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Research Paper

Base Isolation System Planning in High Rise Building Structures

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ABSTRACT: *One of the methods used to increase the building's resistance to earthquake forces is to use a Base Isolation system which functions to isolate the structure from ground movement when an earthquake occurs. The components of the base isolation system can be applied to both low-rise building and high-rise buildings, especially in earthquake-prone areas, because they are able to properly reduce the earthquake load received by the structure. The object of this research is the Begawan Apartment Building, Malang City Grid 7 - 17. The building consists of 22 floors, the height of the building is 69.225 m, the building has a tread length and width of 78 m and 11.6 m, respectively. In this research, an isolated structure of the Lead Rubber Bearing (LRB) type will be planned. Furthermore, the structure is tested for resistance to earthquake forces using the Spectrum Response Method. The isolated structure is able to produce structural deviations with a drift ratio/drift index of 0.0021 on the main axis and -0.0035 on the non-main axis. And has a maximum shear-storey of 9666.195 kN on the ground floor, and is able to reduce the design earthquake load by 45.5%. The use of a base isolator on the structure of the Begawan Apartment Building was able to reduce the dimensions of the structural elements of the existing structure by 50,203% on the base column and by 16.570% on the main beam on the ground floor.*
KEYWORDS: *Base isolation; Lead Rubber Bearing; Respons Spektrum Analysis; High Rise Building; Earthquake*

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I. INTRODUCTION

The position of the country of Indonesia which is in the "Ring of Fire" zone or the Pacific Ring of Fire has resulted in areas in this country having high seismic activity potential. The Pacific Ring of Fire or "Ring of Fire" is an area with a high potential for earthquakes and volcanic eruptions, which surrounds the Pacific Ocean basin. Moreover, Indonesia is located above 3 (three) continental plate collisions, namely Indo-Australia in the south, Eurasia from the north, and the Pacific from the east. Large earthquakes are prone to occur in the Plate Boundaries, especially in the subduction zone. namely Sumatra and southern Java and the friction zone, namely Maluku and Papua.

Given the magnitude of the impact of damage that can be caused, it is necessary to make efforts to minimize the occurrence of damage/losses due to earthquakes. There are 3 (three) approaches that can be taken in this regard. First, namely the structural approach, by following the correct construction rules and using seismic parameters in designing buildings. Second, through regional planning by designing structural regulations related to earthquakes, one example is by making a map of the earthquake area. Third, through intensive socialization to the community regarding the impacts and ways to deal with the effects of earthquakes.

One of the methods used to increase the building's resistance to earthquake forces is to use a Base Isolation system which functions to isolate the structure from ground movement when an earthquake occurs. The components of the base isolation system can be applied to both low-rise building and high-rise buildings, especially in earthquake-prone areas, because they are able to properly reduce the earthquake load received by the structure.

The research object used is the Begawan Apartment Building, Malang City Grid 7 - 17. In general, the Begawan Apartment Building has 3 different main structures, grid 7-17 is located in the center of the site. This building uses an internal seismic resistance system in the form of the application of a core wall. Grid 7 – 17 buildings consist of 21 floors with the top floor as the Roof Top Area, the building height is 65.1 m. The building has a footprint of 78 m and 11.6 m in length and width, respectively.

In this study, an isolated structure (with a base insulator) of the Lead Rubber Bearing (LRB) type will be planned. Furthermore, the structure is tested for resistance to earthquake forces using the Spectrum Response Method. The stability of the structure with the base isolator will be controlled which includes drift, drift (drift ratio and storey drift), shear forces, and forces in structural elements. After that, an application will be planned in the form of an implementation method that can be used in accordance with the rules and regulations in the field. The conclusion of the research is obtained from the results of the analysis of the performance of the isolated structure, the design of Lead Rubber Bearing and the method of carrying out the work.

II. RESEARCH METHODS

Materials and Methods

The object of research is the Begawan Malang Apartment Building Grid 7 - 17. This building is located on Jl. Tlogomas No. 1-3, Tlogomas, Kec. Lowokwaru, Malang City.

Building Technical Data

- Building height : 68.25 m
- Elevation

Table 1. Begawan Apartment Building Elevation

Floor	Elevation	Floor	Elevation
LG Floor	-4,125	12th Floor	+36.750
Ground Floor	±0.000	13th Floor	+39.900
UG Floor	+4.200	14th Floor	+43.050
3rd Floor	+8.400	15th Floor	+46.200
4th Floor	+11.550	16th Floor	+49.350
5th Floor	+14.700	17th Floor	+52.500
6th Floor	+17.850	18th Floor	+55.650
7th Floor	+21.000	19th Floor	+58.800
8th Floor	+24.150	20th Floor	+61.950
9th Floor	+27.300	Roof Floor	+65.100
10th Floor	+30.450	Roof Top	+68.250
11th Floor	+33.600		

- Number of bay portal,
  - Length : 11
  - Transverse : 4
- Length : 65 m
- Wide : 11,6 m

Material and Material Data

The quality of the materials used is as shown in Table 2.

