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THE EFFECT OF SEISMIC ISOLATION SYSTEM TYPE FRICTION PENDULUM SYSTEM (FPS) ON A 12-STOREY APARTMENT HIGHRISE BUILDING IN BANJARMASIN, SOUTH KALIMANTAN

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ABSTRACT

Indonesia is a region that is prone to earthquake. To minimize the damage done to the structure, one way it to use a Base Isolation. One type of Base Isolation is Friction Pendulum System (FPS). Considering Banjarmasin City is now in an earthquake zone, the implementation of FPS can reduce the damage done to the structure with the usage of FPS. Therefore this research will discuss the behavior of structures by comparing fixed-base with friction pendulum system. The research adheres to SNI 1726:2019, SNI 1727:2020, dan SNI 2847:2019 to facilitate the analysis the research utilize SAP2000 program. The research utilizes concrete with a compressive strength of 30 MPa and rebars with yield strengths of 420 MPa and 280 MPa. It's revealead that the base shear remained nearly identical between the fixed-base and FPS-isolated structures, with the FPS structure experiencing a slight increase (0.05%). Additionally, the use of FPS amplified interstory drift by up to 53%, while offering a beneficial reduction of up to 38% in beam internal forces.

Keywords: *Base Isolation, Friction Pendulum System, SRPMK, Fixed Base, Vibration Period, Displacement, Base Shear, Deflection*

1. INTRODUCTION

Indonesia is an archipelagic country located along three global earthquake belts, making it a seismic-prone area (Setio et al., 2012). Stated by (Budiono & Adelia, 2015) the use of isolation systems in conventional structures simplifies the design process of the superstructure, as the procedures for designing isolated structures are more flexible. The author is interested in studying the effect of the Seismic Isolation System using the Friction Pendulum System (FPS) on a 12-story high-rise apartment building in Banjarmasin, South Kalimantan.

2. THEORITICAL STUDY

Preliminary Design of Structural Elements

Preliminary design is the initial stage of planning a multi-story building structure to obtain effective and strong dimensions. In conducting the preliminary design for each structural element, calculations are made based on the requirements of SNI 2847:2019.

Loads of the Structural Building

The loading on the structure refers to the regulations of SNI 1727:2020 and SNI 1726:2019 for buildings and other structures. The load combinations and resistance factors are based on the FPS concept in SNI 1726:2019.

Equivalent Static Analysis

The equivalent static analysis is a method used in building structure design to estimate the effects of earthquakes by simplifying dynamic seismic forces into equivalent static forces.

Check of Structure Stability

The control of structural behavior is guided by SNI 1726:2019, which outlines the Seismic Resistance Design Procedures for Building and Non-Building Structures. It includes the control of mass participation, structural vibration period, base shear forces, and inter-story drift.

Implementation of the Base Isolation System using the Friction Pendulum System (FPS) with Software.

The stages of modeling the base isolator in the SAP2000 program are as follows:

a) Model the placement of the base isolator by navigating to: Define – Section Properties – Link/Support Properties.

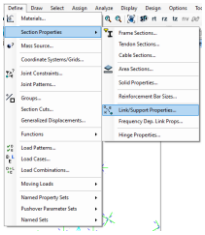

Figure 1 Tools Link/Support Properties

b) Enter the specification data for the dimensions of the FPS that have been obtained..

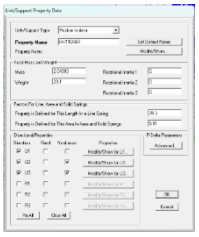

Figure 2 Input Specification FPS

c) Next, enter the Directional properties, which include UI in the vertical direction and U2-U3 in the horizontal direction of the seismic isolation surface.

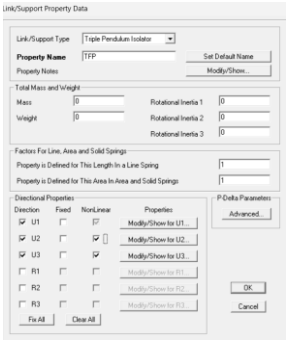

Figure 3 Enter FPS directional properties.

d) Then, enter the property data, including UI in the vertical direction.

