



Comparison of Sliding Wall Double System Structure Design Special Moment Bearing Frame (SRPMK) with Basic Insulation System

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ABSTRACT

Indonesia is in an earthquake-prone zone; therefore, building structures must be designed to be earthquake-resistant. This research aims to evaluate the effectiveness of base isolation systems in enhancing the seismic performance of buildings. Specifically, the study compares the structural performance of buildings equipped with base isolation systems to those without, utilizing earthquake analysis spectrum response methods. The case study focuses on a 22-story apartment building, analyzed using ETABS V.18 software. The results indicate a significant increase in the period of buildings with base isolation systems. Although such structures exhibit notable lateral displacement, the inter-story drift remains relatively small. Furthermore, the base moment in buildings with base isolation systems is generally lower compared to those without, suggesting that base isolation can effectively reduce the seismic forces experienced by the structure.

Keywords: Basic Isolation, Earthquake, Response Spectrum, Period, Displacement, Moment, ETABS.

INTRODUCTION

High-rise buildings are very much built today because they are considered more effective and efficient with existing land conditions (Firmansyah & Machmoed, 2019; Handayani et al., 2022; Liando et al., 2020). The increasing population but increasingly limited land use is a new problem in the current modernization era. In building a building intended for large usability capacity with inadequate land conditions, tall buildings are chosen as one solution to overcome the problem (Agus & Cahya, 2022; Hasibuan & Ma'arif, 2022; Setiawan et al., 2021).

The rapid expansion of high-rise buildings constructed with reinforced concrete is evident in various types of infrastructure, including offices, hospitals, educational facilities, shopping centers, hotels, and apartments (Amin et al., 2019; Pranata et al., 2021). This trend underscores

the increasing reliance on reinforced concrete for structural integrity and durability. However, this widespread adoption also brings forth critical challenges, particularly in ensuring that these structures can withstand external loads and forces over time (Firmansyah & Machmoed, 2019; Honarto et al., 2019). The fundamental issue lies in the precise calculation and consideration of these loads during the structural planning phase, which is crucial to prevent structural failures and ensure safety and longevity (Hassoun & Al-Manaseer, 2020; Martins et al., 2020; Sakti et al., 2022).

The higher a building is, the higher the risk of collapse. Therefore, in building a tall building structure has more complex requirements (Firmansyah & Machmoed, 2019; Maknun & Rosdiyani, 2021). If the building is erected in Indonesia, then the building must meet the requirements of the Indonesian National Standard (SNI) (Rahmawati & Basri, 2019; Santoso & Astawa, 2022; Wicaksana & Rosyidah, 2021).

A reinforced concrete structure is a construction system that uses a combination of concrete and reinforcing steel to form a structure that is strong and resistant to loads. Reinforced concrete structures have high strength and good resistance to loads (Subramani & Shanmuganandam, 2018).

Using a base insulation system, such as the combined SRPMK (Special Reinforced Moment-Resisting Portal) and Sliding Wall system, offers significant benefits in enhancing structural resilience against shear forces (Hasibuan & Ma'arif, 2022; Solikin & Balich, 2023). This dual system optimizes the distribution of shear forces through the interaction between the portal frame and the sliding wall, which have distinct deflection behaviors (Nugroho, 2017). Under lateral loads, the sliding wall primarily bends, while the portal frame undergoes sliding deformation (Suryanita, 2020). Consequently, the frame efficiently bears the shear forces at the top, and the sliding wall at the bottom, leading to an improved overall stability and increased capacity to withstand shear forces, thereby enhancing the structural integrity and safety of buildings.

RESEARCH METHODS

In this study, the method used begins with a literature study and data collection related to the topic to be studied. Furthermore, loading planning is carried out including live loads, dead loads, and earthquake loads. The next stage is the modelling of the SRPMK-Sliding Wall double structure using two approaches, namely without and using base insulators. The result of this modelling is the output of internal forces such as moment, latitude, and axial. Then a repeat calculation is carried out based on the output. The results of this analysis were then compared to see the difference in the structural behavior of the two models. Finally, conclusions and suggestions are given based on the results of the analysis carried out.

