# Pier Performance Level of Jakarta-Bandung High Speed Railway with Isolator under Earthquake Loads using Time History Analysis

Amirah Zakiyyah[1*], Aris Aryanto[2], Bayu Wintoro[1]

[1]Politeknik Negeri Bandung, Bandung, Indonesia
[2]Institut Teknologi Bandung, Bandung, Indonesia

*E-mail address: amirah.zakiyyah@polban.ac.id

***ABSTRACT***

This study analyzes the performance level of a typical pier structure on the Jakarta-Bandung High-Speed Railway (HSR) bridge located in the Bandung area, focusing on the effects of seismic loads. The structure utilizes double spherical bearings (isolators), and its performance is compared with a similar structure without isolators to evaluate the isolators' effectiveness under design-level earthquakes. A Non-linear Time History Analysis (NLTHA) was conducted using 11 pairs of ground motion records. These motions were scaled to match the target response spectrum for Bandung using amplitude scaling in the DeepSoil program. Structural analysis was carried out using Midas Civil to determine the seismic performance levels of the piers. Additionally, pier displacements were examined to further assess isolator performance. The results show that the structure equipped with isolators maintained a Fully Operational (FO) performance level, indicating minimal damage and full functionality after the earthquake. In contrast, the structure without isolators surpassed the elastic range but remained within the Immediate Occupancy (IO) performance level, suggesting minor damage but continued usability. These findings confirm that the use of isolators significantly enhances the seismic resilience of bridge piers in high-speed railway.

**Keywords:** ***Double spherical bearing*, *performance level*, *pier*, *time history analysis***

## 1. INTRODUCTION

Indonesia is located in a high seismic risk zone, making seismic performance verification of piers particularly vital. Numerical simulations show that incorporating elements dampers or isolators can significantly enhance the seismic resilience of piers, potentially improving their performance from collapse prevention to immediate occupancy under strong ground motion [1]. The knowledge and technology related to seismic-resistant design continue to evolve year by year, making it essential for Indonesia to stay updated and apply the latest advancements in structural engineering to enhance public safety and infrastructure resilience.

The assessment of pier performance levels is a critical component in ensuring the safety, functionality, and durability of the Jakarta–Bandung High-Speed Railway (HSR) bridge infrastructure. Given that bridge piers serve as primary vertical load-bearing elements, any deficiency in their performance can lead to severe structural consequences [2].

The Jakarta–Bandung HSR bridge employs seismic isolation bearings on its piers to mitigate earthquake forces and preserve structural integrity [3]. A base isolation system using sliding bearings—specifically Double Spherical Bearings (DSB)—has been implemented. PT KCIC, the project owner and executor, has collaborated with CRDC (China Railway Design Corporation) as the design consultant for the structural components of the project. All HSR bridge structures have been analyzed and designed by CRDC using Chinese design standards. Furthermore, it is necessary to evaluate the seismic performance of HSR bridge structures [4]. Seismic-resistant structural development in Indonesia has advanced significantly, including the adoption of base isolation systems. The fundamental principle of adding a base isolation system is to reduce seismic forces transmitted to the bridge piers. Such systems effectively dissipate large earthquake forces, minimizing structural damage during seismic events. The use of base isolation systems can significantly elongate the building's natural period, resulting in a significant decrease in the base shear, acceleration response, drift, and the plastic hinge formed [5]. This results in the superstructure behaving like a rigid body under seismic excitation.

Performance-based seismic design is a framework used for both new constructions and the retrofitting of existing buildings. It provides a realistic understanding of potential risks, including life safety, occupancy, and economic loss due to future earthquakes [6]. Therefore, this study is conducted with the objective of determining the performance level of the piers in the KCJB bridge structure to ensure user comfort and safety.

## 2. THEORY AND METHODS

### 2.1 Theory

Time-history dynamic analysis, applies real or synthetic earthquake records to the bridge model to determine peak responses and damage potential under varied seismic scenarios [7]. Numerical models incorporating isolation bearings indicate that piers remain largely elastic after major earthquakes, as sliding in the isolators absorbs energy and protects substructure components [3], [8], [9].

According to FEMA 356 (2006), structural damage levels are categorized into four performance levels:

1. Fully Operational (FO): No significant damage to structural or non-structural components; the building remains fully functional.
2. Immediate Occupancy (IO): No significant damage to structural or non-structural components, no permanent displacement, minimal cracking, and all critical systems operate normally.
3. Life Safety (LS): The structure can withstand seismic loads with minor damage; non-structural components remain safe, although some utility damage may occur.

4. Collapse Prevention (CP): The structure is damaged but does not collapse; stiffness degradation occurs [10].

Comparative studies demonstrate that incorporating seismic isolators considerably reduces shear force and moment demands at the pier base—often by more than 70%—by effectively shifting peak responses into the isolators themselves [1], [2]. In high-speed rail contexts, time-history simulations using realistic ground motions and train–bridge interaction confirm that isolators maintain structural performance even under complex dynamic loading [11], [12], [13].

