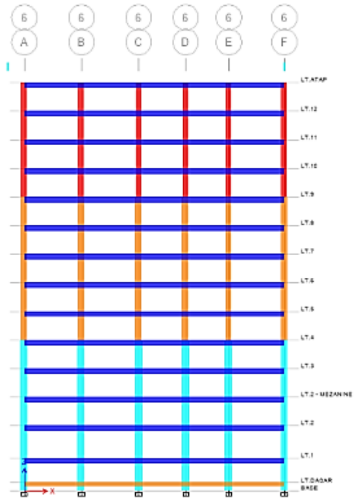

Figure 2. Portal in x-direction without base isolator
(Source: personal data, 2024)

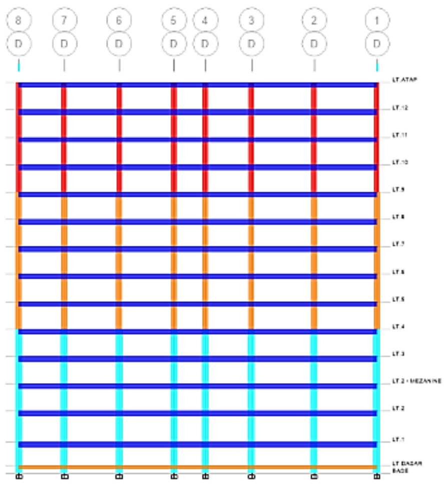

Figure 3. Portal in y-direction without base isolator
(Source: personal data, 2024)

Meanwhile, structural analysis on the fixed base portals for x and y directions with the base isolator, can be seen in Fig. 4 and Fig. 5.

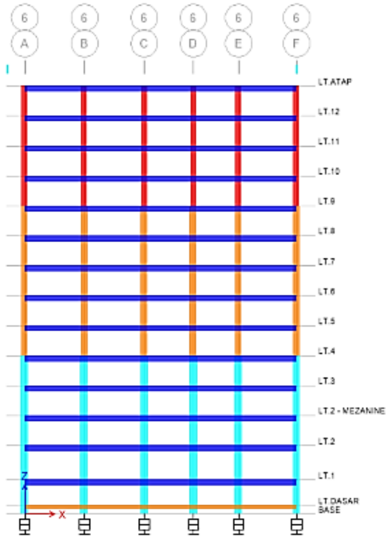

Figure 4. Portal in x-direction with a base isolator

(Source: personal data, 2024)

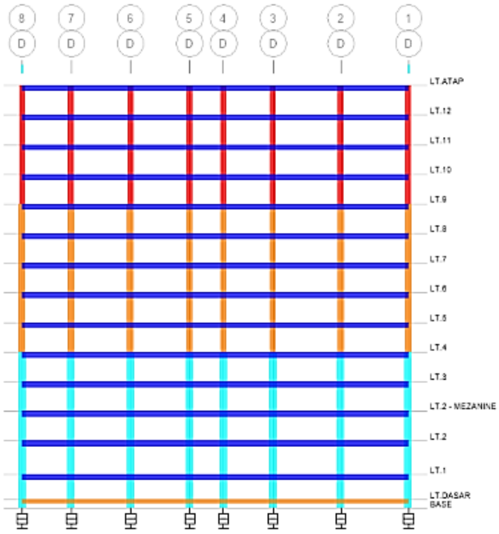

Figure 5. Portal in y-direction with a base isolator

(Source: personal data, 2024)

Checking of The Existing Structures

Design of spectrum response, graph of the response spectrum at the related location is shown in Fig. 6.

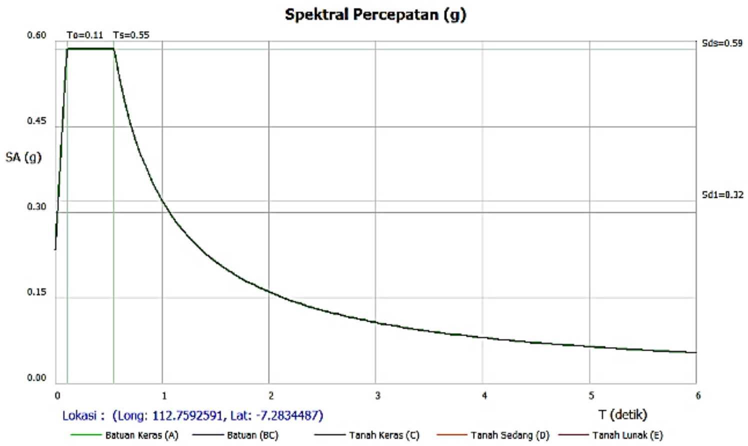

Figure 6. Hard soil (SC) design response curve, Surabaya
(Source: rsa.ciptakarya.go.id, 2024)

