Real Response Modification Value of Reinforced Concrete Structures Using the Pushover Method in Horizontal Irranged Buildings

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ABSTRACT

The country of Indonesia is prone to earthquakes, because geographically Indonesia is located at the meeting point of four tectonic plates, namely the Asian continental plate, the Australian continental plate, the Indian Ocean plate and the pacificocean plate. An earthquake is a vibration or shock that occurs on the surface of the earth due to the sudden release of energy from within, creating seismic waves. Earthquakes are usually caused by movements of the earth's crust (earth plates). Planning an earthquake-resistant building structure in Indonesia is very important, because most areas in Indonesia are in fairly high earthquake areas, so earthquake regulations, namely SNI 1726-2019, have been issued. Design re-planning or follow-up can be done using the real R value. If in the SRPMK structure the real R value is greater than the design R, then the planner can save reinforcement by re-analyzing the structure using real R. With the results of this research analysis, it can be concluded that the SRPMK structure with horizontal irregularities at the Jakarta location, produces a real modified response (R) value (referring to the ATC-40 limit on the ratio of deviations between floors and the rotational capacity of structural components) which is smaller than the specified maximum value. on SNI. In accordance with the provisions of ATC-40, all structural configurations are included in the Damage Control (DO) category level, which means that the transition between Immediate Occupancy (IO) SP-1 and Life Safety (LF) SP-3, the building is still able to withstand the forces of the earthquake that occurred, with the risk of human loss is very small. Only SRPMB's 8-story medium ground structure is included in the Life Safety (LF) category level SP-3. The real R value obtained in the SRPMK structure varies between 7.218 – 8.515. The results of this analysis are not significantly different from existing provisions, and in soft soil conditions the value is smaller than for the SRPMB structure. Real R less than the provisions is the maximum value that can be used based on this research. The real R value obtained in the SRPMB structure varies between 5.081 – 10.276. The results of this analysis are very different from the existing provisions for both soft and medium soil conditions; and Structural optimization has been carried out in each building configuration, but it was found that the cross-sectional dimensions of the SRPMB columns and beams in soft soil conditions were the largest cross-sectional dimensions compared to the others.

Keywords: structure building; SPRMK; SPRMB; ETABS.

INTRODUCTION

The country of Indonesia is prone to earthquakes, because geographically Indonesia is located at the meeting point of four tectonic plates, namely the Asian continental plate, the Australian continental plate, the Indian Ocean plate and the Pacific ocean plate. (http://ilmusocial.net/region-rawanbencana-alam-gempa-bumi). An earthquake is a vibration or shock that occurs on the surface of the earth due to the sudden release of energy from within, creating seismic waves. Earthquakes are usually caused by movements of the earth's crust (earth plates). Planning an earthquake-resistant building structure in Indonesia is very important, because most areas in Indonesia are in fairly high earthquake areas, so earthquake regulations, namely SNI 1726-2019, have been issued.

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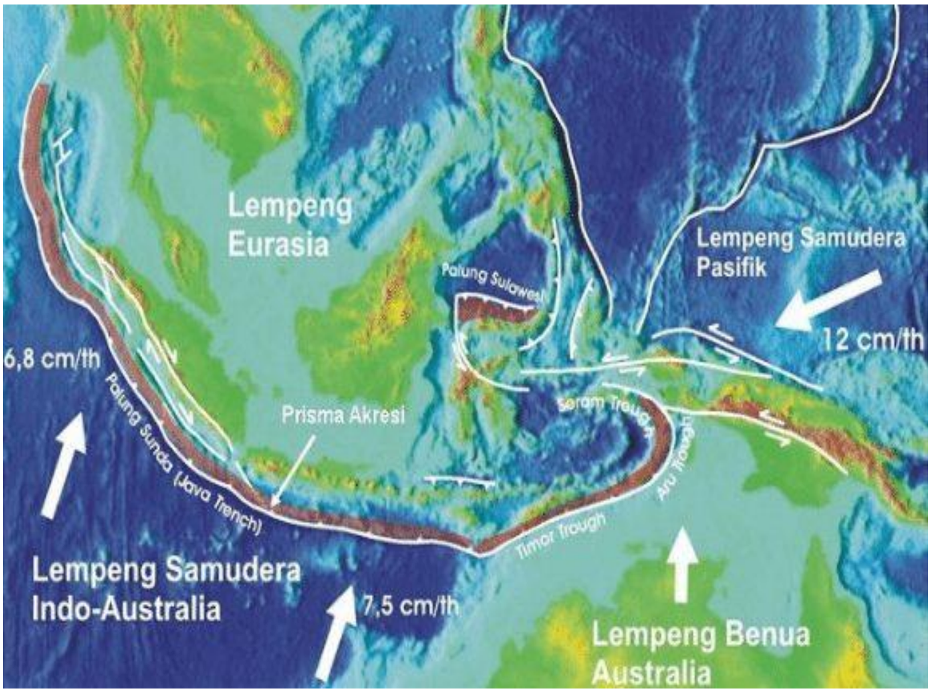

Figure 1. Illustration of tectonic plate movement in Indonesia (Source: Education Lecturer)

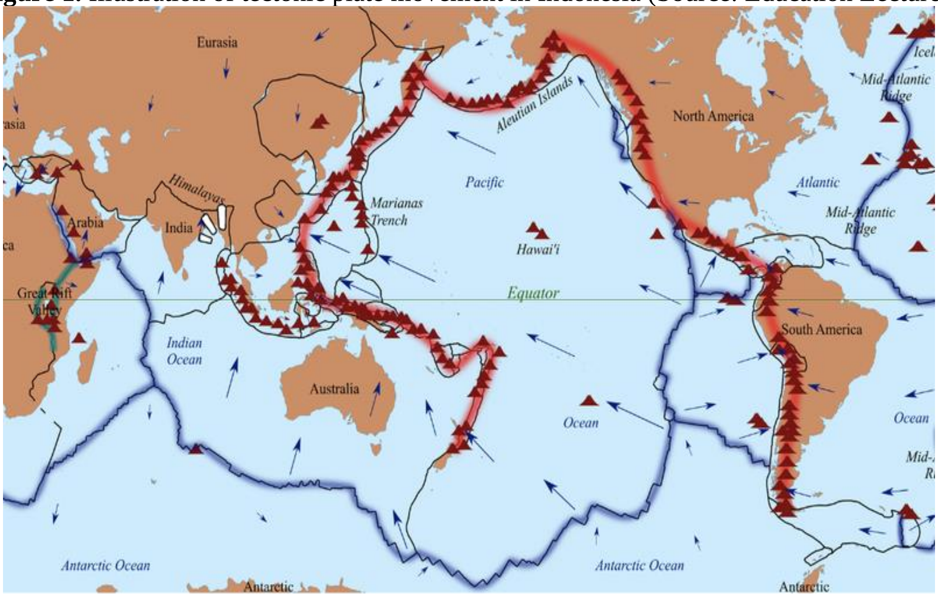

Figure 2. Indonesia is located in the Ring of Fire area (Source: Wikimedia Commons)

If a purely elastic structural design is carried out, the resulting need for large structural elements will result in very expensive construction costs. Therefore, SNI allows reduction. The higher the value of the response modification factor (R), the more rigorous detailing is required to obtain the desired structural ductility, and in general the more difficult it will be so it is necessary to know the influence of the response modification factor with the system. The Special Moment Resisting Frame System (SRPMK) is a frame system that can withstand bending forces, shear forces and axial forces and has a full level of ductility. Because SRMPK has a full level of ductility, it is possible to reduce the design earthquake force with a factor known as the response modification factor (R) or earthquake load reduction factor. Nonlinear pushover static analysis is an analysis carried out to describe the collapse behavior and capacity of a structure as a whole, starting from elastic, plastic conditions, to structural elements collapsing due to earthquake loads. This analysis is carried out by providing a static lateral load pattern on the structure whose value continues to be increased gradually until it reaches the displacement target from a reference point (a point on the roof floor).