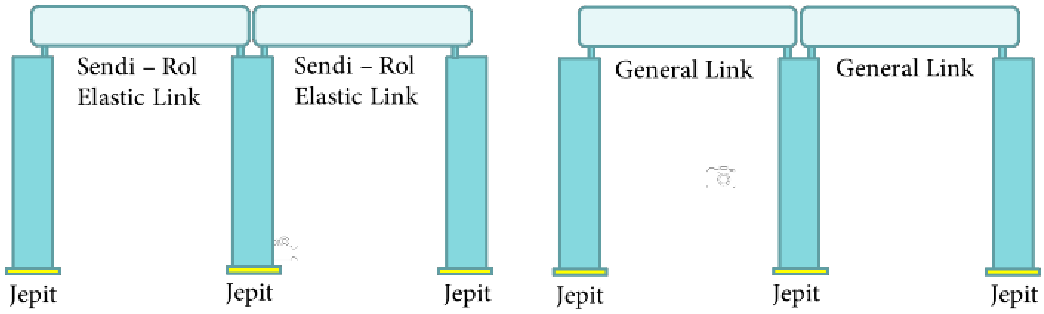
Wiryadi et al. (2022) analyzed the performance level of the Faculty of Tourism building at Udayana University using FEMA 356 and ATC-40. They found that the structure met the Immediate Occupancy (IO) level, indicating safety under seismic loading, with no significant structural or non-structural damage—allowing immediate reoccupation after an earthquake [10].

M. Hasbi et al. (2024) conducted a pushover analysis of a 12-story building. Based on ATC-40, the structure reached the Damage Control (DO) level in the x-x direction and Immediate Occupancy (IO) level in the y-y direction. This indicates the building could withstand seismic events and remain usable, with minimal risk to human life [14].

Further research into site-specific effects—such as soil–structure interaction—and isolator variability under real conditions underscores the importance of sensitivity analyses in time-history modeling to capture realistic pier behavior [12], [15]. Advances in nonlinear viscoelastic isolation models, implemented in finite-element platforms like OpenSees or CSI Bridge, support precise simulation of isolator behavior and pier response under seismic excitation [9], [16], [17].

## 2.2 Methods

The pier—also referred to as a column or bridge support—in the Jakarta–Bandung High-Speed Railway bridge structure represents a typical section in a simply supported bridge configuration. The pier used in this analysis has a height of 18 meters and supports the longest girder span of 32 meters. In this study, structural modeling was carried out using Midas Civil. Two structural models were developed in Midas Civil: one without base isolators and one with base isolators, as shown in Figure 1 and Figure 2, respectively. Both structural models will be analyzed for their seismic performance levels under design-level earthquake loads. The analysis results will then be compared to evaluate the effectiveness of incorporating base isolators.




(a) (b)

**Figure 1.** Model Illustration;
(a) Structure without Isolator; (b) Structure with Isolator

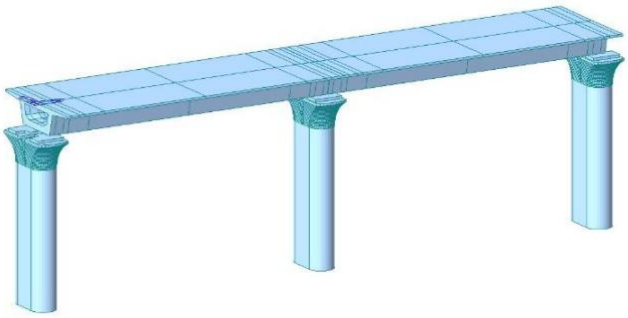


**Figure 2.** 3D Modelling in Midas Civil

The concrete and steel strengths used in this study are based on data from concrete compressive strength tests conducted in the laboratory. The average concrete strength is 52 MPa, and the average steel strength is 585 MPa. For the definition of moment-curvature relationships needed for plastic hinge modeling, Xtract software was used. This software is one of the commonly used cross-section analysis programs that facilitates the analysis process. In the analysis using Xtract, the concrete and steel strengths are based on the previously defined laboratory test data as shown in Figure 3 and Figure 4.

