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THE IMPACT OF APPLYING BASE ISOLATOR IN HOSPITAL BUILDING

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ABSTRACT

Due to Indonesia's location in the earthquake zone, it is necessary for civil engineers in Indonesia to study seismic performance of a building, which is strongly related to the structure of the building itself. Buildings equipped with vibration damping structures, known as an isolation system, will have a different seismic behavior than if it did not have one. This is due to the impact of an earthquake dampening vibration isolator. This final project analyzes the difference between seismic performance of a building using a seismic isolation system and ones without. The conclusion of this final project shows that the isolation system will decrease the internal force of a structure element by about 57.71% for axial force, 84.10% for shear, and 85.75% for moment. The application of an isolation system will also decrease the relative displacement by about 74,28% and extended structure vibration period by about 171.17 %.

Keyword: earthquake, seismic performance, isolation system.

1. INTRODUCTION

In Indonesian civil engineering, it is necessary for researchers to investigate the seismic performance of buildings, referring to the responses and behaviors of buildings to earthquakes. The seismic performance of a building is, however, highly dependent on the structure of the building itself. Buildings equipped with vibration damping structures—also known as isolation systems—will have a different seismic performance compared to buildings without isolation systems due to the impact of isolators in absorbing shockwaves from an earthquake. An example of an isolation system is called a base isolator.

Hospitals provide vital services to the community, especially during or after a natural disaster, such as an earthquake. Therefore it is essential for hospital buildings to be protected against earthquakes to ensure victims are adequately accommodated for when in need of necessary medical care. However, there are numerous hospital buildings in Indonesia that have not yet applied a base isolator, and the Obstetric, Children and Haemodialysis Inpatient Wards in DR. M. Djamil Hospital in Padang is an example. One way for this hospital to be safe against earthquakes is by applying a base isolator in the construction. Therefore, an analysis of the impact of applying a base isolator in hospital buildings should be conducted to show its significant reductions in the internal force, relative displacement, and its extension of the structure's vibration period during earthquakes. The analysis of the effects of the use of base isolators in the Obstetric, Children and Hemodialysis Inpatient Wards in DR. M. Djamil Hospital aims to compare the seismic performances of buildings

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fitted with and without base isolators. The analysis was carried out by measuring the displacement reduction value, internal force, and increase in vibration period induced by the use of base isolators; and by comparing those values to buildings without base isolators.

The result of this research will be very beneficial to engineers designing buildings as it can be taken into consideration when deciding whether or not to use base isolators. It can also be used as a reference for engineers to calculate the possible reduction of the dimensions of the structure.

2. LITERATURE REVIEW

Numerous studies on the effect of the use of base isolators have been done by employing different methods. In general, most of the research conducted focused on the response of the studied structure to earthquakes. One such research was performed by Dekker and Donna (2011) on Hotel Bumi Minang building and Donna (2011) on a polytechnic building. The results of their research showed a reduction in the internal force over 80% and a reduction of the relative displacement exceeding 70%. Research regarding structural response only yielded results in the form of reductions in internal forces and relative displacement. Further research on the effects of the use of base isolators should be done to determine the seismic performance of buildings. The seismic performance of a structure is shown in the form of a hysteresis curve on a base shear versus displacement graph. To obtain such data, the earthquake load used as input in the analysis must be a cyclic load.

One analysis method that uses alternating earthquake load is Time History Analysis. Dynamic analysis of non-linear time history is suitable to analyze the effects of earthquakes on irregular structures. As it is difficult to precisely estimate the ground motion caused by an earthquake at a certain location, the required data was approximated by using simulated ground motion. One study that used the Time History Analysis method was a study conducted by Mehmet Komur et all., 2011. The research was conducted on isolated and fixed base structures of a four story building that used the seismic records of the Erzincan E-W, EW Marmara E-W, and Dusce W-S earthquakes in Turkey. The results produced are shown in a displacement versus building heights graph, and a base shear force versus time graph shown as follows:

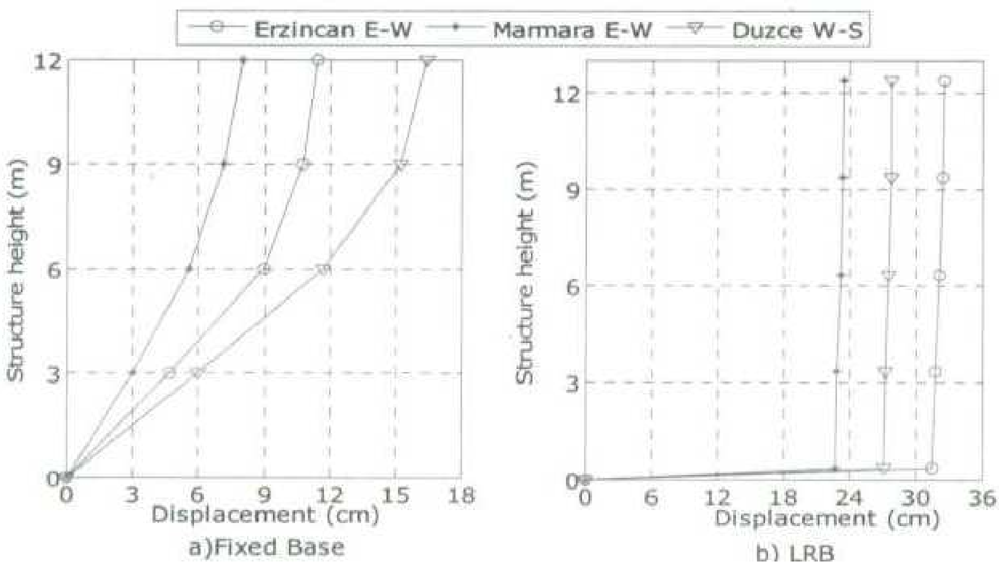
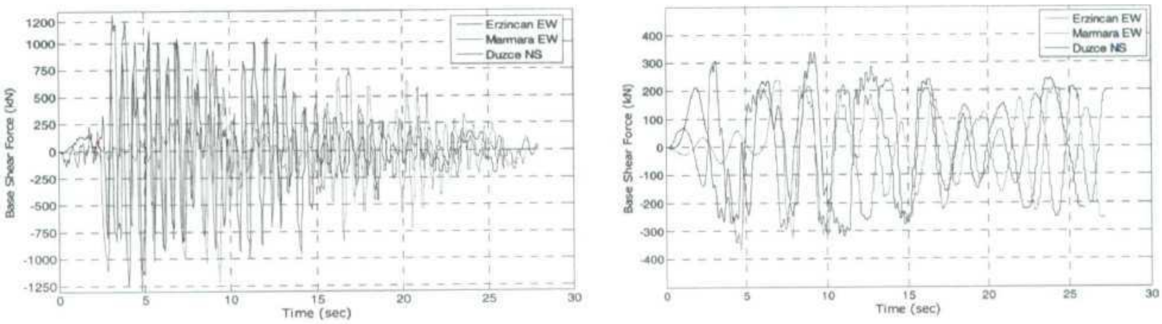