The real R value obtained in the SRPMB structure also varies between 5.081 – 10.276. The results of this analysis are very different from the provisions (R = 3) that exist for both soft and medium soil conditions. This means that planners can redesign the structure with a new R value, so that savings can be made, but of course still maintain the deformation capacity of the cross section in the SRPMB plastic condition.

RESEARCH METHODS

Earthquake Resistant Buildings

Earthquake resistant buildings mean that when a structure experiences strong forces due to earthquake waves, the structure does not immediately collapse, so it can give the occupants time to save themselves.

Building Planning Concept

Earthquake-resistant building structures must have relatively good strength to prevent collapse or structural failure. Therefore, the planning is required to fulfill several boundary conditions, namely:

a. The planned building structure must have sufficient stiffness and strength so that if a small earthquake occurs, the structure is elastic;
b. If a moderate magnitude earthquake occurs, the building structure may not experience structural damage but may experience minor non-structural damage; And
c. When a strong earthquake occurs, building structures can experience structural damage but must remain standing so that loss of life can be avoided.
d. Earthquake resistant building planning aims to maintain every important element of the building's function, reduce residential discomfort and damage to the building so that it can still be repaired when an earthquake occurs (SNI 03-1726-2019).

The concept of structural planning cannot be separated from applicable regulations. ATC-40 (1996) classifies earthquake resistant structures as follows:

a. Immediate Occupancy (SP-1), a condition of post-earthquake damage where only very limited structural damage occurs. The vertical and lateral force resisting system at the base of the building maintains almost all of its characteristics and capacity before the earthquake occurred.
b. Damage Control (SP-2), this condition is actually not a certain level of damage but rather an estimate of the condition of damage after an earthquake which varies from SP-1, Immediate Occupancy to Life Safety SP 3.
c. Life Safety (SP-3), where the state of damage after an earthquake occurs where significant damage to the structure may have occurred but some limits to total or partial structural collapse still exist. This level of damage is lower than the level of structural stability. The main structural components are safe and do not threaten life safety both inside and outside the building.
d. Limited Safety (SP-4), This term is actually not a certain level but a range of conditions of post-earthquake damage which is less than SP-3, Life safety and better than SP-5, structural stability. This is a condition where the reinforcement may not meet all the structural requirements of the safety level, but is better than the structural stability level.
e. Structural Stability (SP-5), a condition where the structure has experienced damage either partially or completely. The damage that occurred has caused a degradation of strength and stiffness in the lateral force resisting system.
f. Not Considered, (SP-6), this is not a performance level, but a situation where only nonstructural seismic evaluation or retrofit would be performed.

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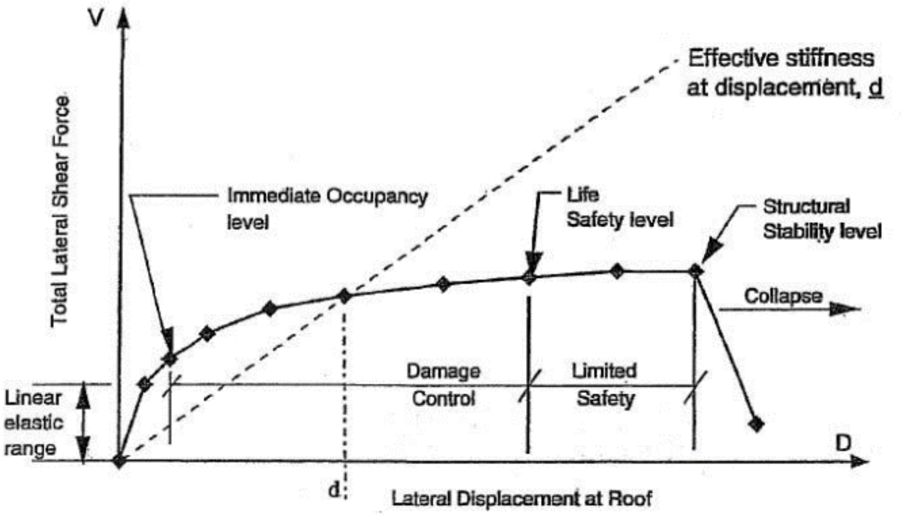

Figure 3. Building Collapse Rate (Source: ATC Regulations-40,1996)

Building Structural Systems

In accordance with SNI 2847:2019 article 18, basic structural systems for resisting lateral loads can generally be divided into Moment Resisting Frame Systems (SRPM), Structural Wall Systems (SDS), and Dual Systems.

a. Moment Resisting Frame System (SRPM)
   1. Ordinary Moment Resisting Frame System (SRPMB), this frame system has limited ductility and is used for areas with low earthquake risk;
   2. Medium Moment Resisting Frame System (SRPMM), this frame system has a medium ductility value; And
   3. Special Moment Resisting Frame System (SRPMK), this frame system has a high ductility value.

b. Structural Wall Systems (SDS)
   1. Ordinary Structural Wall System (SDSB), a wall that has a limited level of ductility and can be used in earthquake zones 1 to 4; And
   2. Special Structural Wall System (SDSK), a wall that has a full level of ductility and can be used in earthquake zones 5 and 6.

c. Dual System

This system consists of a frame system and a structural wall system. The moment-resisting frame must be able to withstand a minimum of 25% of the applied lateral load, and the structural wall system must withstand 75% of the lateral force.

Pushover Analysis

The result of pushover analysis is a capacity curve. The capacity curve is the relationship between the base shear force (Base Shear, V) and the roof displacement (Roof Displacement, Δroof). Pushover analysis can be used as a method in planning earthquake-resistant building structures, but observations are needed because the nature of the pushover analysis loading is static monotonic, so it will produce an approach. Apart from that, the selection of the lateral load pattern that will be used in the analysis is an important factor that needs to be considered. This analysis must also take into account the inelastic load deformation characteristics of critical elements and also the effects of P-Delta.

a. Plastic Joints

One of the occurrences of plastic joints is that they first reach a fatigue condition which will then be followed by a melting condition in the next joint. This process will continue to occur until the end, the deviation at the top of the structure reaches the target deviation or what is usually called an unstable condition.

b. Capacity curve

Pushover analysis will provide a certain static loading pattern in the lateral direction which will be increased gradually. This concept aims to provide an overview of the inelastic response of a building. The results of this nonlinear static analysis are in the form of a curve that shows the relationship between base shear force and roof displacement.

c. Capacity spectrum

According to ATC-40, the capacity spectrum is obtained by converting the capacity curve into a capacity spectrum which is in the ADRS (Acceleration Displacement Response Spectrum) format. In the capacity curve, the relationship between base shear and roof displacement is used, but in the capacity spectrum the relationship between spectral acceleration (Sa) and spectral displacement (Sd) is used.