In this study, there are several formulations of problems discussed, namely procedures for planning building structures using the SRPMK dual system with Sliding Walls, earthquake load calculation procedures with the Spectrum Response method, and the results of comparison of structural planning using Base Insulators with without Base Insulators. The purpose and purpose of writing this research is to compare the design of the special moment bearing frame double system structure (SRPMK)-sliding wall with the basic insulation system and design supporting structural elements based on reference books, regulations, and building structure planning standards applicable in Indonesia. Other objectives include planning the loading of building structures such as live loads, dead loads, and earthquake loads, conducting structural modelling using ETABS V.18 software, and conducting structural analysis from modelling to obtain dimensions of structural components.

RESULTS AND DISCUSSION

Model analysis is an analysis that determines the dynamic behavior of a structure at the time of an earthquake in the form of natural frequency, damping factors and the form of deformation that occurs. Below is a model analysis for structures that use basic insulation without using basic insulation.

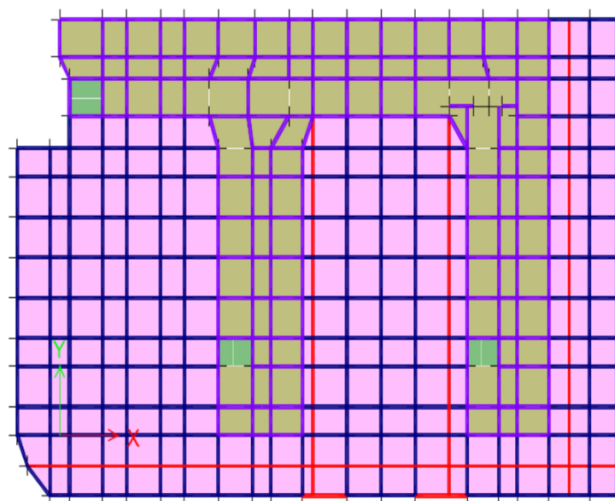


Figure 1. Ground Floor Plan

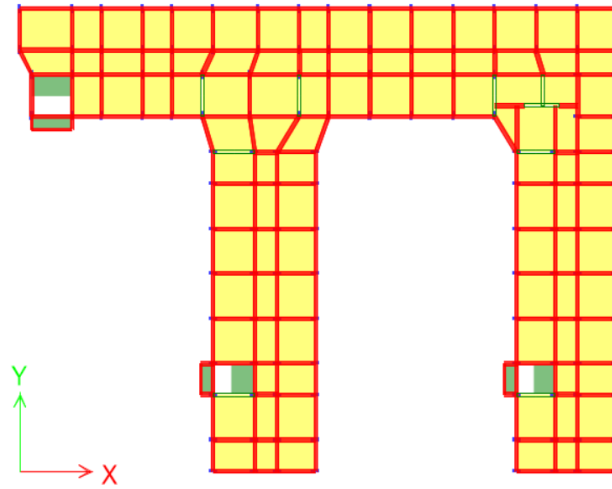


Figure 2. 1st Floor Plan – Roof

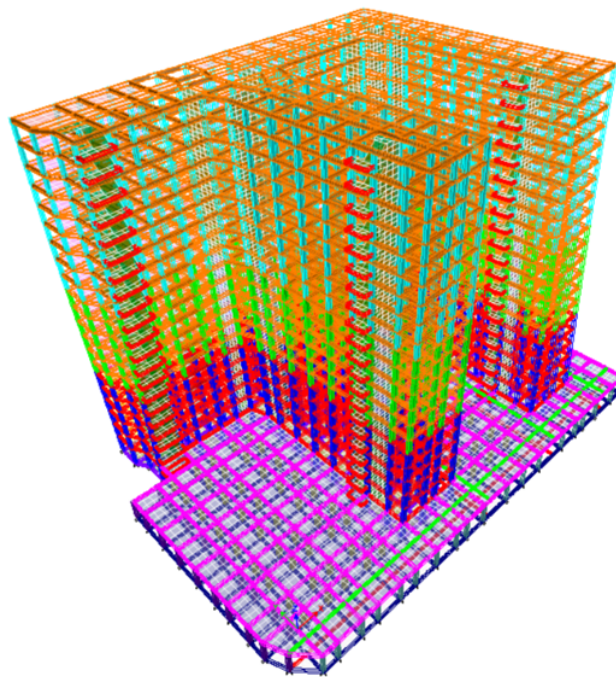


Figure 3. First Model Form without the use of Basic Insulation

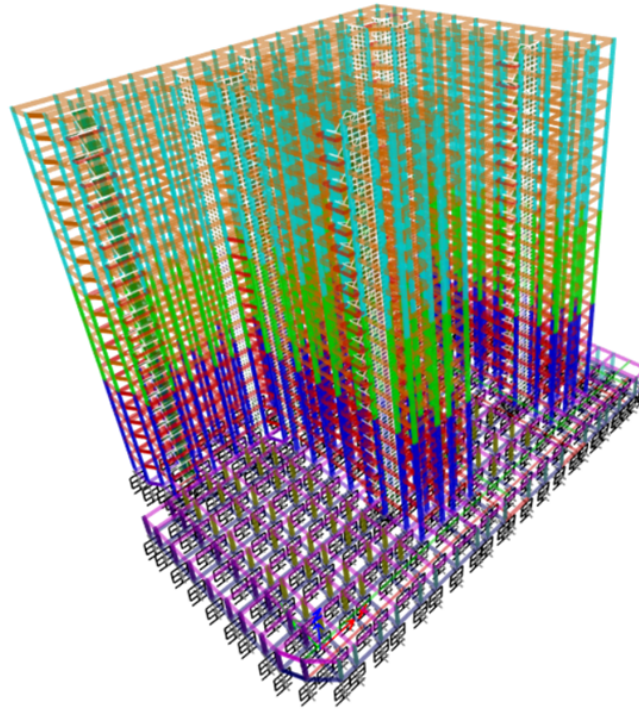


Figure 4. First Model Form using Basic Insulation