Figure 2.1 Various displacements for every 4-storyheights.
(Source : Mehmet et all ., 2011)



a) Fixed-base b) LRB

Figure 2.2 Various base shear forces versus time for 4-story buildings.
(Source : Mehmet et all ., 2011)

From the base shear force versus time graph, noticeable differences were observed between the structure fitted with a base isolator (b) and the structure without a base isolator (a), shown by weaker vibrations experienced by the former. This shows the effect of the base isolator application on the structure when rocked by an earthquake. Ideally, the input used for a building seismic performance analysis should originate from a seismic recording of an accelogram in the region of the structure. However, due to the unavailability of a seismic recording in Indonesia, the input data of this research was obtained from seismic recordings available in other parts of the world (Teddy Boen., 2007). Below is the list of the global earthquake data records from different places:

Table 2.1 list of earthquake data records from different sources in the world.

Location of Earthquakes	Date	Fault Type	Magnitude	Epicenter Distance (km)	Depth (km)
Chi-Chi, Taiwan	20-09-1999	Thrust fault	7.62	7.64	6.8
El-Centro (Imperial Valley) , US	19-05-1940	Strike Slip fault	6.95	12.99	8.8
Kobe, Japan	16-01-1995	Strike Slip fault	6.9	18.27	17.9
Loma Prieta, US	18-10-1989	Reverse fault	6.93	28.64	17.5
Northridge, US	17-01-1994	Thrust fault	6.69	10.91	17.5
San Fernan do, US	09-02-1971	Reverse fault	6.61	11.86	13
Tabas, Iran	16-09-1978	Thrust fault	7.35	55.24	5.8

(Source : Boen, 2007)

3. STRUCTURE DESCRIPTION

The object of this research is as follows:

1. The structure studied was the Obstetric, Children and Hemodialysis Inpatient Wards in DR. M. Djamil Hospital Padang block C S1, which consists of two parts, namely:
   a. The upper structure which is the main building.
   b. The lower structures which constitute the foundation of the building.
2. The modeling of the structure was carried out in three dimensions using the following loads:
   a. dead load
   b. live load
   c. earthquake load
3. An analysis of the seismic performance was performed using the Time History Analysis method, utilizing Structure Analysis Program (SAP) 2000 software.
4. The technical data of the Obstetric, Children and Hemodialysis Inpatient Wards in DR. M. Djamil Hospital is as follows:

Type of structure : Reinforced Concrete
Concrete quality :

a. Upper structure: K-300 and K-400
b. Lower structure: K-450

Steel Quality : fy 400 and 240 MPa
Building functions : Hospital
Number of floors : 5 floors
Height of building : 10,465 m2
Type of foundation : mini pile

4. METHODOLOGY

4.1. Time History Analysis

Dynamic time history method is suitable to analyze the effects of earthquakes on buildings. As the earthquake ground motion at a site is difficult to estimate precisely, the required data can be approximated by using a simulated ground motion analysis. In this analysis, ground motion acceleration caused by an earthquake was used as input data. The seismic ground motion recordings were obtained from the accelogram of the El-Centro NS earthquake recorded on May 15, 1940. Figure 4.1 shows the data entry process imputed into the SAP 2000 software. In this analysis, the scale factor used was 1.6. This figure was derived from the multiplication of the acceleration of gravity (g) by (I / R), where R is the earthquake damping factor (in this case, full ductility R = 8.5), and I is the primacy factor of the building (1.4). To be able to enter the Time History earthquake loads into SAP2000, the ground motion data must first be defined in the Time History Case. For an output duration of 40 seconds with an interval of 0.01 seconds, the amount of the output steps was 40/0.1 = 4000. The data is entered into SAP2000 for a Time History in the X (U1) and Y (U2) directions as shown in Figure 4.2:

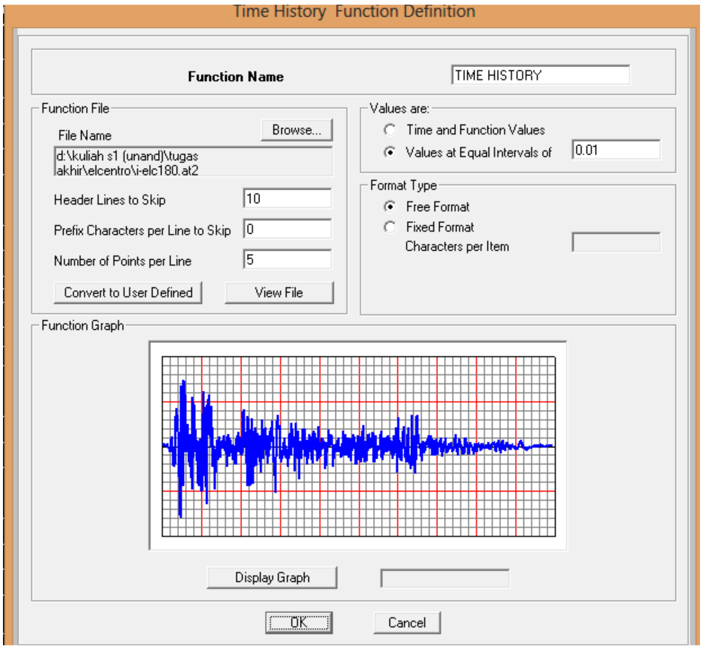


Figure 4.1 Elcentro Data Input

After defining the Time History Case and other variables an analysis of a building without base isolators—also known as a fixed base structure—was performed.