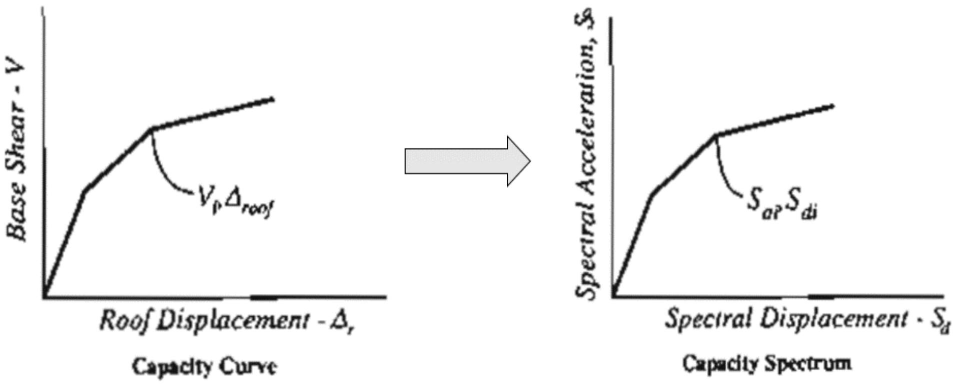

Figure 4. Modification of the Capacity Curve to a Capacity Spectrum (Source: ATC-40 Regulations, 1996)

d. Response Modifying Factors (R)

The response modification factor (R) is one of the factors in the earthquake resistance planning stages for structures. According to SNI 1726:2019 concerning earthquake resistance planning regulations, the R value required in determining seismic shear forces ranges from 1.5 to 8 depending on the type of seismic force resisting system used in the structure. The main components of the R value are the overstrength response modification factor and the ductility response modification factor obtained from the capacity curve results from pushover analysis. RS is the ratio obtained from the maximum/ultimate seismic base shear force (Vu) to the design base shear force (Vd). $R\mu$ is a linear approach to the ability of a structure to behave ductilely when excessive earthquake forces occur so that large deformations occur before collapse so that there is time to reduce losses both in material and life. This factor is calculated as the ratio of the basic shear force which considers the maximum/ultimate shear force (Vu) to the elastic shear force (Ve). For R it will take into account the effect of the degree of redundancy in a structure.

e. More Strong Response Modifying Factors

According to ATC-19, the maximum lateral strength that will be generated in a structure will generally exceed the design strength. The steps taken to determine the value of the stronger response modification factor are as follows:

a. Create a capacity curve, namely the relationship between base shear force and roof displacement);
b. Use the ultimate base shear force value (Vu) of the biliner;
c. Calculate the value of the overstrength response modification factor (RS), (ATC-19.

f. Ductility response modification factors

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ATC-19, states that the T value uses the fundamental period of the building structure analysis results.

Methods

Research Design

In the research methodology chapter, this research develops Damayanti's research. (2022), so the structural data is the same and uses a regular building structure, but in this study an irregular building structure was used, then looked for the value of the response modification factor (R) on the performance of the structure against the 2019 SNI 1726 earthquake regulations. This research conducted analysis of the building structure using the pushover analysis method by taking into account the response modification factor (R) on the performance of the structure, several important stages are treated which will be carried out in accordance with the provisions applicable to this analysis procedure.

References and Regulations for Using SNI

To make carrying out this research easier, several references and literature containing updated regulations were used. The following is a source of the regulations and conditions that will be used in designing the building structure. The literature sources used in this research are as follows:

a. SNI 03 – 1726 – 2019, Procedures for Earthquake Resistance Planning for Building and Non-building Structures.
b. SNI 03 – 1727 – 2020, Minimum Design Loads and Related Criteria for Buildings and Other Structures.
c. SNI 2847 – 2019, Structural Concrete Requirements for Buildings and Explanations. ATC – 40, 1996. Seismic Evaluation and Retrofit of Concrete Buildings.

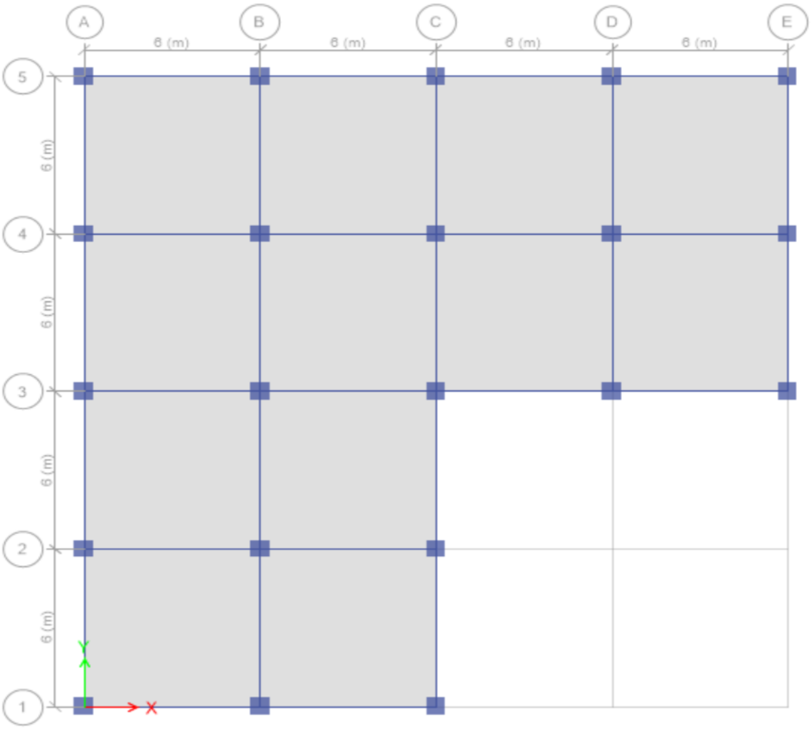

Figure 5. Building Structure Planning Layout (Source: ETABS Data, Project Research Process)

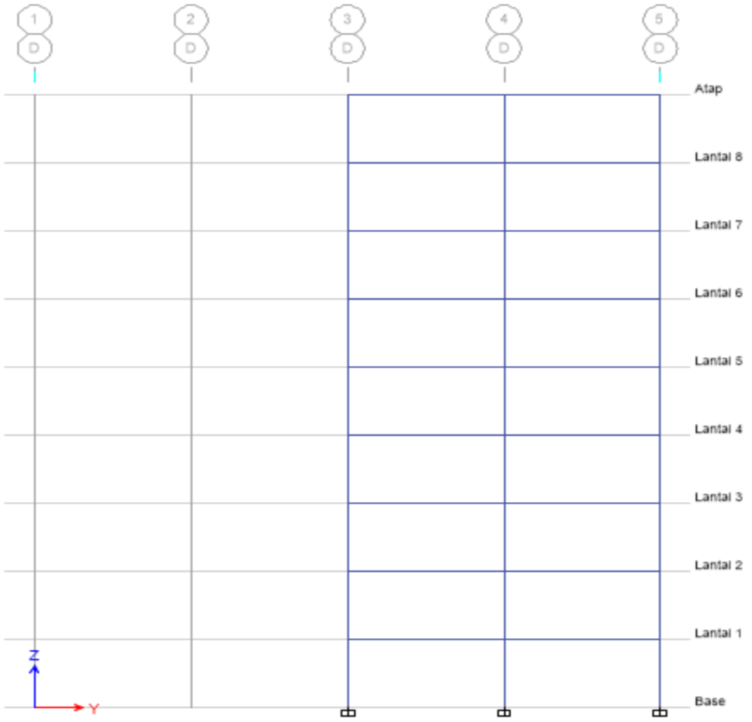

Figure 6. Side View of The Structure Of An 8-Story Building, Section D (Source: ETABS Data, Project Research Process)