The model shape of each pedestal type can be seen in Figures 2 and 3 with different displacement shapes from each other. It can be seen that structures that use basic insulation experience considerable lateral displacement compared to structures without basic insulation, but structures that use basic insulation have a fairly small inter-floor deviation compared to structures without basic insulation. The natural period value of the basic isolation type structure in the 1st mode period is 3.778 seconds, greater than the structure without basic insulation with the 1st mode period of 1.605 seconds. The results of the comparison of basic and no basic insulation type model analysis for each mode are as follows:

Table 1. Comparison of Structural Value using Base Isolation and Structure without Base Isolation

Case	Mode	STRUCTURE WITHOUT BASE ISOLATION	STRUCTURE USING BASE ISOLATION
Modal	1	1,605	3,778
Modal	2	1,500	3,571
Modal	3	1,420	3,373
Modal	4	0,513	3,312
Modal	5	0,463	2,931
Modal	6	0,417	2,774

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Modal	7	0,275	2,497
Modal	8	0,239	2,425
Modal	9	0,207	1,398
Modal	10	0,180	1,281
Modal	11	0,153	1,242
Modal	12	0,130	0,913
Modal	13	0,129	0,784
Modal	14	0,108	0,453
Modal	15	0,100	0,235
Modal	16	0,092	0,131
Modal	17	0,084	0,110
Modal	18	0,082	0,105
Modal	19	0,072	0,095
Modal	20	0,068	0,085
Modal	21	0,067	0,084
Modal	22	0,059	0,073
Modal	23	0,057	0,069
Modal	24	0,056	0,068
Modal	25	0,050	0,059
Modal	26	0,048	0,057
Modal	27	0,047	0,057
Modal	28	0,044	0,050
Modal	29	0,041	0,048
Modal	30	0,040	0,047

From the table above, it can be concluded that structures that use basic isolation provide a greater period value than structures without basic insulation.