Seismic design category, with S_{DS} = 0.5852 g and S_{D1} = 0.3206 g, according to (SNI 1726,2019), the location includes KDS-D. Seismic force-bearing factors, for the category of buildings with special moment-bearing reinforced concrete frames, the value of the response modification coefficient (R) is 8, the stronger factor over the system (Ω_0) is 3 and the deflection magnification factor (C_d) is 5.5 according to (SNI 1726, 2019).Structure period, the period of the x-direction structure is 2.246 seconds, while for the y-direction it is 1.604 seconds. Total capital participation ratio, the sum of the mass ratios of capital participation of the x direction and y direction is 100% in mode 45. Base shear earthquake force, the base shear earthquake force in the x direction was 2544.44 kN and the y direction was 2686.28 kN. Earthquake force scale, the magnitude of the x-direction and y-direction earthquake force is 1.2775. Horizontal and vertical irregularities scale, the building does not have irregularities of torque, inner angles, soft stiffness, and also weight (mass). Interlevel deviation, the maximum deviation between levels in elastic condition (Inelastic drift) that occurs on the top floor is 4.17 mm (x direction) and 3.29 mm (y direction), this value is still smaller than the required 27 mm. Effect of P-Delta, the maximum stability coefficient that occurs on the 4rd floor is in the x direction of 0.0775 and the y direction of 0.0600, this is still smaller than the structure stability limit of 0.0909. Check strong column-weak beam (SC-WB), After checking the SC-WB at three points of the beam-column joint, the nominal moment of the column ≥ 1.2 from the nominal moment of the beam.

Pushover analysis

The results of pushover in the x-direction show that the occurrence of plastic hinges begin at step 3 and ends at step 26 are shown in Fig. 7 and Fig. 8.

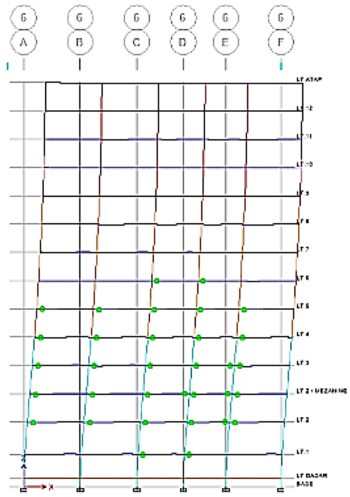

Figure 7. Formation of plastic hinges in the x-direction in step 3
(Source: personal data, 2024)

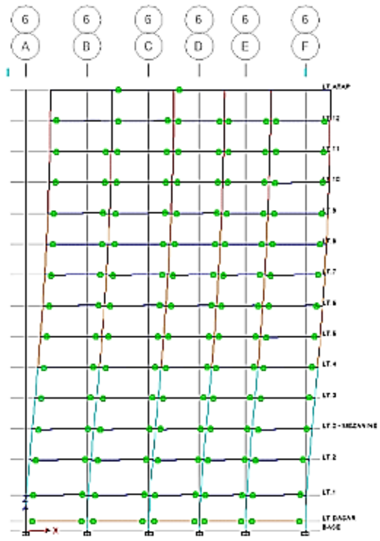

Figure 8. Formation of plastic hinges in the x-direction in step 26
(Source: personal data, 2024)

The results of pushover in the y-direction show that the occurrence of plastic hinges begin at step 2 and ends at step 20, as shown in Fig. 9 and Fig. 10.