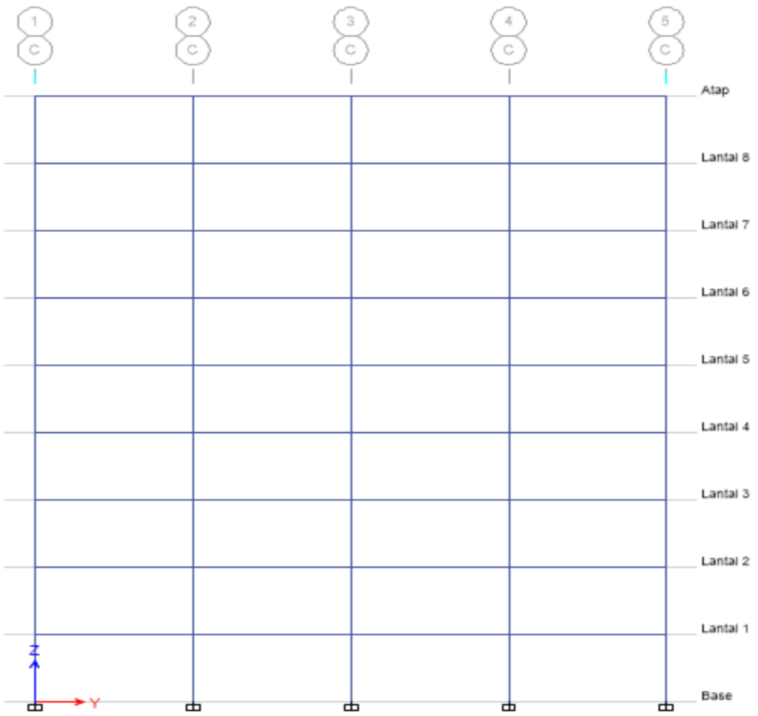

Figure 7. Side View Of The 8-Story Building Structure, Section C (Source: ETABS Data, Project Research Process)

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Analysis Data Method

The analysis of this research will be limited to structural components with non-linear static analysis (pushover) using computer assistance and the ETABS program. Apart from that, this research also uses the ATC-40, 1996 method.

Building Structure Data

The specifications and data used in this research are as follows:

Table 1. Building Structure Data

Structure Type	:	Assume clamp support
Building Type	:	Irregular building
Structure Function	:	Office building
Building Location	:	DKI Jakarta
Location coordinates	:	-6.126276, 106.823025
Type of soil	:	Medium soil and soft soil
Number of Floors	:	8 lantai
Span Length in X Direction	:	24 meter
Span Length in Y Direction	:	24 meter
Height between floors	:	4 meter
Foundation depth	:	3 meter
Foundation Type	:	Assume clamp support
Structural Systems	:	SRPMK dan SRPMB

(Source: Project Research Data)

Data Analysis
Floor Slab

The dimensions of floor plates have different sizes according to the length of the span and the type of direction of the plate. This building structure has the same span in the X and Y directions, namely 6000 mm, so the plate is a two-way plate. The following is a calculation of the plate size that will be used:

- L_y = 6000 mm
- L_x = 6000 mm
- β = = = 1,0 …… Two-way plate

In accordance with Table 1 In SNI 2847:2019, the minimum thickness of the two-way non-prestressed slab for the beam between the supports will use the α value, with the initial assumption that the slab thickness is 120 mm. Floor slab dimensions will be used as follows:

Table 2. Calculation of α Values on Floor Plates

Beam	Ecb	Ecp	I_b	I_p	α
	MPa	MPa	mm^4	mm^4	
BL	23500	23500	5400000000	864000000	6,250
BT	23500	23500	5400000000	864000000	6,250

(Source: Project Research Data)

Table 3. Floor Plate Thickness Calculation

Plate Type	Beam type	α	$\bar{\alpha}$	Floor plate thickness	
				Need (mm)	Use (mm)
Center Plate	4 x B2	25,000	6,250	139,333	
Corner Plate	2 x B1	12,500	3,125	139,333	140
Edge Plate	(2 x B1) + (1 x B2)	18,750	4,688	139,333	

(Source: Project Research Data)

Column

Column dimensions have different sizes on each floor. The following is the column dimension calculation that will be used:

Table 4. One Floor Load Planning on Columns

Load on Roof Floor		Specific Gravity	Width	Length	Height	Weight
		kN/m^3	m	m	m	kN
Weight of Block L	:	23,6	0,25	3,00	0,50	8,85
Weight of T Beam	:	23,6	0,25	3,00	0,50	8,85
Floor Slab Weight	:	23,6	6,00	6,00	0,14	118,94
Dead load weight (DL)						**136,64**
Ceiling hanger	:	0,1	6,00	6,00		3,60
Ceiling Weight	:	0,05	6,00	6,00		1,80
ME Installation Weight	:	0,19	6,00	6,00		6,84
Waterproof Layer	:	0,05	6,00	6,00		1,80
Additional Dead Load Weight (SIDL)						**14,04**
Roof	:	0,96	6,00	6,00		34,56
Live Load Weight (LL)						**34,56**
Total Weight on Roof Floor						**185,24**
Load on floor 2-8		**Specific Gravity**	**Width**	**Length**	**Height**	**Weight**
		kN/m^3	**m**	**m**	**m**	**kN**
Weight of Block L	:	23,6	0,30	3,00	0,60	12,74
Weight of T Beam	:	23,6	0,30	3,00	0,60	12,74
Floor Slab Weight	:	23,6	6,00	6,00	0,14	118,94
Dead Load Weight (DL)						**144,43**
Ceramics and Specs	:	1,10	6,00	6,00		39,60
Ceiling Hanger	:	0,10	6,00	6,00		3,60
Ceiling Weight	:	0,05	6,00	6,00		1,80
ME Installation Weight	:	0,19	6,00	6,00		6,84
Wall	:	2,30		12,00	4,00	110,40

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Additional Dead Load Weight (SIDL)						**51,84**
Office Room	:	2,4	6,00	6,00		86,40
Corridor	:	3,83	6,00	6,00		137,88
Live Load Weight (LL)						**224,28**
Total Weight on Floors 2-8						**420,55**
Load on 1		**Specific Gravity**	**Width**	**Length**	**Height**	**Weight**
		kN/m^3	**m**	**m**	**m**	**kN**
Weight of Block L	:	23,6	0,33	3,00	0,65	14,96
Weight of T Beam	:	23,6	0,30	3,00	0,60	12,74
Floor Slab Weight	:	23,6	6,00	6,00	0,14	118,94
Dead Load Weight (DL)						**146,64**
Ceramics and Specs	:	1,10	6,00	6,00		39,60
Ceiling Hanger	:	0,10	6,00	6,00		3,60
Ceiling Weight	:	0,05	6,00	6,00		1,80
ME Installation Weight	:	0,19	6,00	6,00		6,84
Wall	:	2,30		12,00	4,00	110,40
Additional Dead Load Weight (SIDL)						**162,24**
Lobby and Corridor Floors	:	4,79	6,00	6,00		172,44
Live load weight (LL)						**172,44**
Total Weight on Floor 1						**481,32**

(Source: Project Research Data)

Table 5. Column Dimension Planning

Floor	Floor weight (Pu)	Accumulative weight (Pu)	Concrete quality (fc')	Area(Ag)	Side	Column Dimensions
	N	N	Mpa	mm^2	mm	mm x mm
Roof	185244	185244	35	15121,96	122,971	300 x 300
8th floor	420552	605796	35	49452,73	222,380	500 x 500
7th floor	420552	1026348	35	83783,51	289,454	
6th floor	420552	1446900	35	118114,29	343,678	

Floor	Floor weight (Pu)	Accumulative weight (Pu)	Concrete quality (fc')	Area(Ag)	Side	Column Dimensions
5th floor	420552	1867452	35	152445,06	390,442	600 x 600
4th floor	420552	2288004	35	186775,84	432,176	
3rd floor	420552	2708556	35	221106,61	470,220	
2nd Floor	420552	3129108	35	255437,39	505,408	
1st floor	481324,5	3610432,5	35	294729,18	542,890	

(Source: Project Research Data)

The cross-sectional dimensions of the beams, floor plates and columns above are the initial planning dimensions in accordance with the optimum requirements determined by SNI 2847:2019. Then the dimensions in the initial planning are applied to ETABS, but if the initial planning dimensions of the building structure do not meet the provisions then the dimensions are enlarged and adjusted until the structure can withstand the building load. The following are the cross-sectional dimensions used in this building structure.