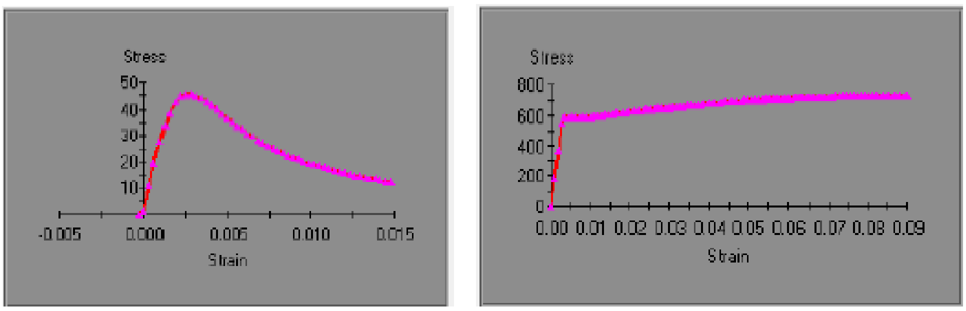



**Figure 3**. Definition of Concrete and Steel Materials of Pier in Xtract Software

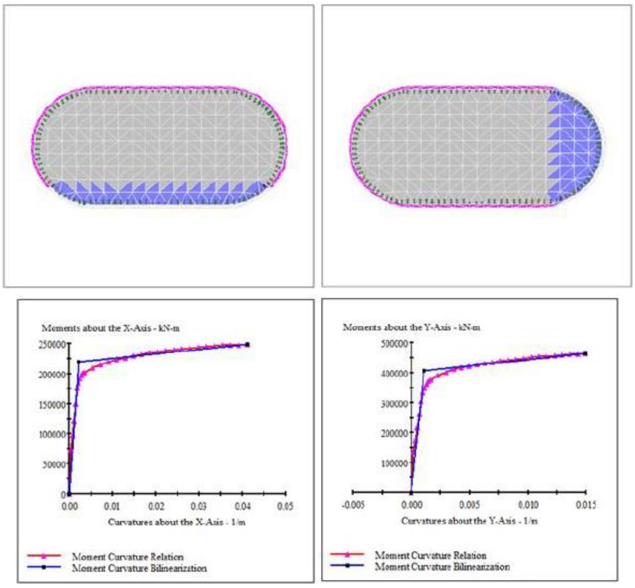



**Figure 4**. Moment-Curvature Definition of Pier in Xtract Software

In this study, Non-Linear Time History Analysis (NLTHA) was conducted using 11 pairs of ground motion time history data obtained from PEER. To obtain accurate results, the time history data were selected to best match the specific geological and seismological conditions of the analysis site. An earthquake deaggregation was carried out to determine the characteristics of the ground motion to be used in the analysis, based on the magnitude and distance of the earthquake source that closely resemble the conditions of the study site, namely the city of Bandung. Subsequently, scaling was performed on the target response spectra using the amplitude scaling method. This scaling method is used because it does not alter the characteristics of the earthquake, with the scaling factor used ranging from 1 to 40 as shown in 2 out of 11 example of ground motion for Hyuganda and Tohoku in Figure 5 and Figure 6.

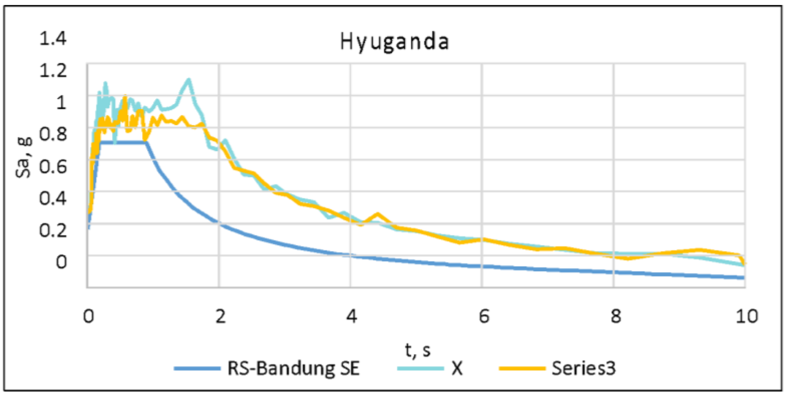



**Figure 5**. Amplitude Scaling – Hyuganda

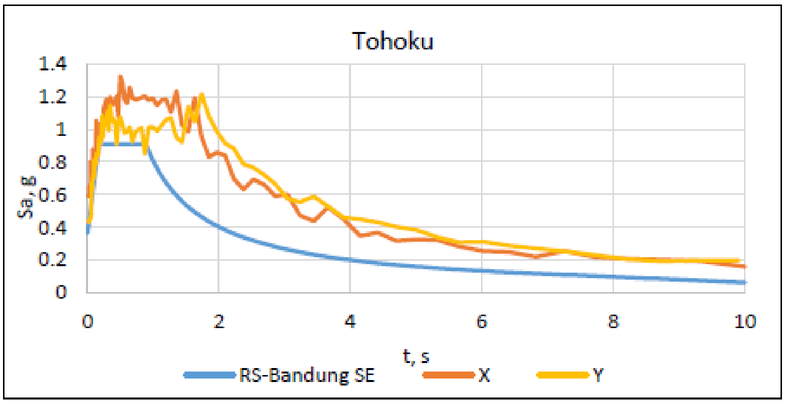



**Figure 6**. Amplitude Scaling – Tohoku

The scaling was carried out by multiplying the Peak Ground Acceleration (PGA) by a certain factor to match the target response spectrum presented in Table 1. The response spectra of the ground motions were obtained using the DeepSoil software, and the scaling was performed for both earthquake directions, namely X and Y.