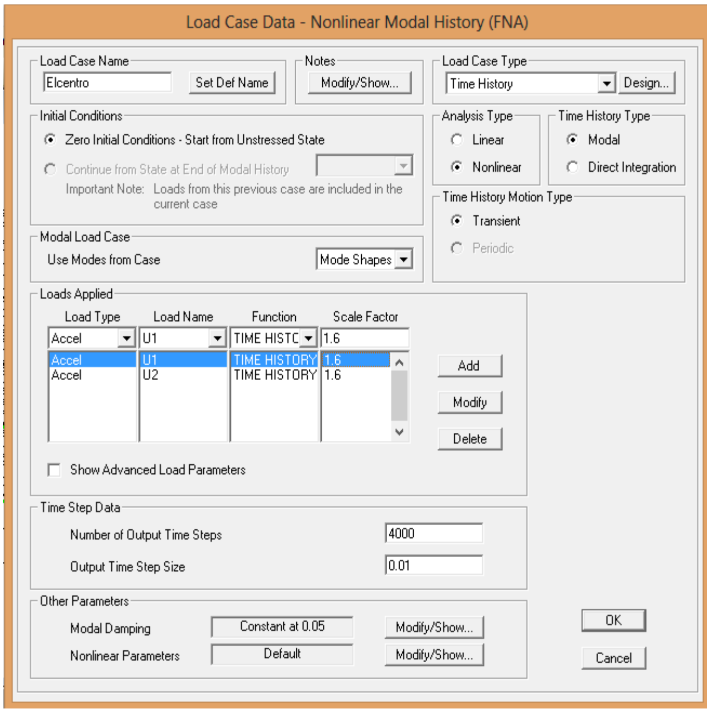


Figure 4.2 Time History data input

4.2. Fixed Base Structure

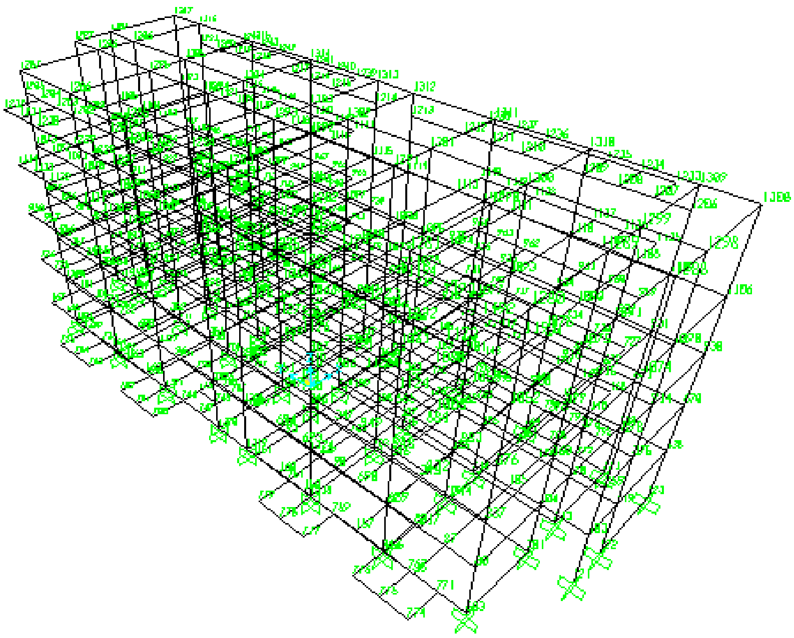


Figure 4.3 Fixed Base Structure

An analysis of a fixed base structure was carried out prior to any analysis of buildings fitted with base isolators to determine the joint reactions. The joint reactions of each column in the building were then used to determine the properties of the base isolator that would be used. Table 4.1 summarizes the reactions of each column in the base story caused by a combination of loads.

Table 4.1 Joint Reactions of the side columns

Joint ID	Grid Location	Joint Reactions (kN)
121	A-5	1163.816
122	A-6	943.078
123	A-7	771.345
211	T-5	817.446
212	T-6	1305.58
213	T-7	1065.385
683	B-2	1341.493
701	B-5	1448.777
712	S-5	1625.266
721	B-7	1640.283
728	I-7	1288.519
729	J-7	1573.073
731	N-7	2398.143
733	P-7	2448.374
736	S-7	1328.14
756	G-7	2425.321
763	E-2	2398.409
764	E-7	2448.091
1318	G-2	2410.852
1319	I-2	1553.263
1320	J-2	1403.971
1321	N-2	2500.799
1322	P-2	2430.989
1323	S-2	1181.99

Table 4.2 Joint Reactions of the center columns

Joint ID	Grid Location	Joint Reactions (kN)
702	E-5	1913.933
703	G-5	1951.397
705	I-5	1806.316
706	J-5	1625.67
709	N-5	2010.945
711	P-5	1911.356
713	B-6	1756.986
714	E-6	1964.499
715	G-6	1956.449
716	I-6	1565.527
717	J-6	1873.133
718	N-6	1953.942
719	P-6	1956.88
720	S-6	1435.882

From the tables above, the maximum joint reactions of both side and center columns were determined.

Column Location	Maximum Joint Reaction (kN)
Side Column	2500.799
Center Column	2010.945

The next stage of the process was to select the properties of the base isolator that would be used based on the maximum joint reaction of the columns.