Table 6. Cross-Sectional Dimensions of the SRPMK Soft Soil 8 Floor Structure

Floor	Beam L		Beam T		Colum			Floor
	b	h	b	h	Corner	Center	Perip heral	
	mm	mm	mm	mm	mm	mm	mm	mm
Roof	250	500	250	500	550	550	550	140
8th floor	300	600	300	600	650	650	650	140
7th floor	300	600	300	600	650	650	650	140
6th floor	300	600	300	600	650	650	650	140
5th floor	300	600	300	600	650	650	650	140
4th floor	325	650	300	600	650	700	700	140
3rd floor	325	650	300	600	650	700	700	140
2nd Floor	325	650	300	600	650	700	700	140
1st floor	325	650	300	600	650	700	700	140

(Source: Project Research Data)

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Table 7. Cross-sectional Dimensions of the SRPMK Medium Soil 8 Floor Structure (Source: Project Research Data)

Floor	Beam L		Beam T		Colum			Floor
	b	h	b	h	Corner	Center	Peripheral	
	mm	mm	mm	mm	mm	mm	mm	mm
Roof	250	500	250	500	550	550	550	140
8th floor	300	600	300	600	650	650	650	140
7th floor	300	600	300	600	650	650	650	140
6th floor	300	600	300	600	650	650	650	140
5th floor	300	600	300	600	650	650	650	140
4th floor	300	600	300	600	650	700	700	140
3rd floor	300	600	300	600	650	700	700	140
2nd Floor	300	600	300	600	650	700	700	140
1st floor	300	600	300	600	650	700	700	140

RESULT AND DISCUSSION
Structural Modeling

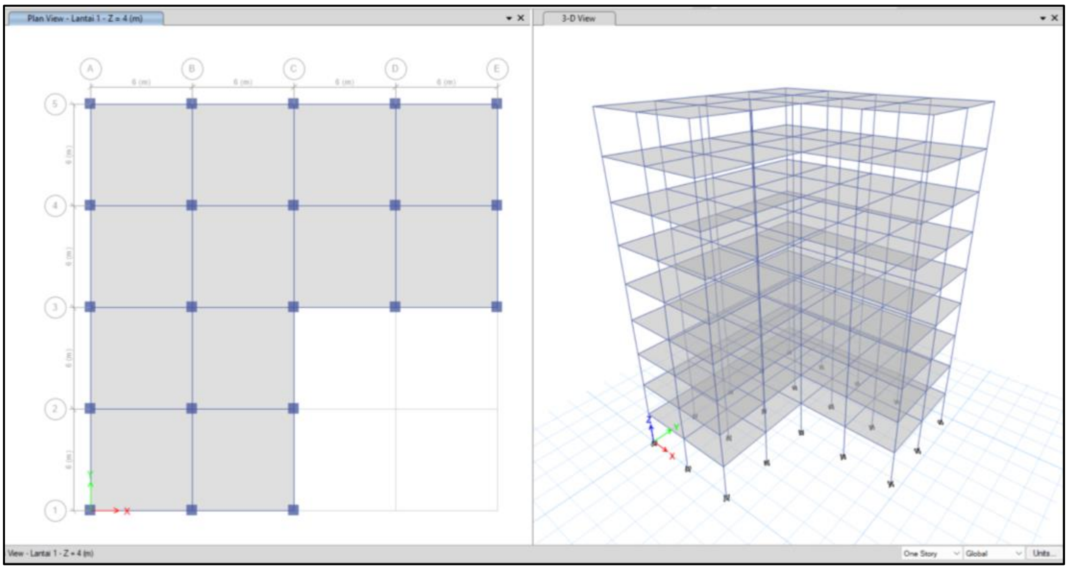

Figure 8. 8 Floor Structure Model (Source: ETABS Data, Project Research Process)

In SNI 1726:2019 Article 7.9.1.1 it is stated that the analysis must include a sufficient number of variations to obtain a combined mass participation of at least 90% of the actual mass in each orthogonal horizontal direction of the response considered by the model. The amount of mass participation can be determined by displaying the Table: Capital Participating Mass Ratio on ETABS then looking at the Sum UX and Sum UY columns. The following is the capital output participating mass ratio:

Table 8. Capital Participating Mass Ratio 8 Floor Structure Soft Soil SRPMK

Case	Variety	Period (s)	UX	UY	UZ	Sum UX	Sum UY	Sum UZ
Modal	1	2,778	0,3809	0,3839	0	0,3809	0,3809	0
Modal	2	2,778	0,3839	0,3809	0	0,7648	0,7648	0
Modal	3	2,316	0,0031	0,0031	0	0,7679	0,7679	0
Modal	4	0,874	0,0532	0,0532	0	0,8211	0,8211	0
Modal	5	0,873	0,0536	0,0536	0	0,8747	0,8747	0
Modal	6	0,745	0,0003	0,0003	0	0,875	0,875	0
Modal	7	0,467	0,0237	0,0237	0	0,8987	0,8987	0
Modal	8	0,467	0,0237	0,0237	0	0,9225	0,9225	0
Modal	9	0,405	0	0	0	0,9225	0,9225	0
Modal	10	0,294	0,014	0,014	0	0,9365	0,9365	0
Modal	11	0,293	0,014	0,014	0	0,9505	0,9505	0
Modal	12	0,256	0	0	0	0,9505	0,9505	0

(Source: ETABS Data, Project Research Process)

It can be seen in the table above, the combined participating mass ratio is more than 90%, namely in the X direction and Y direction it is 95.05%. The structure period value of ETABS in variety 1 is 2.778 (dominant translation in the Y direction is 0.3839) and in variety 2 is 2.778 (dominant translation in the X direction is 0.3839).

Earthquake Shear Force

Table 9. Seismic Response Coefficient

	SPRMK		SPRMB	
	Soft	**Medium**	**Soft**	**Medium**
		8 lt		
Ct	0,0466	0,0466	0,0466	0,0466
hn	35 m	35 m	35 m	35 m
x	0,9	0,9	0,9	0,9
Cu	1,4	1,4	1,4	1,4
Ta min	1,14	1,14	1,14	1,14
Ta max	1,6	1,6	1,6	1,6
Cs	0,08	0,08	0,22	0,22
Cs max	0,04	0,04	0,11	0,11
Cs min	0,02	0,02	0,02	0,02
Cs use	0,04	0,04	0,11	0,11

(Source: ETABS Data, Project Research Process)

In accordance with the provisions of SNI 1726:2019, the Cs value used in this period is Cs max. On ETABS, the seismic weight can be seen by displaying the Table: Center of Mass and Rigidity as follows:

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Table 10. Center of Mass and Rigidity Structure 8 Floors Soft Soil SRPMK

Story	Diaphragm	Mass X	Mass Y	XCM	YCM	Cum Mass X	Cum Mass Y
		ton	ton	m	m	ton	ton
Roof	D1	498,21	498,21	10,06	13,93	498,21	498,21
8th floor	D1	656,95	656,95	10,16	13,83	1155,17	1155,17
7th floor	D1	681,14	681,14	10,16	13,83	1836,32	1836,32
6th floor	D1	681,14	681,14	10,16	13,83	2517,46	2517,46
5th floor	D1	681,14	681,14	10,16	13,83	3198,61	3198,61
4th floor	D1	693,37	693,37	10,16	13,83	3891,99	3891,99
3rd floor	D1	706,98	706,98	10,17	13,82	4598,97	4598,97
2nd Floor	D1	706,98	706,98	10,17	13,82	5305,95	5305,95
1st floor	D1	706,98	706,98	10,17	13,82	6012,93	6012,93
Total Seismic Weight					=	6012930 kg	

(Source: ETABS Data, Project Research Process)

Table 11. Static Basic Shear Force

	SRPMK		SRPMB	
	Medium	Soft	Medium	Soft
	8 lt			
Cs	0,075	0,060	0,199	0,161
W (kg)	6012930	6012936	7956182,8	6012936,4
V (kN)	4509,69	3607,76	15832,80	9680,82

(Source: ETABS Data, Project Research Process)

In the table above it can be seen that structural systems with special moment resisters produce smaller earthquake shear force values compared to ordinary moment resister systems. This is because the response modification factor for special moments is greater than for ordinary moments, therefore the scale of the earthquake at special moments is smaller than for ordinary moments.