**Table 1.** Recorded Ground Motion

| No. | Recorded Ground Motion (PEER) | Direction | PGA (g) | Scale | PGA Scaled (g) | Duration (s) |
|---|---|---|---|---|---|---|
| 1 | Kern County | X | 0.042 | 11 | 0.465 | 70.00 |
| | | Y | 0.059 | 13 | 0.767 | |
| 2 | Tabas Iran | X | 0.027 | 35 | 0.940 | 39.98 |
| | | Y | 0.027 | 35 | 0.958 | |
| 3 | Kocaeli Turkey | X | 0.013 | 40 | 0.538 | 180.27 |
| | | Y | 0.013 | 40 | 0.538 | |
| 4 | Hollywood Storage | X | 0.035 | 12 | 0.420 | 78.62 |
| | | Y | 0.059 | 15 | 0.888 | |
| 5 | Tohoku | X | 0.586 | 1 | 0.586 | 240.00 |
| | | Y | 0.432 | 1 | 0.432 | |
| 6 | Hyouguken | X | 0.773 | 1.5 | 1.159 | 30.00 |
| | | Y | 0.781 | 1.5 | 1.172 | |
| 7 | Tokachi | X | 0.548 | 1 | 0.548 | 120.00 |
| | | Y | 0.631 | 1 | 0.631 | |
| 8 | Hyuganda | X | 0.427 | 1.3 | 0.555 | 40.00 |
| | | Y | 0.491 | 1.2 | 0.589 | |
| 9 | Southern Calif | X | 0.050 | 30 | 1.491 | 40.00 |
| | | Y | 0.050 | 25 | 1.243 | |
| 10 | Elcentro | X | 0.245 | 3.5 | 0.857 | 53.46 |
| | | Y | 0.357 | 2 | 0.714 | |
| 11 | Chichi | X | 0.034 | 35 | 1.190 | 60.00 |
| | | Y | 0.034 | 30 | 1.020 | |

Subsequently, a performance evaluation of the piers was conducted (under design earthquake loads) for both types of structures (with and without isolators). Base shear checks on the piers were also performed for both structural types to assess the effectiveness of using isolators on the KCIC Jakarta-Bandung bridge structure. After collecting the time history earthquake data and performing the scaling, a trial earthquake angle analysis was carried out to determine the angle at which the applied seismic load produces the most significant effect on the structure. This trial earthquake angle analysis was conducted at angles of 0º, 30º, 45º, 60º, and 90º, with the results presented in Table 2.

**Table 2.** Summary of Earthquake Trial Angles Based on Corresponding Base Shear Values

| No. | *Motion* | Base Shear (kN) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **0º** | **30º** | **0º** | **45º** | **60º** | **90º** |
| | | X | X | Y | Y | Y | Y |
| 1 | Kern County | 4849.5 | 4351.22 | 4374.97 | 3022.7 | 2578.88 | 2057.12 |
| 2 | Tabas Iran | 4657.43 | 3867.39 | 6655.21 | 5128.65 | 3927.51 | 2132.95 |
| 3 | Kocaeli Turkey | 4057.97 | 4361.14 | 4884.22 | 4654.57 | 3086.61 | 1880.86 |
| 4 | Hollywood Storage | 3862.82 | 3282.29 | 3864.86 | 2852.46 | 2184.94 | 1993.69 |
| 5 | Tohoku | 3885.6 | 3352.38 | 5504.75 | 4010.37 | 2936.74 | 1885.57 |
| 6 | Hyouguken | 4098.7 | 4716.33 | 5401.43 | 2063.97 | 3373.23 | 2572.16 |
| 7 | Tokachi | 3875.13 | 3278.46 | 5145.53 | 3844.43 | 2738.88 | 1854.15 |
| 8 | Hyuganda | 4381.08 | 3303.55 | 5611.34 | 3679.2 | 2972.03 | 1721.03 |
| 9 | Southern Calif | 3497.6 | 3031.16 | 5637.72 | 3917.13 | 3096.51 | 1585.55 |
| 10 | Elcentro | 4138.81 | 3042.85 | 3934.77 | 3521.68 | 2814.6 | 1499.59 |
| 11 | Chichi Taiwan | 4448.64 | 3303.55 | 4216.92 | 2968.93 | 2972.03 | 1672.11 |

Based on Table 2, the angle that has the most significant influence on the structural response is 0º for both the X and Y directions, except for the Kocaeli (Turkey) and Hyouguken ground motions, where a 30º angle is used for the X direction.

## 3. RESULTS AND DISCUSSION

Table 3 presents a comparison of base shear and structural period results, which was conducted to evaluate the effectiveness of using isolators in the bridge structure.

**Table 3.** Comparison of Base Shear and Structural Period

| **System** | **Shear (kN)** | | **Period (s)** | |
|---|---|---|---|---|
| | **x** | **y** | **x** | **y** |
| Isolator | 4849.50 | 6655.21 | 2.06 | 1.99 |
| Non-Isolator | 18963.20 | 14542.5 | 0.86 | 0.47 |
| Ratio | 3.91 | 2.19 | 2.40 | 4.23 |

The implementation of seismic isolators was found to significantly reduce the seismic forces acting on the pier, with the base shear reduced by a factor of up to 3.91 and the structural period increased by a factor of up to 4.23. Subsequent evaluations were conducted to assess the seismic performance of the pier under design-level earthquake loading for both structural configurations—namely, with and without base isolation. The performance assessment was carried out by incorporating plastic hinges at the base of the pier elements in the structural model. The performance levels were then determined based on the force–deformation relationships and classified into four distinct levels, following established performance-based seismic design criteria.