Table 2. Material Quality Technical Data

Material	Spesification
Flatslab Concrete	F'c = 30 Mpa
Concrete Beam + Plate	F'c = 30 Mpa
Column Concrete	F'c = 35 Mpa
Reinforcement Steel Beam + Plate	BJTD 40, BJTD 50
Column Reinforcing Steel	BJTD 40, BJTD 50

Land Investigation Data

Soil investigation in the form of 11 drill points as deep as 40 m for the purposes of Soil Test (SPT and laboratory test) and 10 points of light sondir.

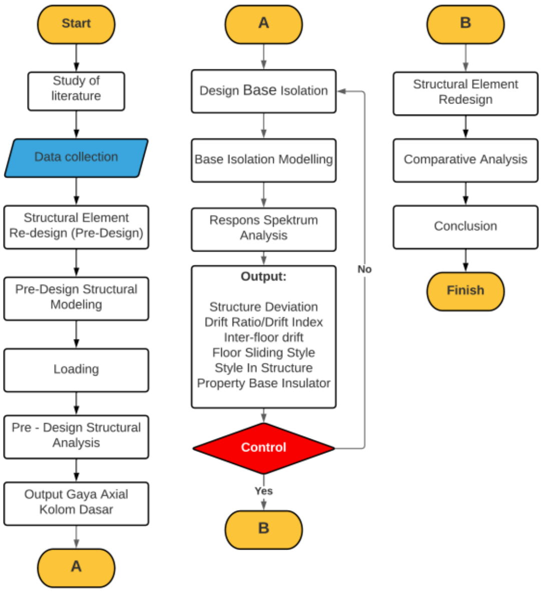
Table 3. N Value Recapitulation

No	Drilling Point	N Value
1	DB1	15,48935
2	DB2	12,66645
3	DB3	19,21225
4	DB4	17,40647
5	DB5	17,44575
6	DB6	14,09308
7	DB7	14,99703
8	DB8	19,9923
9	DB9	17,29058
10	DB10	62,52704
11	DB11	72,10682
	Average	**25,74792**

From the table above, it can be concluded that the Begawan Apartment Building has a site class of Medium Land (SD).

Planning Flowchart

The planning flow chart is displayed as shown below,



III. RESULTS AND DISCUSSION

Pre-designed Beam and Column Dimension Planning Portland Cement

Table 4. Recapitulation of Beam and Column Dimensions

Type	Description	L (mm)	Dimention
BI 1	Length	6500	60/40
BI 2	Transvers 1	6550	60/40
BI 3	Transvers 2	3750	40/35
K1 A	*Ground - UG Floor*	4200	50/80
K1 B	*3rd – 12th Floor*	3150	50/80
K2	*15th – 18th Floor*	3150	45/75
K3	*19th - Roof Floor*	3150	40/70

Rigid Floor Planning

Rigid floor is a moving medium between the Base Insulator and the upper structure of the building, the thickness dimensions of the rigid floor are 900 mm with the following reinforcement:

Table 4. Rigid Floor Reinforcement

Direction	Reinforcement	
	Support	Fields
X	Major D25-100 mm Minor D13-100 mm	Major D25-100 mm Minor D13-100 mm
Y	Major D25-100 mm Minor D13100 mm	Major D25-100 mm Minor D13-100 mm

Loading

- Dead Load

The dead load of the structure consists of the self-weight of the structural elements which is calculated automatically through the ETABS assistance program.

Table 5. Superimposed Dead Load

No	Superimposed Dead Load	Weight (kn/m^3)
1	Ceramic	0,022
2	Sand	0,16
3	*Spesi*	0,66
4	Mechanical Electrical	0,25
5	Ceiling and Hangers	0,2
	Total	1,292

- Live Load
  The live load used for the floor is 1.92 kN/m2 and the live load for the roof floor is 0.96 kN/m2.

- Earthquake Loads

Based on Table 3 of SNI 1726:2019, the Begawan Apartment Building is included in the Risk Category II (Apartment Buildings / Flats).