Earthquake Force Scale Factor

Regarding the earthquake force scale, it is known by displaying Table: Base Reaction, then the comparison of static base shear force with dynamic base shear force will be obtained as follows:

Table 12. Base Reaction Structure 8 Floors Soft Soil SRPMK

Case	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
SX	-3016,06	0	0	-0,000006	-80124,73	41786,45
SY	0	-3016,06	0	80124,73	0,0000037	-30599,17
DX	1085,96	1085,96	0	24162,72	24162,72	18635,58
DY	1085,96	1085,96	0	24162,72	24162,72	18635,63

(Source: ETABS Data, Project Research Process)

The calculation of the earthquake force scale factor is calculated in the table below:

Table 13. Earthquake Scale Factors for Special Moment Resisting Framing Systems

	Dinamic (*Vd*)	Static (*Vs*)	Factor Scale	Check	FS Last
	(kN)	(kN)	(Vs/Vd)	Vd >100% Vs	(kN/m2)
Soft ground 8 floors					

Direction X	1085,96	3016,06	2,77	**NOT OK**	**1,67**
Direction Y	1085,96	3016,06	2,77	**NOT OK**	**1,67**
Medium Land 8 Floors					
Direction X	879,77	2411,04	2,74	**NOT OK**	**1,67**
Direction Y	879,77	2411,04	2,74	**NOT OK**	**1,67**

(Source: ETABS Data, Project Research Process)

From the table above, it can be concluded that the dynamic shear force requirements have not been met in accordance with the provisions in SNI 1726:2019 Article 7.9.4.1 that the dynamic shear force must be greater than 100% of the static shear force. If these requirements are not met, then the earthquake force scale is adjusted to the final earthquake scale factor

Beam Reinforcement Design

Figure 9. Location of Beam Frame B2 275X550 (Source: ETABS Data, Project Research Process)

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Design data for beam reinforcement requirements:

Concrete quality (*fc'*)	= 25 Mpa
Reinforcement quality (*fy*)	= 420 Mpa
Beam width (*b*)	= 275 mm
Beam height (*h*)	= 550 mm
Diameter of longitudinal reinforcement (d_b)	= 19 mm
Diameter of transverse reinforcement (d_s)	= 10 mm
Concrete covers (c_c)	= 40 mm
Column width (c_1)	= 550 mm

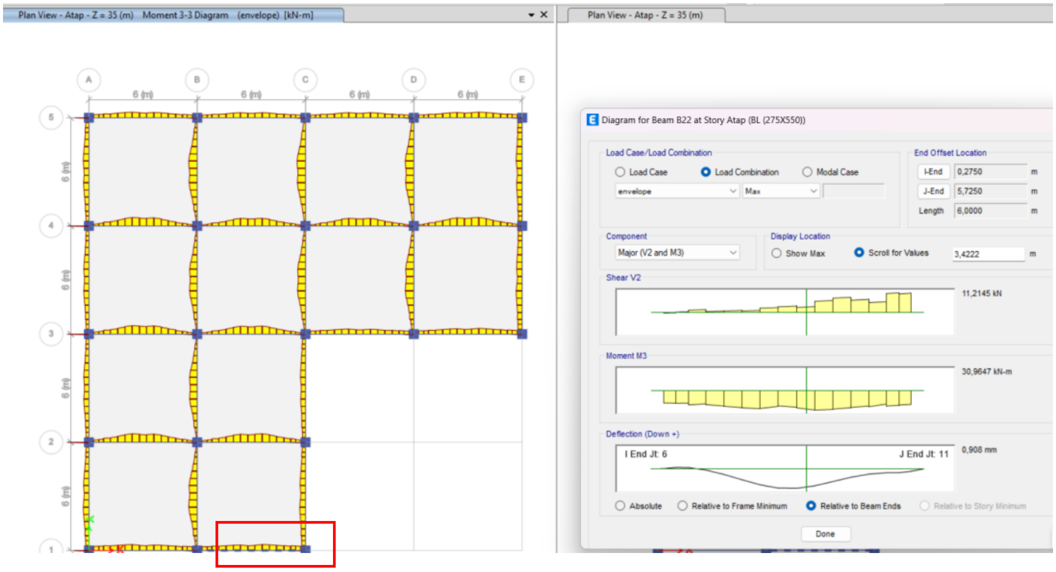

Figure 10. Moment and Shear Diagram for Beam B2 275X550 (Source: ETABS Data, Project Research Process)

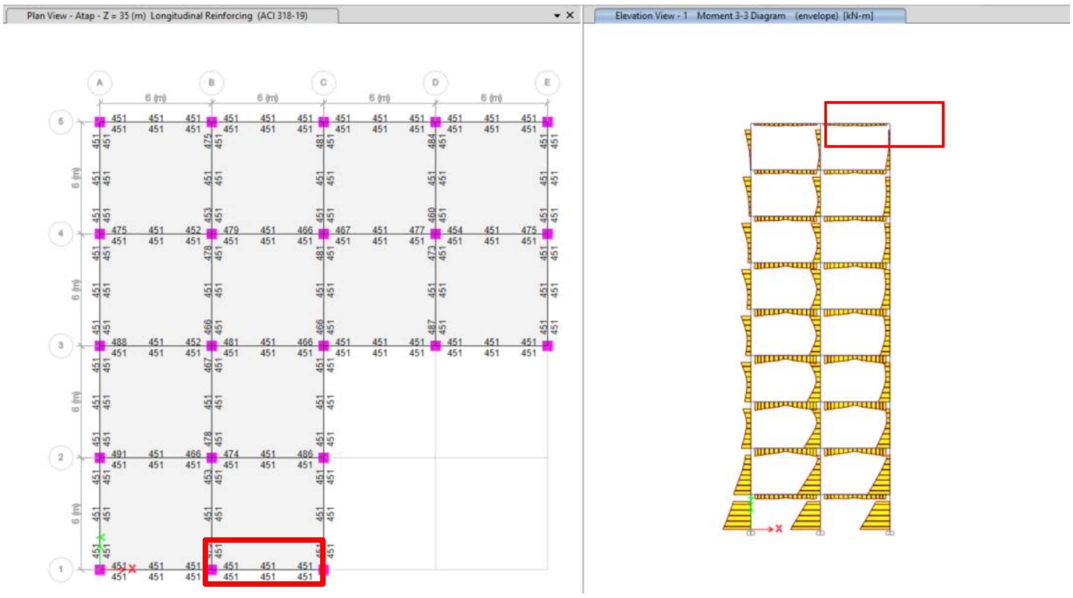

Figure 11. Diagram of Support and Field Areas on Beam B2 275X550 *(Source: ETABS Data, Project Research Process)*

The results of the design moments for each beam frame can be seen in ETABS by displaying force/stress diagrams. The following are the results of the internal forces on the B2 275X550 frame:

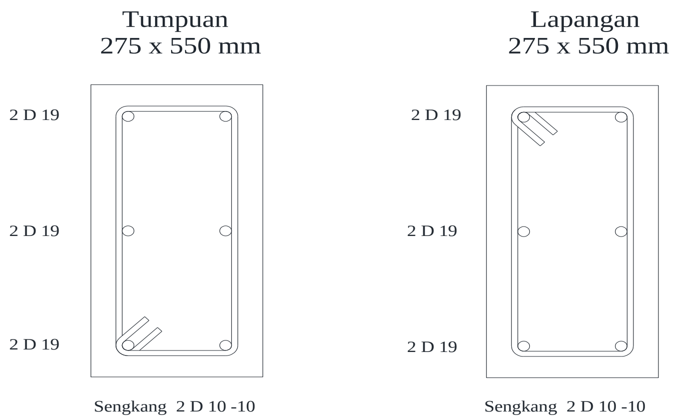

Figure 12. Sketch of Reinforcement in 275X550 Beam (Source: ETABS Data, Project Research Process)

Table 14. Results of B2 275X550 Beam Design Reinforcement from Etabs Area

	Area of Etabs (mm^2)	**Number of Reinforcement**	**Reinforcement Diameter**	**Area of 1 Reinforcement (mm^2)**	**Calculation Results (mm^2)**
Top Focus	451	2	19	283,52	567,05
Bottom Focus	451	2	19	283,52	567,05
Upper Field	451	2	19	283,52	567,05
Lower Field	451	2	19	283,52	567,05

(Source: ETABS Data, Project Research Process)

Table 15. Results of Design Moments for Beam B2 275X550 Due to Loading Combinations

Location	Value
Mu Tumpuan (-)	-70,71 kNm
Mu Tumpuan (+)	28,61 kNm
Mu Lapangan (-)	-6,90 kNm
Mu Lapangan (+)	30,96 kNm
Vu Tumpuan	75,091 kN
Vu Lapangan	24,10 kN
Vg Tumpuan	78,1 kN
Axial	0
Torque	9,4 kN

(Source: ETABS Data, Project Research Process)

Displays Capacity Curve

After the running analysis pushover process is complete, you will get a pushover curve for the x direction by selecting Static Nonlinear Case, select PUSH The following are the results of the capacity curve as well as a table of the magnitudes of displacement and shear forces that occur.

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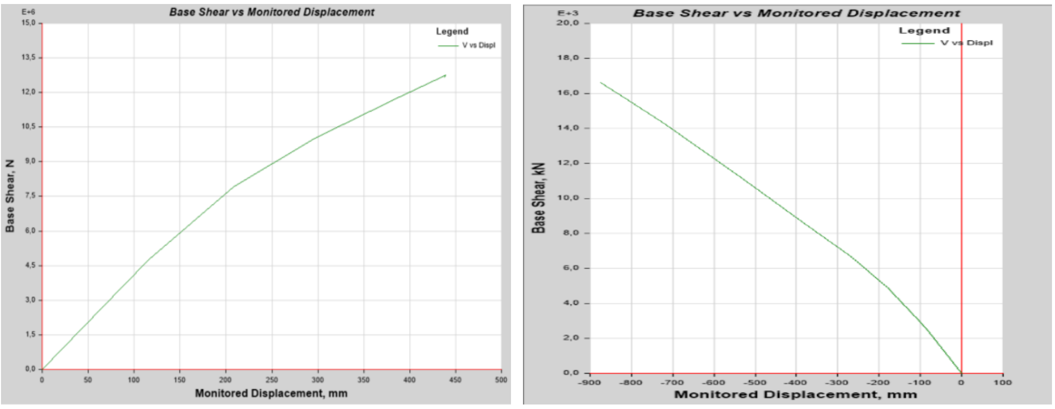

Figure 13. SRPMK Soft Soil 8 Floor Structure Capacity Curve Damayanti Research, 2022 and This Research

Table 16. Results of Shear Force and Displacement of the SRPMK Soft Soil 8-Story Structure

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
	mm	kN										
0	0	0	1908	0	0	0	0	1908	0	0	0	1908
1	-87,5	2.599,5	1908	0	0	0	0	1908	0	0	0	1908
2	-92,3	2.741,0	1900	8	0	0	0	1908	0	0	0	1908
3	-180,0	4.907,1	1548	360	0	0	0	1908	0	0	0	1908
4	-271,2	6.716,3	1422	486	0	0	0	1898	0	0	10	1908
5	-374,9	8.490,9	1376	532	0	0	0	1886	12	0	10	1908
6	-540,3	11.285,0	1322	586	0	0	0	1866	30	0	12	1908
7	-630,5	12.789,3	1292	616	0	0	0	1864	30	0	14	1908
8	-719,9	14.266,8	1218	690	0	0	0	1848	46	0	14	1908
9	-815,6	15.744,3	1078	830	0	0	0	1804	72	6	26	1908
10	-875,0	16.605,5	1040	868	0	0	0	1738	128	10	32	1908

(Source: ETABS Data, Project Research Process)

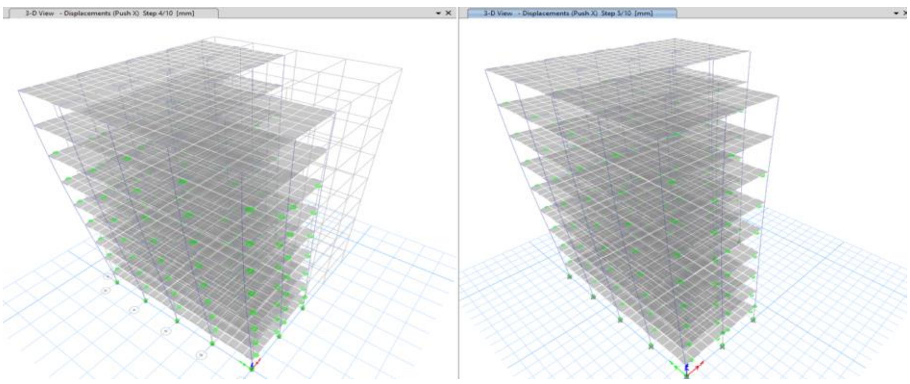

Figure 14. Results of Pushover Analysis of SRPMK Soft Soil 8 Floor Structure (Source: ETABS Data, Project Research Process)

Table 17. Structure Performance Level Based on ATC 40 Method

Structure	Direction	D	D1	H Structure	Maximum Total Deviation		Maximum Inelastic Deviation	
		(mm)	(mm)	(m)	Rasio		Rasio	
8 lt SRPMK soft	PUSH X	875	87,5	35	0,02	Damage	0,02	Damage
	PUSH Y	875	87,5	35	0,02	Control	0,02	Control
8 lt medium SRPMK	PUSH X	875	87,5	35	0,02	Damage	0,02	Damage
	PUSH Y	875	87,5	35	0,02	Control	0,02	Control
8 lt SRPMB soft	PUSH X	791,7	85,7	35	0,02	Damage	0,02	Damage
	PUSH Y	791,7	85,7	35	0,02	Control	0,02	Control
8 lt medium SRPMB	PUSH X	875	87,4	35	0,02	Damage	0,02	Damage
	PUSH Y	875	87,4	35	0,02	Control	0,02	Control

(Source: ETABS Data, Project Research Process)

So in accordance with the provisions of ATC-40, the structure is included in the Damage Control (DC) category level, which means the transition between Immediate Occupancy (IO) SP-1 and Life Safety (LF) SP-3, the building is still able to withstand the forces of the earthquake that occurred, with the risk of casualties the human soul is very small. However, the results of this nonlinear pushover analysis are that structural systems with ordinary moments use large column and beam cross-sectional dimensions and the number and dimensions of the reinforcement used are also very large. If the ordinary moment structure system uses the same cross-section and reinforcement data as the special system, the building cannot accept both gravity loads and lateral loads.