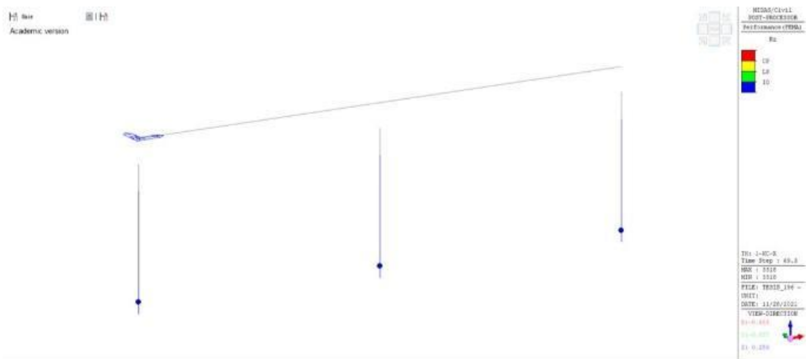


**Figure 7.** Plastic Hinge – Hyuganda X

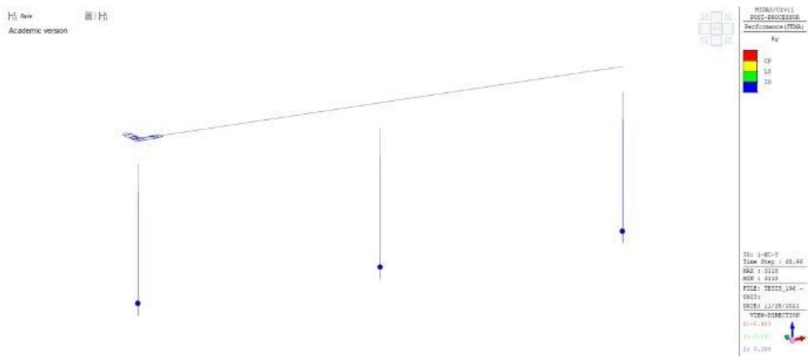


**Figure 8.** Plastic Hinge – Hyuganda Y

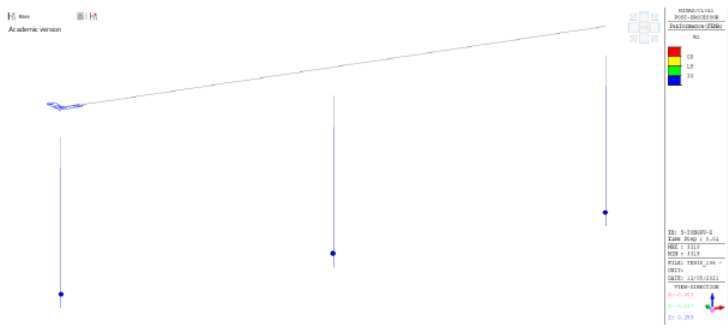


**Figure 9.** Plastic Hinge – Tohoku X

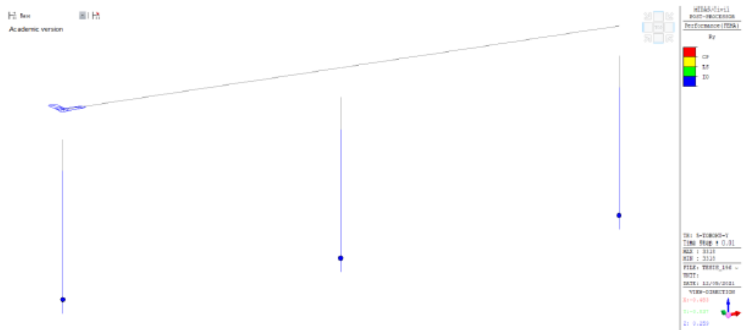


**Figure 10.** Plastic Hinge – Tohoku Y

The performance level evaluation of the pier under Hyuganda and Tohoku ground motion in the X and Y directions for the structure without base isolation are indicate identical outcomes, where the pier response has exceeded the elastic range and reached the Immediate Occupancy (IO) performance level. The results for all 11 earthquake ground motions are presented in Table 4 and Table 5.