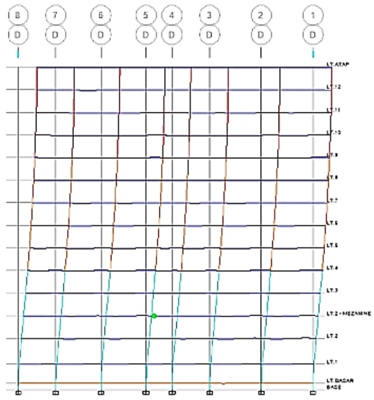

Figure 9. Formation of plastic hinges in the y-direction in step 2
(Source: personal data, 2024)

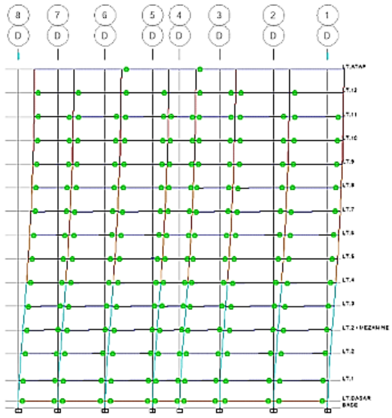

Figure 10. Formation of plastic hinges in the y-direction in step 20
(Source: personal data, 2024)

In addition, performance points are also known based on ASCE 41-13 NSP, as shown in Fig. 11 and Fig. 12.

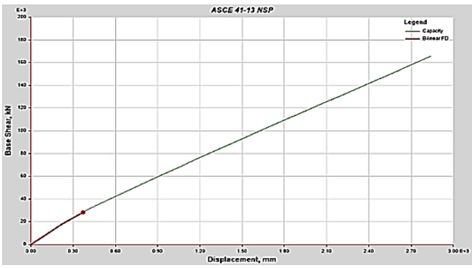

Figure 11. x-directional pushover curves based on ASCE 41-13 NSP
(Source: personal data, 2024)

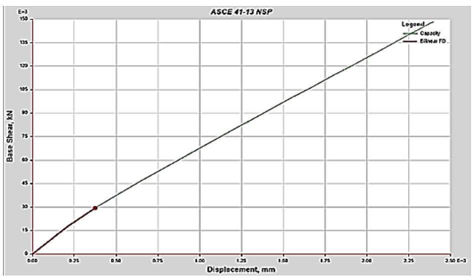

Figure 12. y-directional pushover curves based on ASCE 41-13 NSP
(Source: personal data, 2024)

Based on the results of superposition performance points on the performance of structures (ASCE 14-13, 2013), it is found that the performance level of the structure is included in the Immediate Occupancy (IO) category level, as shown in Fig. 13 and Fig. 14.

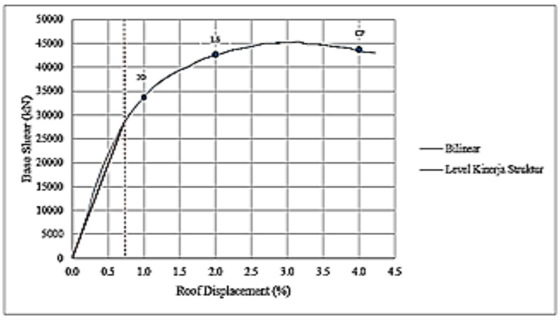

Figure 13. Superposition of performance points of x-directional based on ASCE 41-13 NSP
(Source: personal data, 2024)

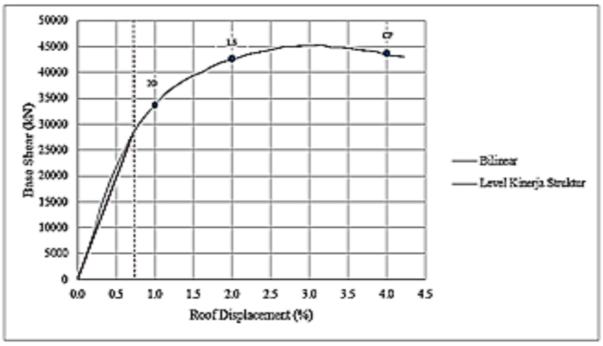

Figure 14. Superposition of performance points of y-directional based on ASCE 41-13 NSP
(Source: personal data, 2024)

Here are the performance points based on FEMA 440, as shown in Fig. 15 and Fig. 16.