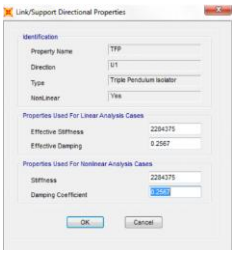

Figure 4 Link properties U1 direction

e) Next, enter the property data, including U2 and U3 in the horizontal direction.

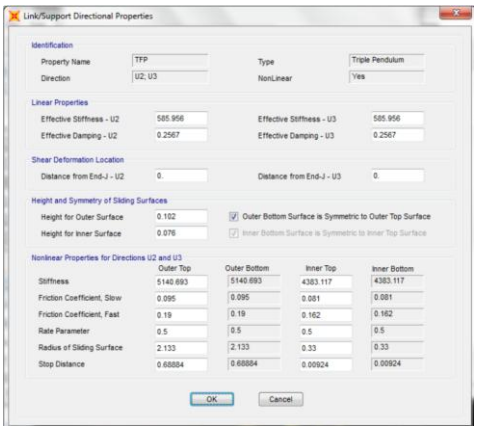

Figure 5 *Properties* U2 dan U3

3. METHOD

This research was conducted on a fictional 50.0 m high-rise building located in Banjarmasin. The material quality and function of each floor can be seen in the following table:

Concrete Strength : 30 MPa

Steel Quality : bjts 42

Steel Quality : bjts 28

Here is the diagram or flowchart illustrating the steps in the execution of this research.

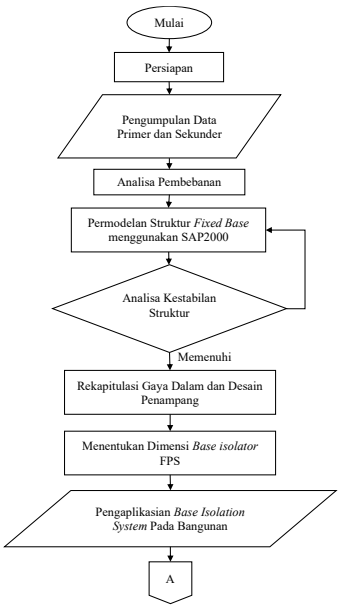

Figure 6 Research Flowchart

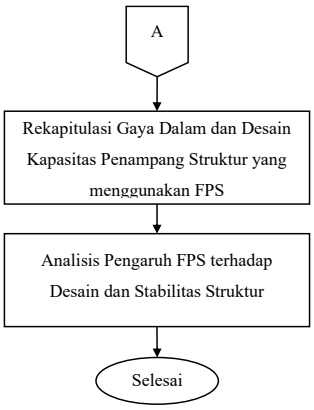

Figure 7 Research Flowchart

4. RESULT AND DISCUSSION

Based on the structural analysis calculations that have been performed, the following results were obtained.

Table 1 Results of the Beam Reinforcement Analysis.

Types of Frame	Types of Force	FB	BI	Ratio
Main Beam 600/450	$M_{u,\ Support}$ (-)	562,326	513,802	-8,63%
	$M_{u,\ Support}$ (+)	562,326	385,872	-31,38%
	$M_{u,\ Field}$ (-)	350,795	381,893	8,86%
	$M_{u,\ Field}$ (+)	308,156	317,842	3,14%
	$V_{u,\ Support}$	412,16	404,71	-1,81%
	$V_{u,\ Field}$	231,929	257,347	10,96%
	T_u	24,0222	29,9338	24,61%
Roof Beam 500/350	$M_{u,\ Support}$ (-)	78,7997	85,7591	8,83%
	$M_{u,\ Support}$ (+)	27,7531	30,1742	8,72%
	$M_{u,\ Field}$ (-)	51,2044	58,9388	15,10%
	$M_{u,\ Field}$ (+)	25,5584	28,8541	12,89%
	$V_{u,\ Support}$	113,082	117,532	3,94%
	$V_{u,\ Field}$	53,761	55,44	3,12%
	T_u	9,3636	9,6962	3,55%

Table 2 Results of the Column Reinforcement Analysis.