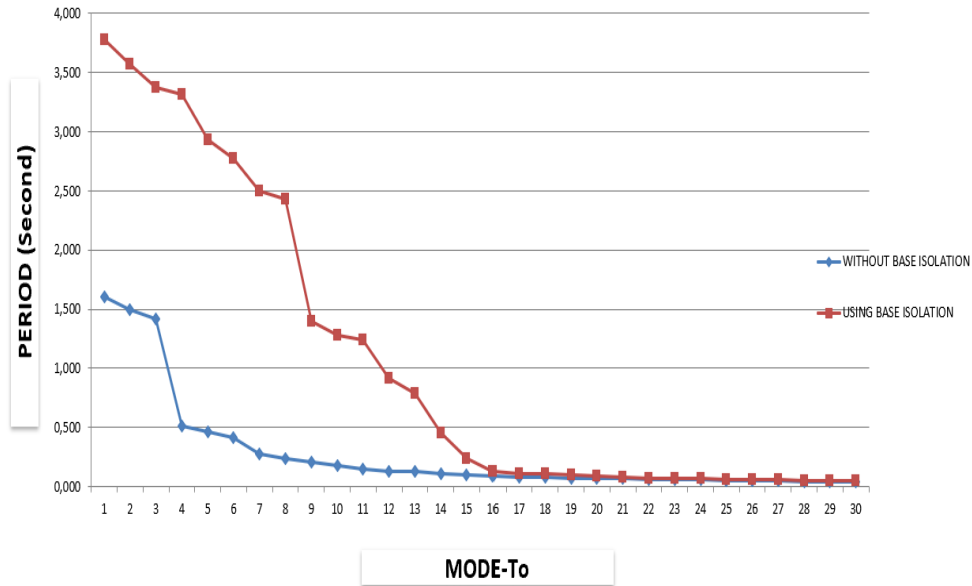


Figure 5. Period Comparison Chart

Table 2. Displacement & Interchange Between Floors X-Direction Permits for Structures Without the Use of Insulation

Story	Load/Case Combo	Direction	Displacement mm	Drift	Cd/Ie	Drift x Cd/Ie	Δ Izin	Cek
ATAP	SPECX	X	70	0.001121	5.5	0.006166	0.02	OK
STORY20	SPECX	X	67	0.001159	5.5	0.006375	0.02	OK
STORY19	SPECX	X	65	0.001198	5.5	0.006589	0.02	OK
STORY18	SPECX	X	62	0.001240	5.5	0.006820	0.02	OK
STORY17	SPECX	X	60	0.001307	5.5	0.007189	0.02	OK
STORY16	SPECX	X	61	0.001375	5.5	0.007563	0.02	OK
STORY15	SPECX	X	54	0.001435	5.5	0.007893	0.02	OK
STORY14	SPECX	X	50	0.001488	5.5	0.008184	0.02	OK
STORY13	SPECX	X	47	0.001516	5.5	0.008338	0.02	OK
STORY12	SPECX	X	43	0.001556	5.5	0.008558	0.02	OK
STORY11	SPECX	X	40	0.001592	5.5	0.008756	0.02	OK

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STORY10	SPECX	X	36	0.001625	5.5	0.008938	0.02	OK
STORY9	SPECX	X	32	0.001652	5.5	0.009086	0.02	OK
STORY8	SPECX	X	28	0.001668	5.5	0.009174	0.02	OK
STORY7	SPECX	X	25	0.001655	5.5	0.009103	0.02	OK
STORY6	SPECX	X	21	0.001638	5.5	0.009009	0.02	OK
STORY5	SPECX	X	17	0.001591	5.5	0.008751	0.02	OK
STORY4	SPECX	X	13	0.001502	5.5	0.008261	0.02	OK
STORY3	SPECX	X	10	0.001395	5.5	0.007673	0.02	OK
STORY2	SPECX	X	6	0.001170	5.5	0.006435	0.02	OK
STORY1	SPECX	X	2	0.000530	5.5	0.002915	0.02	OK