The base isolators used for the fixed base structure were Bridgestone Japan products of type H-Bearing High Damping Rubber Bearings (HDRB). Based on the joint reactions, the selected properties of the base isolators used were as follows:

Column Location	Base Isolator's Properties
Side Column	HH065X6R
Center Column	HH065X6R

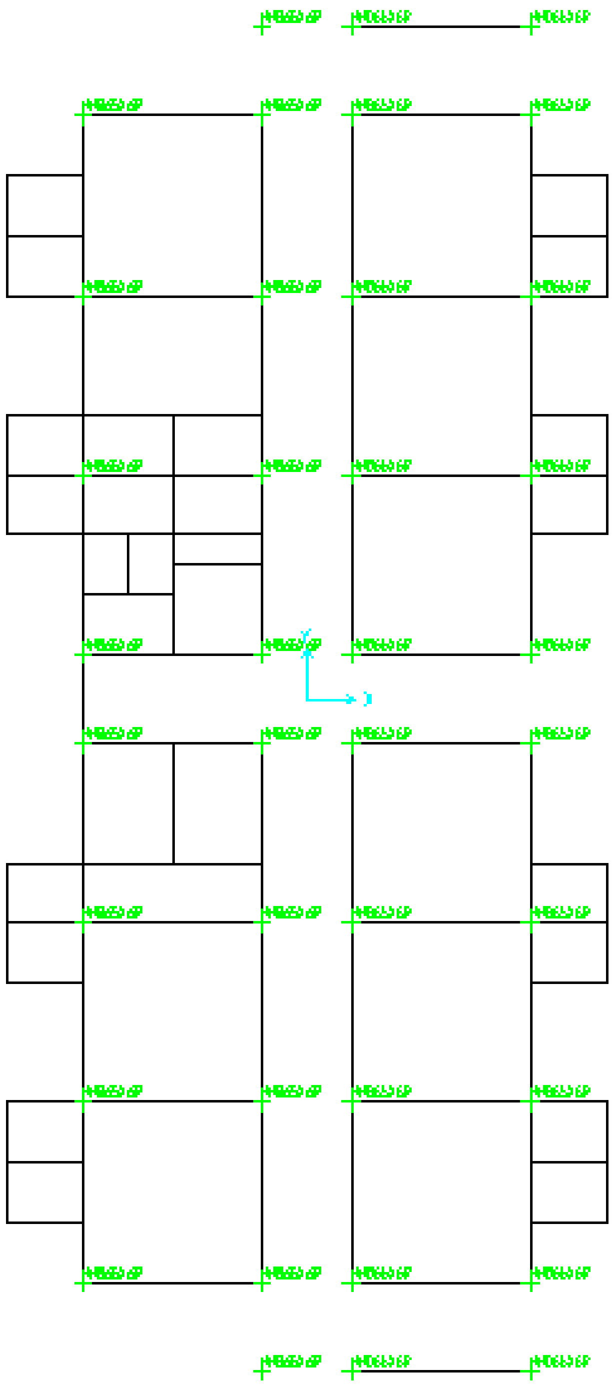


Figure 4.4 Location of Base Isolators

4.3. Base Isolated Structure

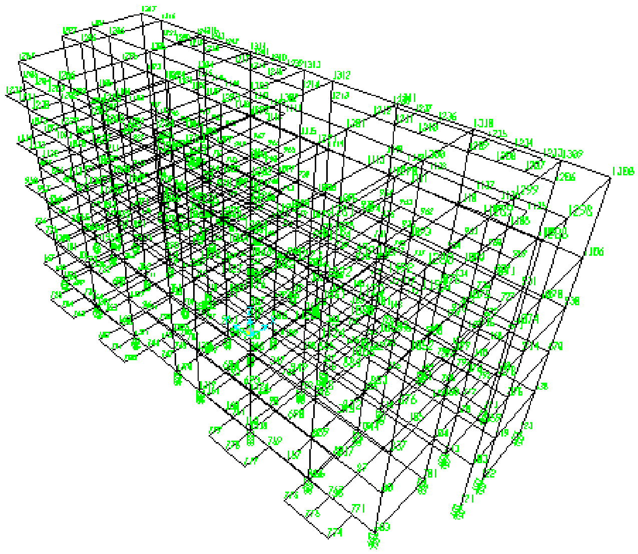


Figure 4.5 Base Isolated Structure

The next step was the selection of the beam, column and joint that would serve as a sample in the internal force output.

4.4. Sample of Joint and Frame

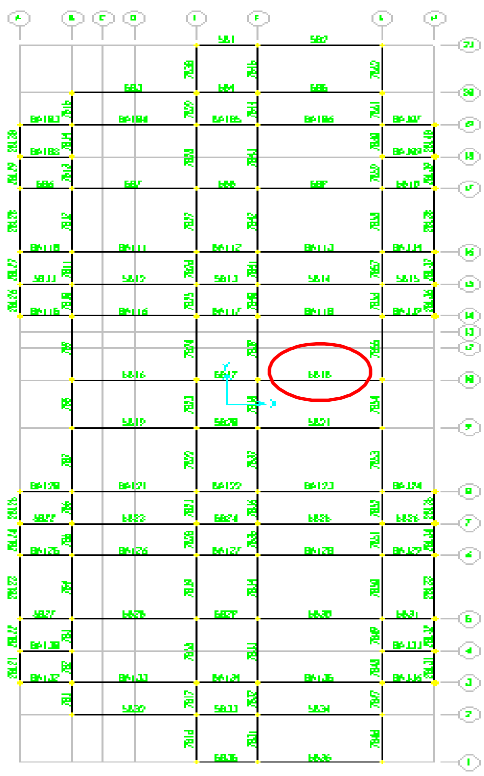


Figure 4.6 Beams for internal force output.