Figure 15. x-directional pushover curves based on FEMA 440.
(Source: personal data, 2024)

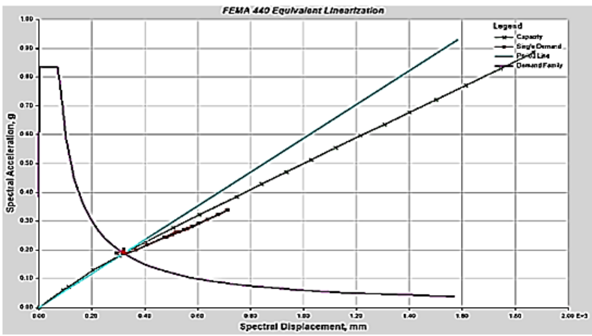

Figure 16. y-directional pushover curves based on FEMA 440
(Source: personal data, 2024)

Based on the results of (FEMA 440, 2005), the ratio of maximum total deviation of the x direction is 0.0078 and the y direction is 0.0080, where this figure shows the level of performance of the structure. So according to (ATC 40, 1996) the structure is included in the Immediate Occupancy (IO) category level.

Sway mechanism behavior

To determine the type of base isolator used, an analysis will be carried out on the displacement that occurs in existing buildings by providing horizontal forces due to earthquake loads. In this study will use the type of base isolator High Damper Rubber Bearing (HDRB) HH Series with a total rubber thickness of 20 cm produced by (Bridgestone, 2017). Based on the results of the analysis, displacement in the x direction and y direction occurred using the HDRB base isolator HH160X6R, as shown in Fig. 17 and Fig. 18.

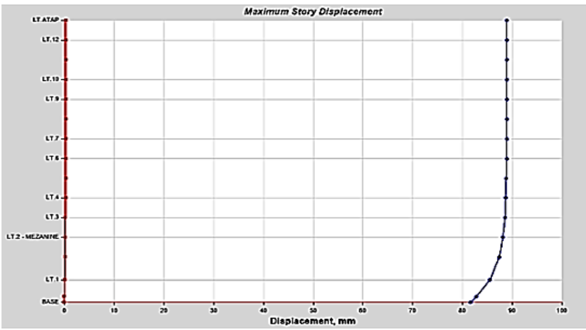

Figure 17. Displacement in the x-directional using base isolator HH160X6R
(Source: personal data, 2024)

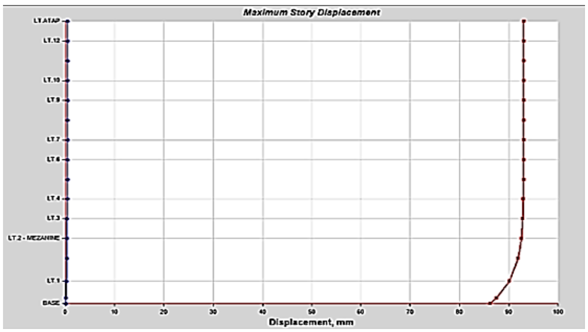

Figure 18. Displacement in the y-directional using base isolator HH160X6R
(Source: personal data, 2024)

After obtaining the displacement that occurs, a check will be made against the displacement limit with 0.7 of the thickness of the base isolator. The following are the results of checking displacement using HDRB base isolator HH160X6R, as shown in Table 1.

Table 1. Result of the displacement check using the HDRB base isolator HH160X6R.

Story	d_x (mm)	d_y (mm)	Displacement limits (mm)
15	88.97	93.11	365
14	88.97	93.10	365
13	88.96	93.09	365

Story	d_x (mm)	d_y (mm)	Displacement limits (mm)
12	88.95	93.09	365
11	88.95	93.08	365
10	88.92	93.07	365
9	88.91	93.06	365
8	88.91	93.04	365
7	88.84	93.01	365
6	88.74	92.94	365
5	88.54	92.79	365
4	88.16	92.52	365
3	87.39	91.88	365
2	85.53	90.14	365
1	82.79	87.48	365

The following are the results of checking displacement using HDRB base isolator HH160X6R, as shown in Table 2.