**Table 4.** Performance Level of Pier without Isolator in the X Direction

| Load | Deform (m) | Force (kN) | max(D/D1) | State | Performance Level Kinerja |
|---|---|---|---|---|---|
| 1-KC-X | -0.002 | -303325 | 1.462 | B~C(+) | IO(-) |
| 2-TI-X | 0.006 | 329993 | 4.308 | B~C(+) | IO(+) |
| 3-KT-X | -0.003 | -306591 | 1.971 | B~C(+) | IO(-) |
| 4-Holly-X | 0.002 | 302257 | 1.348 | B~C(+) | IO(+) |
| 5-Tohoku-X | 0.001 | 182453 | 0.6102 | Elastic | FO(+) |
| 6-hyoukugen-X | -0.001 | -264199 | 0.8836 | Elastic | FO(-) |
| 7-Tokachi-X | 0.0008 | 182457 | 0.6102 | Elastic | IO(+) |
| 8-Hyuganda-X | 0.0015 | 299887 | 1.113 | B~C(+) | IO(+) |
| 9-SC-X | -0.001 | -228759 | 0.7651 | Elastic | IO(-) |
| 10-Elcentro-X | -0.001 | -225490 | 0.7541 | Elastic | IO(-) |
| 11-BOCHI-X | 0.0015 | 300033 | 1.11 | B~C(+) | IO(+) |
| **Average** | | | **1.358** | **B~C(+)** | **IO(+)** |

**Table 5.** Performance Level of Pier without Isolator in the Y Direction

| Load | Deform (m) | Force (kN) | max(D/D1) | State | Performance Level Kinerja |
|---|---|---|---|---|---|
| 1-KC-Y | -0.00793 | -178060 | 2.871 | B~C(+) | IO(-) |
| 2-TI-Y | -0.00845 | -178674 | 3.061 | B~C(+) | IO(-) |
| 3-KT-Y | -0.00854 | -177465 | 3.092 | B~C(+) | IO(-) |
| 4-Holly-Y | 0.00550 | 175212 | 1.992 | B~C(+) | IO(+) |
| 5-Tohoku-Y | 0.01086 | 179663 | 3.933 | B~C(+) | IO(+) |
| 6-hyoukugen-Y | 0.00870 | 178968 | 3.152 | B~C(+) | IO(+) |
| 7-Tokachi-Y | 0.01132 | 182040 | 4.1 | B~C(+) | IO(+) |
| 8-Hyuganda-Y | 0.00288 | 172114 | 1.044 | B~C(+) | IO(+) |

| Load | Deform (m) | Force (kN) | max(D/D1) | State | Performance Level Kinerja |
|---|---|---|---|---|---|
| 9-SC-Y | -0.01493 | -186281 | 5.41 | B~C(+) | IO(-) |
| 10-Elcentro-Y | 0.00309 | 172387 | 1.12 | B~C(+) | IO(+) |
| 11-BOCHI-Y | 0.00260 | 162290 | 0.944 | Elastic | FO(+) |
| **Average** | | | **2.793** | **B~C(+)** | **IO(+)** |

The average performance level of the pier in both the X and Y directions for the structure without base isolation is classified as IO (Immediate Occupancy), indicating that the piers have, on average, exceeded their elastic range. The performance level results for the isolated structure can be seen in Table 6 and Table 7.

**Table 6.** Performance Level of Pier with Isolator in the X Direction

| Load | Deform mm (m) | Force (kN) | max(D/D1) | State | Performance Level Performance Level |
|---|---|---|---|---|---|
| 1-KC-X | -0.00005 | -12246 | 0.04096 | Elastic | FO(-) |
| 2-TI-X | 0.00005 | 11765 | 0.03935 | Elastic | FO(+) |
| 3-KT-X | 0.00039 | 88920 | 0.2974 | Elastic | FO(+) |
| 4-Holly-X | 0.00004 | 9330 | 0.03121 | Elastic | FO(+) |
| 5-Tohoku-X | -0.00042 | -94006 | 0.3144 | Elastic | FO(-) |
| 6-hyoukugen-X | 0.00004 | 10075 | 0.0337 | Elastic | FO(+) |
| 7-Tokachi-X | -0.00004 | -8250 | 0.02759 | Elastic | FO(-) |
| 8-Hyuganda-X | -0.00027 | -61810 | 0.2067 | Elastic | FO(-) |
| 9-SC-X | 0.00004 | 9790 | 0.03274 | Elastic | FO(+) |
| 10-Elcentro-X | 0.00005 | 11721 | 0.0392 | Elastic | FO(+) |
| 11-BOCHI-X | 0.00004 | 9636 | 0.03223 | Elastic | FO(+) |
| **Average** | | | **0.100** | **Elastic** | **FO(+)** |

**Table 7.** Performance Level of Pier with Isolator in the Y Direction

| Load | Deform mm (m) | Force (kN) | max(D/D1) | State | Performance Level |
|---|---|---|---|---|---|
| 1-KC-Y | 0.00022 | 13851 | 0.08053 | Elastic | FO(+) |
| 2-TI-Y | -0.00032 | -19906 | 0.1157 | Elastic | FO(-) |
| 3-KT-Y | 0.00159 | 98920 | 0.5751 | Elastic | FO(+) |
| 4-Holly-Y | -0.00016 | -10088 | 0.05865 | Elastic | FO(-) |
| 5-Tohoku-Y | 0.00152 | 94629 | 0.5502 | Elastic | FO(+) |
| 6-hyoukugen-Y | 0.00031 | 19065 | 0.1108 | Elastic | FO(+) |
| 7-Tokachi-Y | -0.00028 | -17501 | 0.1018 | Elastic | FO(-) |
| 8-Hyuganda-Y | -0.00102 | -63589 | 0.3697 | Elastic | FO(-) |
| 9-SC-Y | 0.00026 | 16129 | 0.09378 | Elastic | FO(+) |

| Load | Deform mm | Force | max(D/D1) | State | Performance Level |
|---|---|---|---|---|---|
| | (m) | (kN) | | | |
| 10-Elcentro-Y | 0.00028 | 17483 | 0.1017 | Elastic | FO(+) |
| 11-BOCHI-Y | 0.00031 | 19223 | 0.1118 | Elastic | FO(+) |
| **Average** | | | **0.206** | **Elastic** | **FO(+)** |