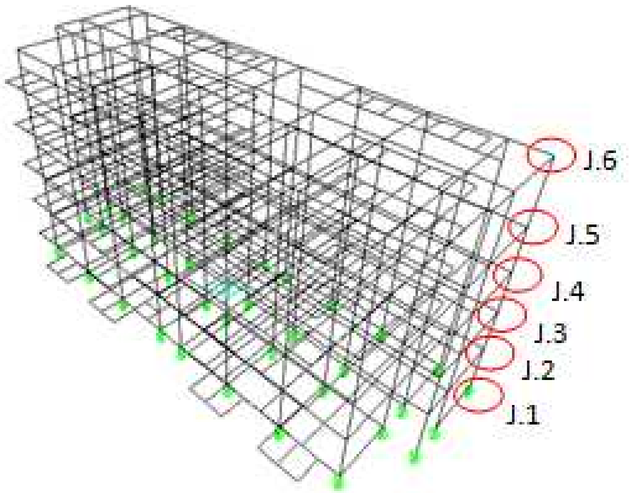


Figure 4.7 Joints for displacement output for each story

Table 4.3 Joints for displacement output for each story

Joint	Locations	Story
J.6	G1	6
J.5	G1	5
J.4	G1	4
J.3	G1	3
J.2	G1	2
J.1	G1	1

Table 4.4 Beams for internal force output

Frame Label	Description	Storey
5B18	Beam	5
4B80	Beam	4
2B18	Beam	3
DK23	Column	1
DK24	Column	1
DK25	Column	1

Subsequently, an analysis of the selected beam, column and joint was conducted for both base isolated and fixed base structures.

5. ANALYSIS AND DISCUSSION

5.1. Comparison of the Seismic Performances of Fixed Based and Base Isolated Structures

Displacement

The results of the joint analysis are shown in the following Time History graphs:

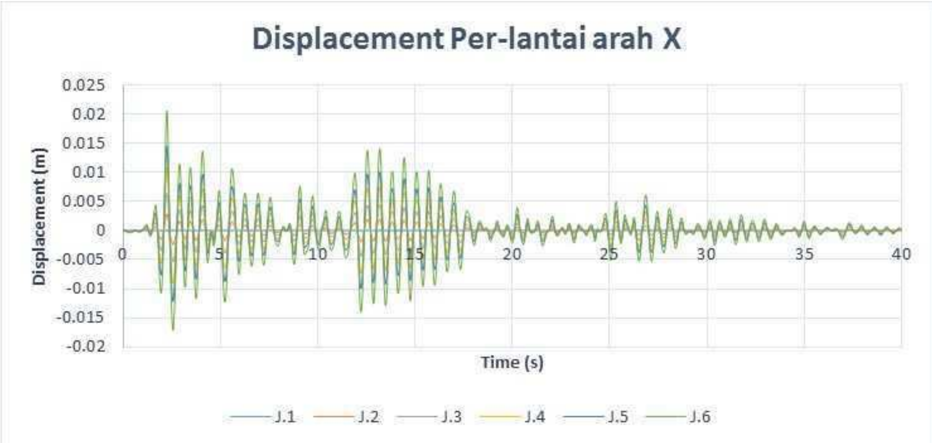


Figure 5.1 Output graph of the Displacement in the X direction for the fixed base structure

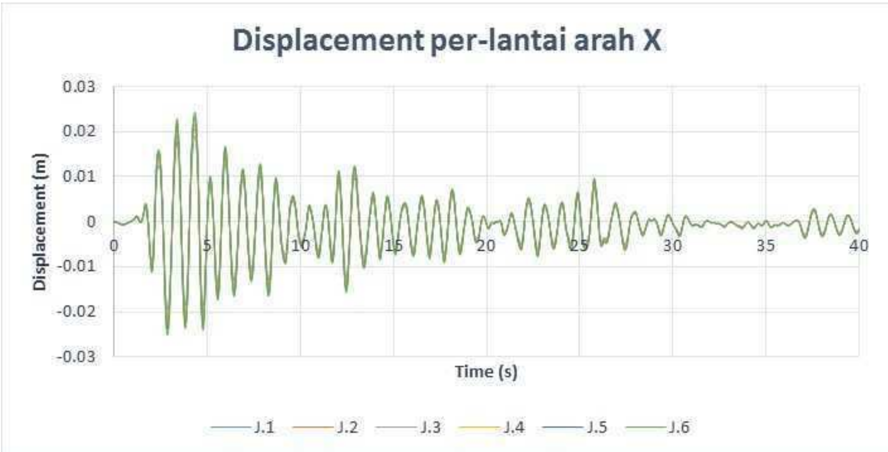


Figure 5.2 Output graph of the Displacement in the X direction for the base isolated structure

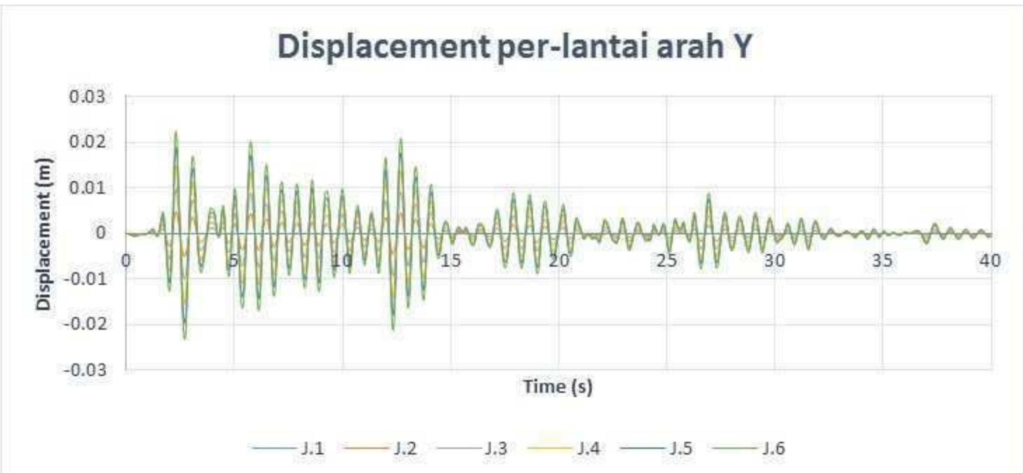


Figure 5.3 Output graph of the Displacement in the Y direction for the fixed base structure