Types of Column	Fixed *Base* Structure				*Base Isolated*				Perbandingan			
	Axial.	Momen		Shear	Axial.	Momen		Shear	Axial.	Momen		Shear
	kN	Major (kNm)	Minor (kNm)	kN	kN	Major (kNm)	Minor (kNm)	kN	kN	Major (kNm)	Minor (kNm)	kN
Kolom 1000 x 1000	6631,33	557,346	562,326	124,585	6631,33	557,3461	562,3264	203,664	0%	0%	0%	63%

Table 3 Results of the Slab Reinforcement Analysis.

Jenis plat	Fixed *Base*		*Base isolator*		Selisih	
	Mu x	Mu y	Mu x	Mu y	Mu x	Mu y
Floor Slab 130 mm	14,954	11,916	14,954	11,916	0%	0%

Preliminary *Friction Pendulum System* (FPS)

Properties from FIP Industriale catalog he design forces are as follows:

- Stiffness, Coefficient of friction, μ = 7.16%
- Maximum horizontal force, Fmax = 13,638.487 kN

- Effective fundamental period, Te = 2.750 s
- Minimum and Maximum Effective Stiffness of the Isolation System

  K_{min} = K_c = 26,475 kN m
  $K_{M\,max}$ = 32,35883029 kN m
- Minimum Lateral Force, Vs = 151.376 kN
- Damping Coefficient, BM = 1.89
- Effective Period of the Isolated Structure, TM = 4.352 s
- Maximum Displacement = 0.114

Analysis of the Base Isolation Structure of the Building.

The fundamental period of the structure with the FPS base isolator increased by 1.055 times compared to the fixed base structure, due to the reduced stiffness at the base of the structure as a result of using the base isolator, as can be observed below:

T *Fixed Base* = 1,863 s
T *Base isolator* = 1,966 s

Base shear in the base isolation system decreased by 0.05% in the x-direction and by 0.05% in the y-direction compared to the fixed base. This is because the response modification coefficient, R, for base isolation is smaller than that of the fixed base, resulting in a larger seismic force.

Table 4 Comparison Base Shear

Arah	FB (kN)	BI (kN)	Deviation
Arah y	8183,092	8187,297	0,05%
Arah x	8247,942	8252,180	0,05%

The comparison between inter-story displacements due to seismic loads on the fixed base structure and the structure with the base isolator can be seen in the following table:

Table 5 Comparison of Fixed Base and Base Isolation.

Story	FB		BI		Deviation	
	Story Drift		***Story Drift***			
	δeX	***δeY***	***δeX***	***δeY***	***δeX***	***δeY***
	(mm)	**(mm)**	**(mm)**	**(mm)**	**(mm)**	**(mm)**
13	0,959	0,914	1,662	1,591	42%	43%
12	1,327	1,282	2,323	2,253	43%	43%
11	1,865	1,815	3,286	3,210	43%	43%
10	2,423	2,369	4,285	4,201	43%	44%

9	2,951	2,894	5,224	5,136	44%	44%
8	3,430	3,371	6,067	5,976	43%	44%
7	3,851	3,791	6,789	6,697	43%	43%
6	4,197	4,137	7,347	7,256	43%	43%
5	4,425	4,366	9,369	9,248	53%	53%
4	4,424	4,369	5,679	5,633	22%	22%
3	3,890	3,849	5,948	5,889	35%	35%
2	1,981	1,968	0,000	0,000	-	-

Based on Figure and Table 5, the structure with the base isolator has larger inter-story displacements compared to the fixed base structure. The use of the base isolator can amplify the inter-story displacements by up to 53% in the x-direction and 53% in the y-direction. Below is the comparison of internal forces in the structure:

Table 6 Beams Comparison

Jenis Frame	**Jenis gaya**	**FB**	**BI**	**Ratio**
Main Beam 600/450	$M_{u,\ Support}$ (-)	562,326	513,802	-8,63%
	$M_{u,\ Support}$ (+)	562,326	385,872	-31,38%
	$M_{u,Field}$ (-)	350,795	381,893	8,86%
	$M_{u,\ Field}$ (+)	308,156	317,842	3,14%
	$V_{u,\ Support}$	412,16	404,71	-1,81%
	$V_{u,lapangan}$	231,929	257,347	10,96%
	T_u	24,0222	29,9338	24,61%
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	$M_{u,\ Field}$ (-)	51,2044	58,9388	15,10%
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	$V_{u,\ Field}$	53,761	55,44	3,12%
	T_u	9,3636	9,6962	3,55%

From the comparison in Table 6, it can be concluded that the FPS is able to reduce the forces experienced by the beam by up to 31%, which has a positive impact on the building.

Table 7 Column Comparison

Column Type	Fixed *Base* Structure			*Base Isolated*			Perbandingan		
	Axial	Momen	Shear	Axial	Momen	Shear	Axial	Momen	Shear

	kN	Major (kN m)	Minor (kN m)	kN	kN	Major (kN m)	Minor (kN m)	kN	k N	Major (kN m)	Minor (kN m)	k N
Column 1000 x 1000	6631,33	557,346	562,326	124,585	6631,33	557,3461	562,3264	203,664	0 %	0%	0%	63 %

Dari perbandingan Table 7 dapat disimpulkan bahwa FPS tidak berpengaruh pada momen, namun dapat meningkatkan gaya geser hingga 63%

Table 8 Slab Comparison

Slab Type	Fixed *Base*		*Base isolator*		Selisih	
	Mu x	Mu y	Mu x	Mu y	Mu x	Mu y
Floor Slab 130 mm	14,954	11,916	14,954	11,916	0%	0%

From the comparison in Table 8, it can be concluded that the FPS has no effect on the floor slab.

5. CONCLUSION

Based on the analysis conducted on the Residential Building with Base Isolation using the FPS (Friction Pendulum System), the following conclusions can be made:

1. The dimensions of the Friction Pendulum System used are FIP-D L 1900/800, a product of FIP Industriale.
2. The comparison of the behavior between the fixed base structure and the base isolation structure in terms of base shear, structural period, displacement, and inter-story drift is as follows:
   a. The base isolation structure has a base shear relatively similar to the fixed base structure, with a difference of 0.05% higher in the x-direction and 0.05% lower in the y-direction.
   b. The period of the structure with the FPS base isolator is 1.055 times larger than the fixed base structure.
   c. The structure with the FPS base isolator has a larger total displacement (roof) compared to the fixed base structure, with a maximum difference of 38%.
   d. The use of FPS amplifies the inter-story displacement by up to 53%.
3. The comparison of the behavior between the fixed base structure and the base isolation structure in terms of base shear, structural period, displacement, and inter-story drift is as follows:

a. The base isolation structure has a base shear relatively similar to the fixed base structure, with a difference of 0.05% higher in the x-direction and 0.05% lower in the y-direction.
b. The period of the structure with the FPS base isolator is 1.055 times larger than the fixed base structure.
c. The structure with the FPS base isolator has a larger total displacement (roof) compared to the fixed base structure, with a maximum difference of 38%.
d. The use of FPS amplifies the inter-story displacement by up to 53%.

4. The comparison of internal forces between the fixed base and base-isolated structures is as follows:
   a. From the comparison in Table 4.12, it can be concluded that FPS is able to reduce the forces experienced by the beams by up to 31%, which positively impacts the building.
   b. From the comparison in Table 4.13, it can be concluded that FPS does not affect the moments, but it can increase shear forces by up to 63%.
   c. From the comparison in Table 4.14, it can be concluded that FPS has no effect on the floor slab.

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