- Earthquake Priority Factor (I_e) =1,0
- Site Clasification = Medium Soil (SD)
- Parameters of Earthquake Spectral Acceleration (S_s & S_1)
  S_s = 0,856835 g
  S_1 = 0,401391 g
- Site Amplification Factor (F_a & F_v)
  F_a = 1,157266
  F_v = 1,898609
- Spectrum Respons Accelerations (S_{MS} & S_{M1})
  S_{MS} = F_a . S_s
  = 1,157266 . 0,856835
  = 0,991586 g
  S_{M1} = F_v . S_1
  = 1,898609 . 0,40139
  = 0,762085 g
- Design Spectral Acceleration Parameters (S_{DS} & S_{D1})
  S_{DS} = 2/3 . S_{MS}
  = 2/3 . 0,991586 g
  = 0,661057 g
  S_{D1} = 2/3 . S_{D1}
  = 2/3 . 0,762085 g
  = 0,508056 g
- Seismic Design Category (D)

Base Isolation Plan

- Preliminary Design Data

Table 7. Preliminary Design Base isolation data

Data	Value	Unit
Total *Base isolator*	105	unit
Largest Base Column Axial Force	12426	kn
Total Base Column Axial Force	308971	kn
Rubber Modulus, G	1	mpa
Gravity Acceleration, g	9,81	m/s^2
Rubber Shear Stretch, y	1,5	
Strong Melt, u	10	mpa
DBE earthquake target period, TD	2,5	s
Target MCE earthquake period, TM	2,7	s
Earthquake Spectral Acceleration DBE T 1 s, SD1	0,508056	
Damping Ratio, β	23%	

Base Isolation Structure Analysis

• Structural Deviation

In a structure with an isolation base, there are 2 (two) types of deviation, namely absolute deviation (difference at each center of mass of the structure from its initial position to its final position) and relative deviation (difference at each center of mass of the structure after the displacement is reduced by the base isolation deviation). The basic relative deviation of the structure with a base insulator, in the main direction is 147.6260 mm and the non-main direction is -244.2520 mm, with the following graph.

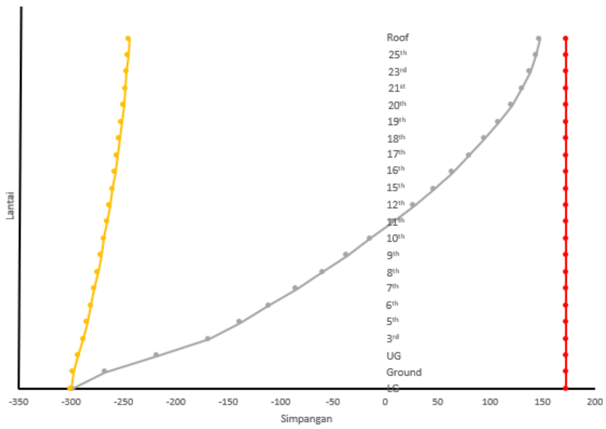


Figure 1. Graph of Structure Deviation

- Drift Ratio / Drift Index

The drift ratio/drift index requirement, based on the International Building Code 2015 Section 1613 (Earthquake Loads) does not exceed 0.0025.

Table 8. *Drift Index/Ratio*

Direction	Drift	Drift Index	Spesification	
X	147,626	0,00213	0,0025	OK
Y	-244,252	-0,0035	0,0025	OK

- Interstorey Drift

Based on the results of the analysis and control obtained, the value of the deviation between floors in both directions has met the value of the deviation between the floors of the permit, with the following graph.

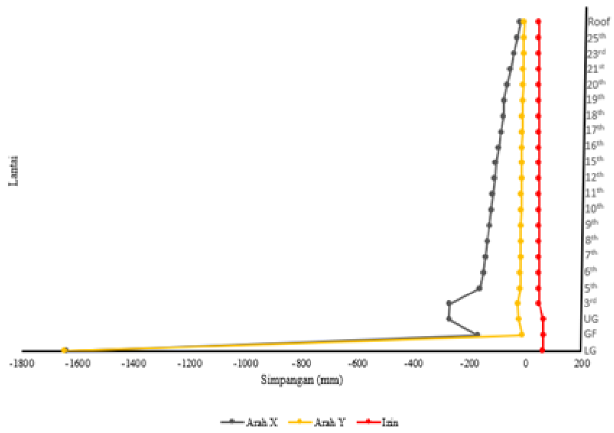


Figure 2. Graph of Interstorey Drift

- Shear Storey

Based on the analysis through ETABS, the maximum floor shear-force of the structure at combination loading 3 is 1.2DL + LL – 1EX -0.3 EY.