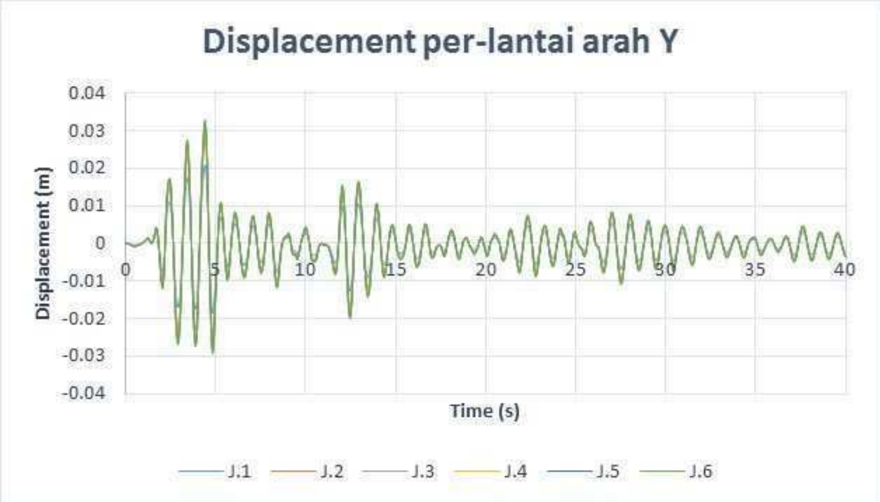


Figure 5.4 Output graph of the Displacement in the Y direction for the base isolated structure

From Figure 5.1 and 5.2, it can be observed that the maximum displacement in the X direction of the fixed base structure occurred on the J.6 joint (on the rooftop) with a value of0.02061 m or ± 2 cm. This value was gained at t=2.25 seconds. On the other hand, the maximum displacement in the X direction of the base isolated structure also occurred on the J.6 joint (on the rooftop) with a value of0.0243 m or ± 2.4 cm. This maximum displacement occurred at 4.34 seconds. It appeared that the maximum displacement of the base isolated structure was higher than that of the fixed base structure. However, the inter-story drift (or relative displacement) of the base isolated structure was much smaller than that of the fixed base structure.

Table 5.1 Comparison of the maximum displacement values for each story in the X direction

Story	Fixedbase (cm)	BaseIsolated (cm)
1	0	1.9
2	0.284	2.059
3	0.647	2.163
4	1.086	2.259
5	1.464	2.332
6	2.061	2.43

Tabel 5.2 Inter-story Drift for each story in the X direction

Story	Fixedbase (cm)	BaseIsolated (cm)
1-2	0.284	0.159
2-3	0.363	0.104
3-4	0.439	0.096
4-5	0.378	0.073
5-6	0.597	0.098
Total	2.061	0.53

The relative displacement of the fixed base structure was 2.061 cm, while the value for the base isolated structure was 0.53 cm. This means that the use of base isolation reduced the relative displacement by 74.28%. The graphs of displacement in the Y direction (Figure 5.3 and 5.4) demonstrate maximum displacement of the fixed base structure on the J.6 joint (on the rooftop) with a value of 0.02244 m or ±2.2 centimeters. This maximum value occurred at 2.29 seconds. For the base isolated structure, the maximum displacement occurred on the J.6 joint (on the rooftop) with a value of 0.03296m or ± 3.3 cm. This maximum value occurred at 4.41 seconds. As of the displacement in the X direction, the base isolated structure exhibited a larger maximum displacement value in the Y direction, but it was a much smaller relative displacement value compared to the fixed base structure.

Table 5.3 Comparison of the maximum

Story	Fixedbase (cm)	BaseIsolated (cm)
1	0	2.082
2	0.48	2.76
3	0.976	2.937
4	1.487	3.091
5	1.899	3.206
6	2.244	3.296

Tabel 5.4 Inter story Drift in the Y direction

Story	Fixedbase (cm)	BaseIsolated (cm)
1-2	0.480	0.678
2-3	0.496	0.177
3-4	0.511	0.154
4-5	0.412	0.115
5-6	0.345	0.09
Total	2.244	1.214

The relative displacement of the fixed base structure was 2.244 cm, while the value for the base isolated structure was 1.214 cm. The reduction in the relative displacement due to base isolators reached 45.9%. Below is the graph of maximum displacements for each story in the X and Y directions:

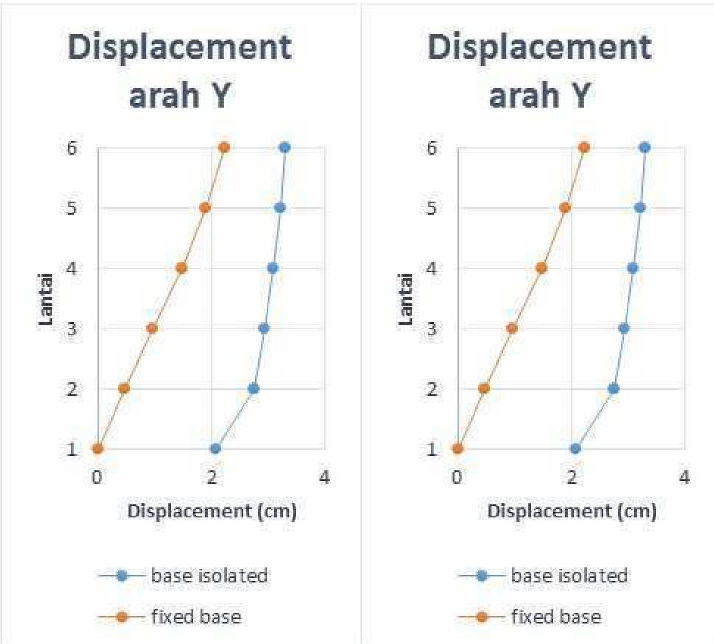


Figure 5.5 Displacement for each story on X and Y directions.

The above graph shows that the base isolated structure exhibited a displacement on the ground floor (base) as the base isolator caused the structure to move as a single unit (represented as a straight line in the graph).