The performance level of the pier in the isolated structure indicates an average response in both the X and Y directions corresponding to the Fully Operational (FO) level. This suggests that the pier remains within the elastic range and the structure continues to function properly without significant damage. A comparison of the average pier performance levels, based on rotation-to-yield rotation ratios for both the non-isolated and isolated structures, is presented in Table 8.

**Table 8.** Comparison Results of Average Pier Performance Levels

| Direction | Yield Rotation | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Non-Isolator** | **State** | **Performance** | **Isolator** | **State** | **Performance** | **Ratio** |
| X | 1.358 | B~C(+) | IO(+) | 0.100 | Elastic | IO(+) | 13.633 |
| Y | 2.793 | B~C(+) | IO(+) | 0.206 | Elastic | IO(+) | 13.534 |

In addition to the performance level evaluation, displacement checks of the pier were also conducted in both the X and Y directions. The results of these evaluations are presented in Table 9.

**Table 9.** Comparison of Pier Displacement with and without Seismic Isolators

| Load | DX (m) | | Ratio | DY (m) | | Ratio |
|---|---|---|---|---|---|---|
| | **Isolator** | **Non** | | **Isolator** | **Non** | |
| KC-X | 0.06 | 0.229 | 3.83 | 0.006 | 0.028 | 4.37 |
| TI-X | 0.057 | 0.315 | 5.54 | 0.008 | 0.03 | 3.57 |
| KT-X | 0.064 | 0.244 | 3.82 | 0.013 | 0.081 | 6.2 |
| Holly-X | 0.047 | 0.225 | 4.81 | 0.006 | 0.019 | 3.13 |
| Tohoku-X | 0.067 | 0.13 | 1.94 | 0.007 | 0.039 | 5.95 |
| hyoukugen-X | 0.053 | 0.188 | 3.54 | 0.012 | 0.095 | 8.14 |
| Tokachi-X | 0.046 | 0.13 | 2.83 | 0.007 | 0.031 | 4.17 |
| Hyuganda-X | 0.044 | 0.218 | 4.93 | 0.006 | 0.012 | 1.91 |
| SC-X | 0.045 | 0.163 | 3.67 | 0.009 | 0.034 | 3.95 |
| Elcentro-X | 0.053 | 0.161 | 3.05 | 0.005 | 0.012 | 2.16 |
| BOCHI-X | 0.053 | 0.218 | 4.12 | 0.007 | 0.01 | 1.34 |
| **Average** | **0.053** | **0.202** | **3.78** | **0.008** | **0.035** | **4.48** |
| KC-Y | 0.024 | 0.068 | 2.88 | 0.015 | 0.126 | 8.22 |
| TI-Y | 0.025 | 0.091 | 3.72 | 0.023 | 0.135 | 5.94 |
| KT-Y | 0.027 | 0.092 | 3.39 | 0.02 | 0.137 | 6.86 |
| Holly-Y | 0.026 | 0.067 | 2.6 | 0.013 | 0.083 | 6.47 |

| Load | DX (m) | | Ratio | DY (m) | | Ratio |
|---|---|---|---|---|---|---|
| | Isolator | Non | | Isolator | Non | |
| Tohoku-Y | 0.025 | 0.039 | 1.58 | 0.019 | 0.179 | 9.33 |
| hyoukugen-Y | 0.02 | 0.069 | 3.52 | 0.019 | 0.14 | 7.26 |
| Tokachi-Y | 0.022 | 0.039 | 1.81 | 0.018 | 0.189 | 10.47 |
| Hyuganda-Y | 0.013 | 0.065 | 5.2 | 0.013 | 0.037 | 2.87 |
| SC-Y | 0.019 | 0.049 | 2.55 | 0.019 | 0.255 | 13.34 |
| Elcentro-Y | 0.017 | 0.048 | 2.79 | 0.016 | 0.04 | 2.61 |
| BOCHI-Y | 0.023 | 0.065 | 2.82 | 0.017 | 0.033 | 1.94 |
| **Average** | **0.022** | **0.063** | **2.9** | **0.017** | **0.123** | **7.06** |

The displacement ratio observed at the pier was evaluated to substantiate the effectiveness of seismic isolation in the structural system. The analysis revealed displacement ratios of 4.48 in the X-direction and 7.06 in the Y-direction. These findings indicate that the implementation of isolators significantly reduces seismic demands on the structure, thereby confirming their effectiveness in enhancing the overall seismic performance.