**Table 3. Displacement & Interchange Between Floors Y-Direction Permit for Structures
Without the Use of Insulation**

Story	Load/Case Combo	Direction	Displacement		Drift	Cd/le	Drift x	Δ	Cek
			mm				Cd/le		
ATAP	SPECY	Y	72	0.001353	5.5	0.007442	0.02	OK	
STORY20	SPECY	Y	70	0.001422	5.5	0.007821	0.02	OK	
STORY19	SPECY	Y	67	0.001500	5.5	0.008250	0.02	OK	
STORY18	SPECY	Y	65	0.001582	5.5	0.008701	0.02	OK	
STORY17	SPECY	Y	62	0.001659	5.5	0.009125	0.02	OK	
STORY16	SPECY	Y	59	0.001729	5.5	0.009510	0.02	OK	
STORY15	SPECY	Y	55	0.001789	5.5	0.009840	0.02	OK	
STORY14	SPECY	Y	52	0.001843	5.5	0.010137	0.02	OK	
STORY13	SPECY	Y	49	0.001867	5.5	0.010269	0.02	OK	
STORY12	SPECY	Y	45	0.001906	5.5	0.010483	0.02	OK	
STORY11	SPECY	Y	41	0.001940	5.5	0.010670	0.02	OK	

STORY10	SPECY	Y	38	0.001969	5.5	0.010830	0.02	OK
STORY9	SPECY	Y	34	0.001985	5.5	0.010918	0.02	OK
STORY8	SPECY	Y	30	0.001984	5.5	0.010912	0.02	OK
STORY7	SPECY	Y	26	0.001938	5.5	0.010659	0.02	OK
STORY6	SPECY	Y	22	0.001876	5.5	0.010318	0.02	OK
STORY5	SPECY	Y	18	0.001751	5.5	0.009631	0.02	OK
STORY4	SPECY	Y	14	0.001549	5.5	0.008520	0.02	OK
STORY3	SPECY	Y	10	0.001412	5.5	0.007766	0.02	OK
STORY2	SPECY	Y	7	0.001205	5.5	0.006628	0.02	OK
STORY1	SPECY	Y	2	0.000592	5.5	0.003256	0.02	OK

Table 4. Displacement & Interchange Between Floors X Direction Permit for Structures Using Insulation

Story	Load/Case Combo	Direction	Displacement mm	Drift	Cd/le	Drift x Cd/le	Δ Izin	Cek
ATAP	SPECX	X	120	0.002121	5.5	0.011666	0.02	OK
STORY20	SPECX	X	117	0.002159	5.5	0.011875	0.02	OK
STORY19	SPECX	X	115	0.002198	5.5	0.012089	0.02	OK
STORY18	SPECX	X	112	0.002240	5.5	0.012320	0.02	OK
STORY17	SPECX	X	110	0.002307	5.5	0.012689	0.02	OK
STORY16	SPECX	X	111	0.002375	5.5	0.013063	0.02	OK
STORY15	SPECX	X	104	0.002435	5.5	0.013393	0.02	OK
STORY14	SPECX	X	100	0.002488	5.5	0.013684	0.02	OK
STORY13	SPECX	X	97	0.002516	5.5	0.013838	0.02	OK
STORY12	SPECX	X	93	0.002556	5.5	0.014058	0.02	OK
STORY11	SPECX	X	90	0.002592	5.5	0.014256	0.02	OK

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STORY10	SPECX	X	86	0.002625	5.5	0.014438	0.02	OK
STORY9	SPECX	X	82	0.002652	5.5	0.014586	0.02	OK
STORY8	SPECX	X	78	0.002668	5.5	0.014674	0.02	OK
STORY7	SPECX	X	75	0.002655	5.5	0.014603	0.02	OK
STORY6	SPECX	X	61	0.002638	5.5	0.014509	0.02	OK
STORY5	SPECX	X	57	0.002591	5.5	0.014251	0.02	OK
STORY4	SPECX	X	43	0.002502	5.5	0.013761	0.02	OK
STORY3	SPECX	X	40	0.002395	5.5	0.013173	0.02	OK
STORY2	SPECX	X	26	0.002170	5.5	0.011935	0.02	OK
STORY1	SPECX	X	12	0.001530	5.5	0.008415	0.02	OK