Internal Force

Analysis of the internal force demonstrated a significant reduction, as shown in the following tables:

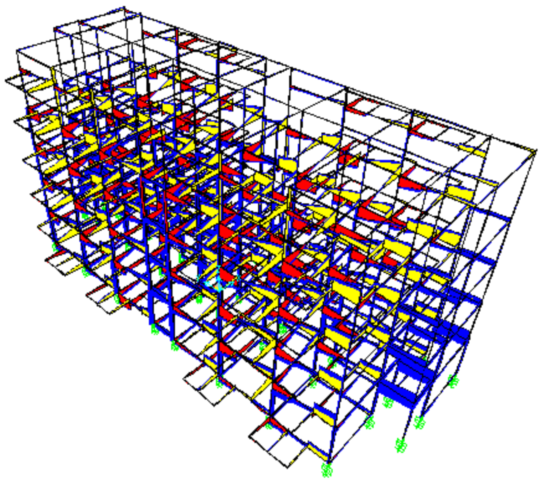


Figure 5.6 Share force in base isolated structure

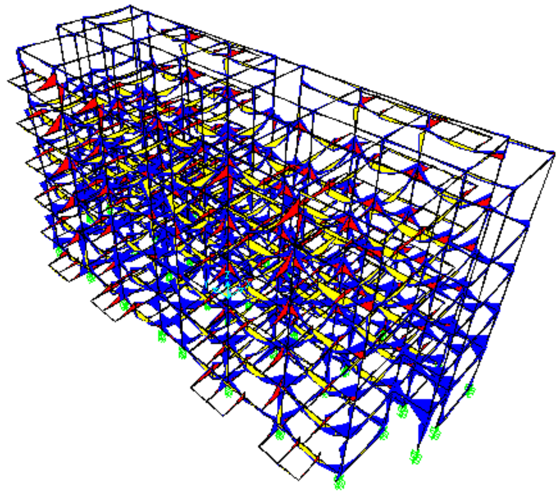


Figure 5.7 Moment in base isolated structure

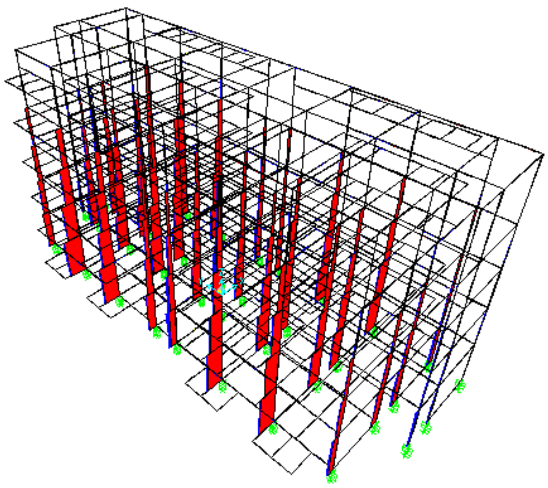


Figure 5.8 Axial force in base isolated structure

Table 5.5 Maximum Internal Force in the beams of the fixed base structure

Frame Label	Axial (kN)	Shear (kN)	Moment (kNm)
5B18	39.809	130.476	174.301
4B80	12.745	148.723	251.003
2B18	20.948	163.721	314.673

Tabel 5.6 Maximum Internal Force in the beams of the base isolated structure

Frame Label	Axial (kN)	Shear (kN)	Moment (kNm)
5B18	30.358	106.075	106.251
4B80	10.76	108.315	121.701
2B18	8.859	106.413	126.911

Figure 5.7 Moment in base isolated structure

Frame Label	Axial (kN)	Shear (kN)	Moment (kNm)
DK23	1449.46	114.625	304.1133
DK24	1478.234	113.863	302.091
DK25	1734.336	114.826	302.5672

Table 5.8 Maximum Internal Force in the columns of the base isolated structure

Frame Label	Axial (kN)	Shear (kN)	Moment (kNm)
DK23	1150.822	18.221	43.5811
DK24	1197.563	18.111	43.0496
DK25	1517.652	23.808	68.8114

The graphs of the internal forces are shown below :