Table 2. The result of checking the displacement of several types of HDRB base isolator

Type	H (mm)	N (kN)	H_{limit} (mm)	Efficiency of displacement	
				x (%)	y (%)
HH160X6R	522.00	26100	365.40	23.45	25.48
HH150X6R	410.20	22900	287.14	34.54	36.25
HH140X6R	405.50	20000	283.85	39.71	41.71
HH130X6R	376.90	17200	263.83	49.02	51.56
HH120X6R	385.60	14700	269.92	55.95	58.88
HH110X6R	390.20	12300	273.14	65.44	68.91
HH100X6R	400.60	10200	280.42	77.04	81.16
HH095X6R	402.40	8780	281.68	87.25	91.95
HH090X6R	410.80	7280	287.56	90.96	95.87
HH085X6R	413.10	5880	289.17	102.00	107.54

Based on the results of the analysis, it was found that the type of base isolator providing better performance was the HDRB base isolator type HH090X6R with an efficiency displacement in the x- direction of 90.56% and in the y-direction of 95.87%.

Conclussion

Based on the results of the analysis, it was found that the type of base isolator providing better performance was the HDRB base isolator type HH090X6R with an efficiency displacement in the x- direction of 90.56% and in the y-direction of 95.87%.

The results of the analysis showed that the HDRB base isolator type HH090X6R provides better performance, where the displacement efficiency reached 90.56% for the x-direction and 95.87% for the y-direction.

BIBLIOGRAPHY

ASCE. (2013). American Society of Civil Engineers, & Structural Engineering Institute. Seismic evaluation and retrofit of existing buildings.

Cahyani, R. O., & Sitanggang, A. N. (2021). Efek penggunaan base isolator terhadap periode natural bangunan gedung bertingkat yang tereksitasi oleh gempa. Journal of Civil Engineering and Planning, 2(2).

Enggartiasto, L., Mahmud, F., & Wisnuaji Widiatmoko, K. (2023). Evaluasi tingkat kelayakan struktur gedung eksisting 8 lantai di kota semarang Info Artikel. 18(1), 12–22. https://doi.org/10.26623/teknika.v18i1.6469

FEMA. (2005). Improvement of nonlinear static seismic analysis procedures fema 440 fema nehrp.

Gunawan, H. A., & Nirbito, W. (2020). Response performance characteristics of lrb base isolator for cyclotron building due to parts sizing. journal of physics: Conference Series, 1519(1). https://doi.org/10.1088/1742-6596/1519/1/012015

BSN. (2019). Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan non gedung. Badan Standarisasi Nasional Indonesia, SNI 1726.

BSN. (2019). Persyaratan beton struktural untuk bangunan gedung dan penjelasannya. Badan Standarisasi Nasional Indonesia, SNI 1727.

BSN. (2019). Beban desain minimum dan kriteria terkait untuk bangunan gedung dan struktur lain. Badan Standarisasi Nasional Indonesia, SNI 2847.

Masrilayanti, Hasibuan, Y. A., Kurniawan, R., Sunaryati, J., & Aidil Fitrah, R. (2023). Performance evaluation of high-rise apartment building using pushover analysis. E3S Web of Conferences, 429. https://doi.org/10.1051/e3sconf/202342905024

Ravi, K., Agha, W. Al, Thakur, M. S., & Umamaheswari, N. (2021). Impact of the lead rubber base isolators on reinforced concrete building. IOP Conference Series: Materials Science and Engineering, 1026(1), 012004. https://doi.org/10.1088/1757-899x/1026/1/012004

Bridgestone. (2017). Seismic isolation product line-up high damping rubber bearing lead rubber bearing natural rubber bearing elastic sliding bearing.

Simanjuntak, P. (2020). Evaluasi kerusakan bangunan akibat gempa di indonesia.

Syahnandito, Suryanita, R., & Ridwan. (2020). Pengaruh penggunaan base isolation high damping rubber bearing pada struktur beton bertulang. Siklus : Jurnal Teknik Sipil, 6(2), 181–194. https://doi.org/10.31849/siklus.v6i2.4906

ATC. (1996). Seismic evaluation and retrofit of concrete buildings volume 1 applied technology council proposition 122 seismic retrofit practices improvement program.

Wijaya, U., & Soegiarso, R. (2019). Seismic performance evaluation of a base-isolated building. In International Journal of Civil Engineering and Technology (IJCIET) (Vol. 10, Issue 1). https://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=1

Wijaya, U., Soegiarso, R., Tavio, & Wijaya, A. (2020). Numerical study of potential indonesian rubber for elastomeric base isolators in highly-seismic zones. Journal of Physics: Conference Series, 1477(5). https://doi.org/10.1088/1742-6596/1477/5/052044