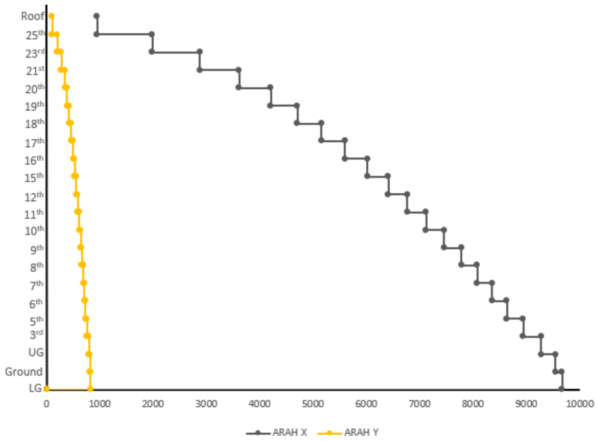


Figure 5. Shear Storey Force Graph

The result of the largest shear force of 9666.195 Kn is controlled by the design earthquake load to get the effectiveness of the base isolator

Earthquake Load Reduction due to Base insulator:

= Vbase - Vu

= 17739 Kn – 9666,195 Kn

= 8072,85 Kn

Reduction Percentage

$$= \frac{\Delta V}{Vbase} x100\%$$

$$= \frac{8072,85}{17739} x100\%$$

= 45,5 %

- Column Axial Force Control

As for the review of Column 1A on the Ground Floor, Column 1B on the 3rd Floor, Column 2 on the 15th Floor and Column 3 on the 19th Floor. The largest column axial force was obtained at 6555.8247 Kn on Column 20 Ground Floor, and the results of the review recap are as follows,

Table 9. Recapitulation of Column Axial Force

Column	Floor	Column reviewed	P (kN)
K3	19th-Roof	C17	-1703,4
K2	15th-18th	C17	-2930,6
K1B	3rd-12th	C20	-5845,6
K1A	GF-UG	C20	-6555,8

- Comparison of Existing Structural Elements with Isolated Structure

In this section, the structural elements that are reviewed are the main beam with the largest moment (Mu) and the ground floor column with the largest axial force (Pu), then the results of the analysis of the elements under review are compared with the existing structural elements.

Table 10. Recapitulation of Reduction Comparison of Structural Elements of Column Beams

Note	Dimention	Beam Reinforced		Mn
		Support	Fields	kN
Existing	40/70	10D22	5D22	865,8
Redesign	40/60	10D22	5D22	722,4
Reduction Ratio		16,570%		
Note	**Dimention**	**Column Reinforced**		**Pn**
		Major	Minor	kN
Existing	125/50	22D32	ST : 4D13-100 LT : D13-100	136,83
Redesign	80/50	26D25	-	501,09
Reduction Ratio		50,203%		

IV. CONCLUSIONS AND SUGGESTIONS

Conclusion

• Base insulator planning needs to consider the minimum vertical load that can be received by the base isolation, the target period determined from the base isolation system, and the deviation of the base isolation plan. The dimensions of the base isolation with a total thickness of 303 mm consist of 23 layers of elastomer with a thickness of 11.435 mm in which there is shim steel with a thickness of 4 mm and a rubber diameter of 1000 mm and a lead plug diameter of 250 mm with a total of 105 base isolation used.

• The isolated structure is capable of producing structural deviations with a drift ratio/drift index of 0.0021 on the main axis and -0.0035 on the non-main axes. This value has met the requirements based on SNI 1726:2019 (Earthquake Resistance Planning Procedures for Building and Non-Building Structures) and International Building Code 2015 Section 1613 (Earthquake Loads). And has a maximum shear-storey of 9666.195 kN on the ground floor, and is able to reduce the design base earthquake load by 45.5%.

• The use of a base isolation on the structure of the Begawan Apartment Building was able to reduce the dimensions of the structural elements of the existing structure by 50.203% on the base column and by 16.570% on the main beam on the ground floor.

Suggestions

• It is necessary to conduct a cost calculation study between the existing structure and the isolated structure in order to determine the effectiveness in terms of budget costs due to the reduction in the dimensions of the beam column.

• It is necessary to conduct an experimental test of the building structure with a base isolation, for example through the use of a shake-table test in the laboratory in order to know the behavior of the isolated structure in real terms.

• It is necessary to conduct research on the effect of using a base isolator on the building structure using other non-linear analysis methods such as dynamic analysis of time history (time history analysis) and static analysis of thrust loads (pushover analysis) so that the analysis results obtained are more actual and can be seen. hysteresis behavior of the base isolator.

• Building structures with base isolation are proven analytically capable of reducing earthquake forces received by the structure, so that they are appropriate to be applied to building structures that have a high level of urgency such as the Emergency Center Building (Hospital), buildings with high human activity (Schools, hotels), meeting halls etc., buildings for storing units of high value goods (museums, banks, etc.) as well as buildings with dangerous impacts in case of damage (nuclear reactors, power plants etc.).

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