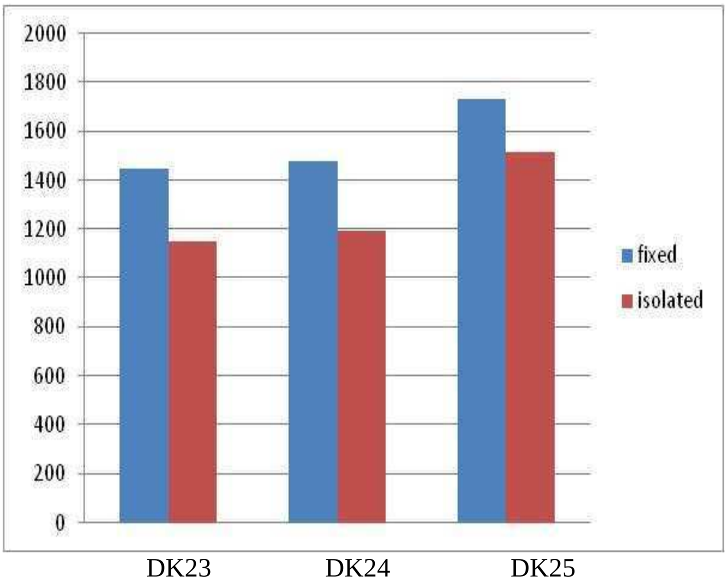


Figure 5.9 Axial force in Column

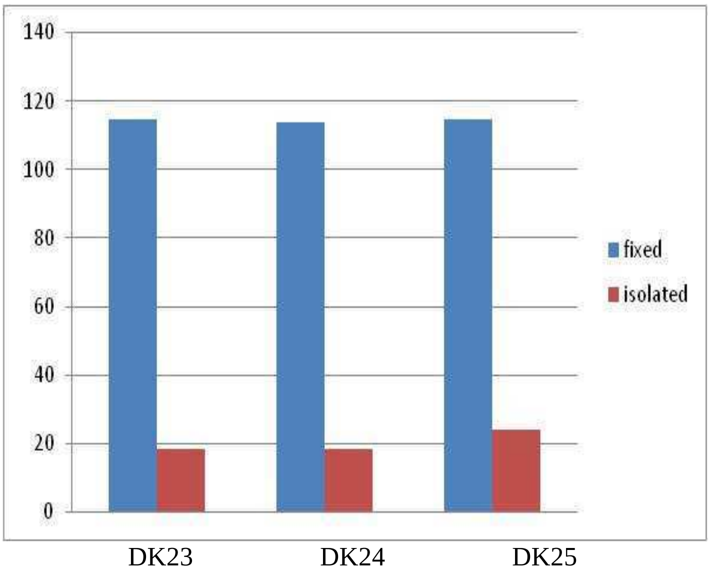


Figure 5.10 Shear in Columns

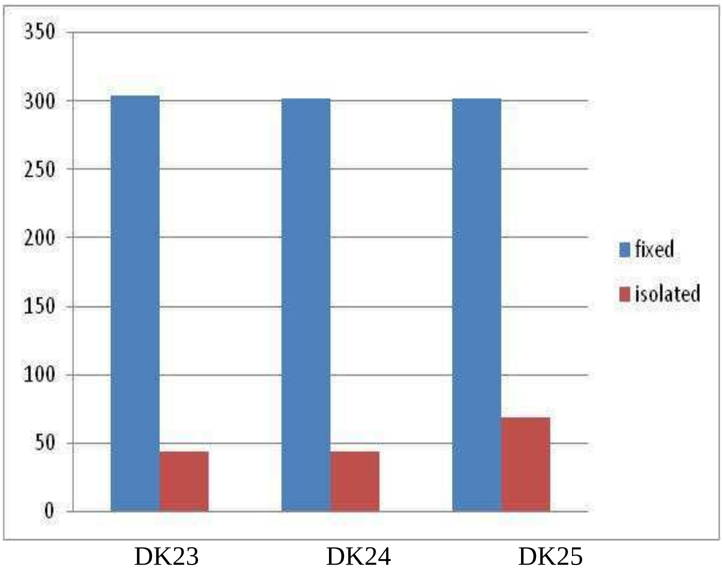


Figure 5.11 Moments in Columns

The tables and graphs above show a significant reduction in the internal forces of the base isolated structure compared to the fixed base structure. The internal forces of the beams appeared as follows: the reduction reached 57.71% for the axial force, 35.01% for the shear force, and 59.67% for the moment. As for the internal forces of the columns: the reduction reached 20.60% for the axial force, 84.10% for the shear force, and 85.75% for the moment.

Vibration Period

From the time history graphs (Figures 5.1-5.4), it can be seen that the vibrations experienced by the fixed base structure are of a higher frequency than that of the base isolated structure.

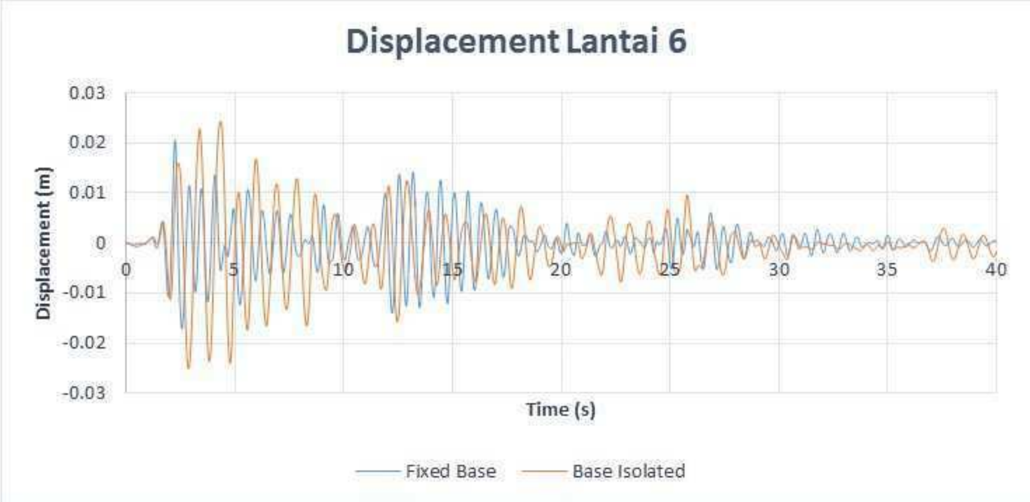


Figure 5.12 Time History graph for joint1308 (top floor)

This means that the period of vibration of the fixed base structure was lower than the period of vibration of the base isolated structure.

Table 5.9 Vibrating Period of Structures

Mode Shape	VibratingPeriod (second)		%of enhancement
	Fixed Base	Base Isolated	
1	0.7223	1.73468	140.16
2	0.62251	1.6881	171.17
3	0.60353	1.60893	166.58
4	0.41965	0.55239	31.63
5	0.41765	0.46758	11.95

The greater the vibration period of the structure, the better it is to withstand an earthquake.

6. ANALYSIS AND DISCUSSION

The conclusions of this study are as follows:

1. The use of base isolators can reduce the internal force of both beams and columns. The reductions in the internal force of beams are as follows: up to 57.71% for the axial force, 35.01% for the shear force, and 59.67% for the moment; while for columns: up to 20.60% for the axial force, 84.10% for the shear force, and85.75% for the moment.
2. The use of base isolators can reduce the relative displacement for each story in both the X and Y directions as much as 74.28% and 45.9%, respectively.
3. The use of base isolators can extend the period of vibration up to 171.17%.

The results of this research showed that there were substantial reductions in the internal force, relative displacement, and vibration period due to the use of base isolators. Therefore, in subsequent studies, analysis of structures such as beams and columns should be conducted to determine the reduction in the dimensions and reinforcements of base isolated buildings.

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