Table 5. Displacement & Interchange Between Floors Y-Direction Permit for Structures Using Insulation

Story	Load/Case Combo	Direction	Displacement mm	Drift	Cd/Ie	Drift x Cd/Ie	Δ Izin	Cek
ATAP	SPECY	Y	123	0.002353	5.5	0.012942	0.02	OK
STORY20	SPECY	Y	120	0.002422	5.5	0.013321	0.02	OK
STORY19	SPECY	Y	117	0.002450	5.5	0.013475	0.02	OK
STORY18	SPECY	Y	115	0.002582	5.5	0.014201	0.02	OK
STORY17	SPECY	Y	112	0.002659	5.5	0.014625	0.02	OK
STORY16	SPECY	Y	109	0.002729	5.5	0.015010	0.02	OK
STORY15	SPECY	Y	105	0.002789	5.5	0.015340	0.02	OK
STORY14	SPECY	Y	102	0.002843	5.5	0.015637	0.02	OK
STORY13	SPECY	Y	99	0.002867	5.5	0.015769	0.02	OK
STORY12	SPECY	Y	95	0.002906	5.5	0.015983	0.02	OK
STORY11	SPECY	Y	91	0.002940	5.5	0.016170	0.02	OK

STORY10	SPECY	Y	89	0.002969	5.5	0.016330	0.02	OK
STORY9	SPECY	Y	84	0.002985	5.5	0.016418	0.02	OK
STORY8	SPECY	Y	80	0.002984	5.5	0.016412	0.02	OK
STORY7	SPECY	Y	86	0.002938	5.5	0.016159	0.02	OK
STORY6	SPECY	Y	72	0.002876	5.5	0.015818	0.02	OK
STORY5	SPECY	Y	68	0.002751	5.5	0.015131	0.02	OK
STORY4	SPECY	Y	54	0.002549	5.5	0.014020	0.02	OK
STORY3	SPECY	Y	40	0.002412	5.5	0.013266	0.02	OK
STORY2	SPECY	Y	27	0.002205	5.5	0.012128	0.02	OK
STORY1	SPECY	Y	17	0.001592	5.5	0.008756	0.02	OK

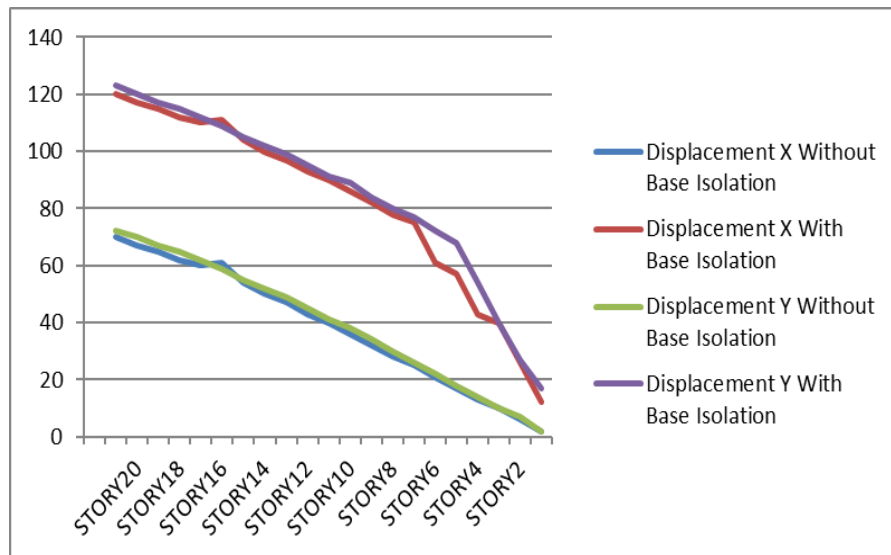


Figure 6. Comparative Graph of Displacement of X direction and Y direction Buildings Using Basic Insulation and Buildings Without Using Basic Insulation