## 4. CONCLUSIONS

Based on the analysis conducted to evaluate the performance level of piers in the typical structure of the Jakarta–Bandung High-Speed Railway (KCJB) bridge, the following conclusions can be drawn:

- The use of a seismic isolation system in the structure can reduce the shear force transmitted to the piers by up to 70%. This reduction is attributed to the significant energy dissipation capability of the isolators, which absorb seismic energy through relative displacements.
- An analysis of the piers under design-level seismic loads was carried out for both structural systems. The results indicate that the piers in the non-isolated structure have exceeded the elastic range in both X and Y directions. In contrast, the piers in the isolated structure remained within the elastic range in both directions.
- The displacement ratio observed was 4.48 (DX) in the X-direction and 7.06 (DY) in the Y-direction, indicating that the use of isolators has a beneficial effect in reducing structural deformation and enhancing seismic performance.

## 5. ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere gratitude to God Almighty for His blessings, guidance, and strength throughout the completion of this research. I would like to extend my deepest appreciation to my supervisor, Prof. Ir. Indra Djati Sidi, M.Sc., Ph.D and Dr. Eng. Aris Aryanto, S.T, M.T. for their continuous support, invaluable guidance, and constructive feedback throughout every stage of this study. Their expertise and encouragement greatly contributed to the completion of this research.

Special thanks are due to my family and friends for their unwavering support, patience, and encouragement throughout this academic journey. Finally, I acknowledge all parties, individuals, and institutions who have provided direct or indirect support and made this work possible. Your contributions are truly appreciated.

**REFERENCES**


[1] A. M. Emilidardi *et al*., "Seismic performance enhancement of a PCI-girder bridge pier with shear panel damper plus gap: Numerical simulation," *Earthquakes and Structures*, vol. 27, no. 1, pp. 69–82, Jul. 2024.

[2] S. Shamshirband *et al*., "Particle swarm optimization model to predict scour depth around bridge pier," *arXiv*, May 2019.

[3] X. Quan et al., "Optimal Selection of Earthquake Resisting Schemes for Jakarta–Bandung High-Speed Railway," *Adv. Civ. Eng.*, 2022.

[4] SNI 2833 Tahun 2016, "Standar Perencanaan Ketahanan Gempa untuk Jembatan."

[5] F.F. Muhammad *et al*., "A Study on the Effects of Implementing Base Isolation System for Existing RC Buildings on Soft Soil.", Journal of Civil Engineering vol. 40 no. 1 hal 12-19, 2025.

[6] Kukuh Kurniawan Dwi Sungkono, E. A. Krisdianti, and G. Gunarso, "Analisis Kinerja Struktur Pada Gedung Bertingkat Dengan Analisis Pushover Berdasarkan Atc-40," *J. Tek. Sipil dan Arsit.*, vol. 29, no. 2, pp. 7–16, 2024, doi: 10.36728/jtsa.v29i2.3300.N. Menga *et al*., "Nonlinear viscoelastic isolation for seismic vibration mitigation," *arXiv*, Jul. 2020.

[7] N. Menga *et al*., "Nonlinear viscoelastic isolation for seismic vibration mitigation," *arXiv*, Jul. 2020.

[8] J. Dong et al., "Seismic fragility of high-speed railway bridge with high pier," in *Seismic Fragility High-Speed Rail Bridges*, T. Fr., 2024.

[9] Journal of Eng. & Appl. Sci., "Effect of material characteristics of lead rubber isolators on seismic performance of box girder bridge," 2024.

[10] I. G. G. Wiryadi, I. P. A. P. Wirawan, I. K. D. K. Tubuh, and I. M. A. Candra, "Level Kinerja Struktur Gedung Fakultas Pariwisata Universitas Udayana Berdasarkan Fema 356 Dan Atc-40," J. Tek. Gradien, vol. 14, no. 1, pp. 25–34, 2022, doi: 10.47329/teknikgradien.v14i1.832.

[11] Mdpi *Materials*, "Seismic response mitigation of reinforced-concrete HSR bridges with hierarchical curved steel dampers," 2024.

[12] W. Di *et al*., "Influence of site conditions on seismic performance of isolated HSR bridges," *Adv. Struct. Eng.*, 2022.

[13] Bin Yan *et al*., "Seismic response law of suspension bridge–track system of HSR," *SAGE*, 2022.

[14] M. H. Zuher, Z. N. Sidiq, A. P. Nasution, M. Masrilayanti, and J. Sunaryati, "Analisa Level Kinerja Struktur Pada Bangunan 12 Lantai Dengan Metode Pushover," J. Talent. Sipil, vol. 7, no. 1, p. 429, 2024, doi: 10.33087/talentasipil.v7i1.508.

[15] Aben SpringerOpen, "Improving seismic safety by equipping railway bridges with FPB," 2022.

[16] X. Huang *et al*., "Seismic mitigation efficiency of steel dampers in HSR bridge–track," *Materials*, 2024.
[17] Mdpi *Buildings*, "Design and seismic performance study of multistage controllable isolation bearing for HSR," 2024.