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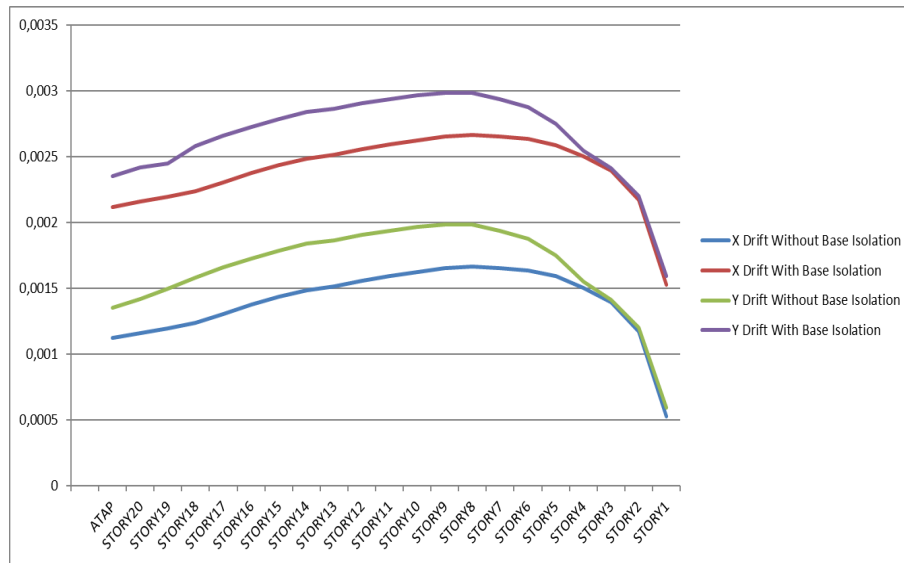


Figure 7. Comparative Graph of Deviation of the X direction and Y direction Buildings Using Basic Insulation and Buildings Without Using Basic Insulation

Table 6. Comparison of Beam Moment Values in Structures Using Base Isolation and Structures Without Base Isolation

FLOOR	MOMENT WITHOUT BASE ISOLATION	MOMENT USING BASE ISOLATION
	kN.m	kN.m
Roof	343,584	171,792
20	355,367	177,683
19	361,467	180,733
18	365,578	182,789
17	373,267	186,633
16	378,588	189,294
15	384,258	192,129
14	389,786	194,893
13	390,089	195,044
12	409,998	204,999

11	420,637	210,318
10	421,327	210,663
9	427,778	213,889
8	429,478	214,739
7	430,969	215,484
6	447,090	223,545
5	453,123	226,561
4	455,238	227,619
3	467,758	233,879
2	468,168	234,084
1	469,975	234,987

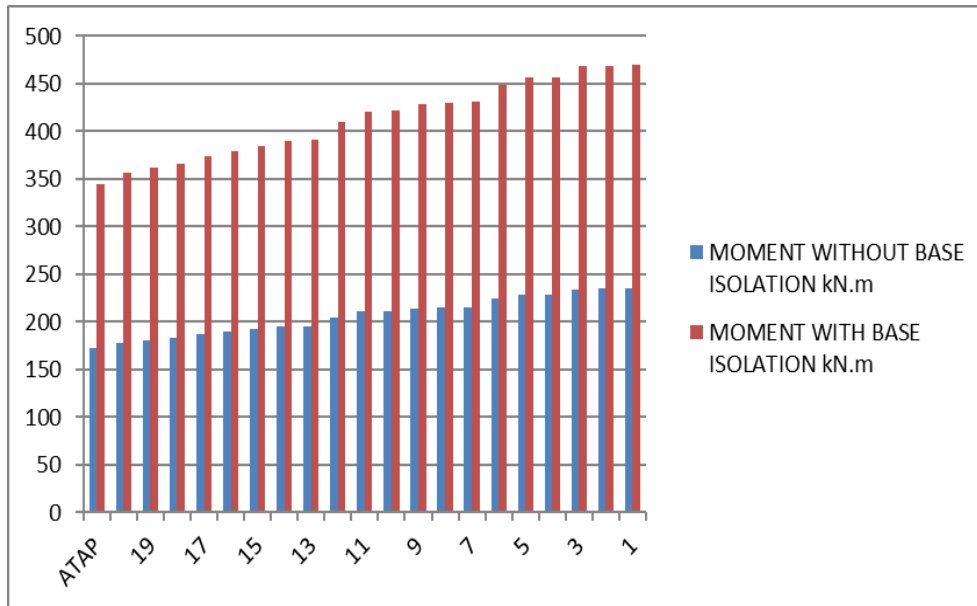


Figure 8. Comparison Diagram of the Moment of Buildings Using Basic Insulation and Buildings Without Using Basic Insulation

Table 7. Comparison Results of Special Moment Resisting Frame with Shear Wall (SRPMK) System Without Using Base Isolation and System Using Base Isolation

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NO.	DATA	BUILDING WITHOUT USING BASE ISOLATION	BUILDING USING BASE ISOLATION
1	Risk Category		II
2	Priority Factor (Ie)		1
3	Mapped Acceleration Spectral:		
	Ss		0,7806
	S1		0,3823
4	Site Class		SE
5	Site Class Coefficient:		
	Fa		1,8776
	Fv		1,9177
6	Acceleration Response Spectrum:		
	SDS		0,6200
	SD1		0,4900
7	Seismic Design Category (KDS)		D
8	Lateral System	SRPMK Dual System with Special Reinforced Concrete Walls	
9	Koefesien Modifikasi Respons [®]		7
10	System Stronger Factor (W0)		2,5
11	Deflection Magnification Factor (Cd)		5,5
12	Period Structure		
	Tx model	1,6050	3,7780
	Ty model	1,5000	3,5710
	Cu . Ta		1,6251
13	Koefesien Respons Seismik		
	Cs = SDS/(R/Ie)		0,0886
	Cs max = SD1/(Ta/(R/Ie))	2,1371	2,1106
	Cs min = 0.044*SDS*Ie		0,0273
	Cs used	0,0886	0,0886
14	Seismic Weight (W)	389725,1433 kN	
15	Minimum Design Base Shear $V=0.85*Cs*W$	29340,7358	
16	Calculated Base Shift on Model:		
	Vx = Cs . W	34518,5127 kN	34518,5127 kN
	Vy = Cs . W	34518,5127 kN	34518,5127 kN
17	Column		
	Pu	10312,5259 kN	10312,5259 kN
	Mx	502,8902 kN.m	215.890 kN.m
	My	684,8079 kN.m	271.807 kN.m
	Vx	405,731 kN	231.944 kN
	Vy	310,768 kN	156.678 kN

18	Beam		
	M max (+)	439.975 kN.m	220.677 kN.m
	M min (-)	469.975 kN.m	234.987 kN.m
	V max (+)	299.759 kN	200.578 kN
	V min (-)	329.867 kN	220.564 kN

CONCLUSION

Based on the analysis, several key conclusions can be drawn. First, planning building structures with a Dual System using Special Moment Resisting Frames (SMRF) and special reinforced concrete shear walls involves crucial steps to ensure the structure can withstand gravity and lateral loads while meeting safety standards, including modeling with ETABS V.18. Second, calculating earthquake loads using the Response Spectrum method involves identifying earthquake parameters, dynamic analysis, and distributing earthquake forces. Third, comparing structures with and without base isolation shows that base isolation, such as Lead Rubber Bearings, significantly increases the natural vibrating period by 2-3 times, reduces inter-floor drift by 8.57%, and makes the structure more rigid during an earthquake, thereby reducing the need for reinforcement and preventing excessive damage. These conclusions emphasize the importance of careful planning and advanced methods in earthquake-resistant building design.

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