According to ATC-19 (1995a) and ATC-34 (1995b) the R value is the product of 3 factors, namely: $R = Rs \times R\mu \times RR$, where Rs is the strength factor, Rμ is the ductility factor (ductility factor), and RR is a redundancy factor. These three factors are influenced by the structure's vibration period.

Tabel 18. Real R Value Results According to Building Configuration

Structural System	Soil condition and number of floors			$R_R=\rho$	R real
SRPMK	Soft 8 lt	3,7	2,0	1,3	9,4
	Medium 8 lt	3,8	2,3	1,3	11,3
SRPMB	Soft 8 lt	1,8	1,5	1,3	3,4
	Medium 8 lt	2,1	1,7	1,3	4,7

(Source: ETABS Data, Project Research Process)

Tabel 19. Comparison of R Values According to Regulations with Real R

Structural System	Soil condition and number of floors	*R* (SNI 1726:2019)	*R real*
SRPMK	Soft 8 lt	8	9,4
	Medium 8 lt	8	11,3
SRPMB	Soft 8 lt	3	3,4
	Medium 8 lt	3	4,7

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(Source: ETABS Data, Project Research Process)

Comparison of Results with Previous Research

The results of the analysis in the previous chapters and sub-chapters will be compared with the results of previous research. In Damayanti's research. (2022) The use of the SRPMK structure is due to the planned earthquake area including seismic design category D.

Tabel 20. Cross-Sectional Dimensions of an 8-Story Structure

Structural System	Soil Type	Floor	Beam		Column	
			b	h	b	h
			mm	mm	mm	mm
SRPMK	Soft	ROOF	275	550	550	550
		Floors 5 - 8	300	600	650	650
		Floors 1 - 4	325	650	700	700
	Medium	ROOF	250	500	550	550
		Floors 5 - 8	300	600	650	650
		Floors 1 - 4	300	600	700	700
SRPMB	Soft	ROOF	275	550	600	600
		Floors 5 - 8	350	700	900	900
		Floors 1 - 4	400	800	1000	1000
	Medium	ROOF	250	500	550	550
		Floors 5 - 8	325	650	800	800
		Floors 1 - 4	325	650	900	900

(Source: ETABS Data, Project Research Process)

Table 21. Cross-Sectional Dimensions of Previous Research (Damayanti, 2022)

Structural System	Soil Type	Floor	Beam L		Beamk T		Column		
			b	h	b	h	Corner	Cente	Rdge
			mm	mm	mm	mm	mm	mm	mm
SPRMK	Soft	ROOF	250	500	250	500	550	550	550
		Floors 5 - 8	300	600	300	600	650	650	650
		Floors 1 - 4	325	650	300	600	650	700	700
	Medium	ROOF	250	500	250	500	550	550	550
		Floors 5 - 8	300	600	300	600	650	650	650
		Floors 1 - 4	300	600	300	600	650	700	700
SPRMB	Soft	ROOF	275	550	275	550	600	600	600
		Floors 5 - 8	350	700	350	700	900	900	900
		Floors 1 - 4	400	800	400	800	1000	1000	1000
	Medium	ROOF	250	500	250	500	550	550	550
		Floors 5 - 8	325	650	300	600	800	800	800
		Floors 1 - 4	325	650	300	600	900	900	900

(Source: ETABS Data, Project Research Process)

From the results of the research analysis, it was found that the cross-sectional dimensions of the beams of the special moment building structure system with soft soil types were the largest cross-sectional dimensions, namely 275 x 550 mm2 compared to Damayanti's research, namely beam dimensions of 250 x 50 mm2. This is because the earthquake scale factor in special moment structural systems with soft soil is large, so the resulting shear force will be large and requires larger cross-sectional dimensions.

From the tables above, it can be seen that the reinforcement requirements for column and beam elements in special and ordinary moment structures in soft and medium soil conditions vary according to the cross-sectional dimensions used, both in terms of the type of dimensions and the location of the elements. Reinforcement requirements from the previous analysis of Damayanti's research (2022), in beam elements required reinforcement with beam dimensions of 300x600 mm2, the amount of reinforcement required is 3 D22, for the top support. Compared with the analysis of this research, the reinforcement requirements in this research are more based on the amount of reinforcement required 4D22. Meanwhile, from the previous analysis of Damayanti's research (2022), reinforcement requirements for column elements require reinforcement with column dimensions of 700x700 mm2, the amount of reinforcement required is 16D22. Compared with the analysis of this research, the need for reinforcement as a result of the research is greater with 16D25 reinforcement.

From the comparison of reinforcement requirements, the results of this research are greater than those of previous research (Damayanti, 2022), because this research uses a building shape that is not symmetrical, so the influence of earthquake loads is very dominant which can cause building torsion moments in buildings. The reinforcement used in situations with torsion moments is more complex and numerous compared to structures that do not experience torsion moments.

Tabel 22. Response Modification Value (R) Research Results

Structural System	Soil Condition and Number of Floors	R (SNI 1726:2019)	R real
SRPMK	Soft 8 lt	8	9,4
	Medium 8 lt		11,3
SRPMB	Soft 8 lt	3	3,4
	Medium 8 lt		4,7

(Source: ETABS Data, Project Research Process)

Tabel 23. Response Modification Value (R) Damayanti Research Results (2022)

Structural System	Soil Condition and Number of Floors	*R* (SNI 1726:2019)	*R real*
SRPMK	Soft 8 lt	8	7,2
	Medium 8 lt		8,129
SRPMB	Soft 8 lt	3	5,081
	Medium 8 lt		6,48

(Source: ETABS Data, Project Research Process)

Table 24. Analysis Results of R-Value Parameters

Structural System	Land Condition and Number of Floors	Seismic Response Coefficient (C_S)	V_d (N)	*R real*
SRPMK	Soft 8 lt	0,089	4.509.690	9,4
	Medium 8 lt	0,085	3.607.760	11,3
SRPMB	Soft 8 lt	0,237	15.832.800	3,4
	Medium 8 lt	0,227	9.680.820	4,7

(Source: ETABS Data, Project Research Process)

The results of the overall configuration analysis can be seen in Table 4.60. with several descriptions as follows:

a. The real R value obtained in the SRPMK structure varies between 9.4 and 11.3. Structures that have a real R value of 9.4 (above a real R value of 8) are in soft soil conditions, namely

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beam B1 325 x 650 mm2 and column 700 x 700 mm2, B2 300 x 600 mm2 and column 650 x 650 mm2 and B3 275 x 550 mm2 and column 550 x550 mm2. Structures that have a real R value of 11.3 (above a real R value of 8) are in medium soil conditions, namely beam B1 300 x 600 mm2 and column 700 x 700 mm2, B1 300 x 600 mm2 and column 650 x 650 mm2 and B2 250 x 500 mm2 and column 550 x550 mm^2.

b. The real R value obtained in the SRPMB structure varies between 3.4 and 4.7. Structures that have a real R value of 3.4 (above the real R value of 3) are in soft soil conditions, namely beam B1 400 x 800 mm2 and column 1000 x 1000 mm2, B2 350 x 700 mm2 and column 900 x 900 mm2 and B3 275 x 550 mm2 and column 600 x600 mm2. Structures that have a real R value of 4.7 (above a real R value of 3) are in medium soil conditions, namely beam B1 325 x 650 mm2 and column 700 x 700 mm2, B1 325 x 650 mm2 and column 650 x 650 mm2 and B2 250 x 500 mm2 and column 550 x550 mm^2.

c. The results of this analysis are very different from the provisions of (R = 8) for SRPMK and (R = 3) for SRPMB which exist for both soft and medium soil conditions. This means that planners can redesign the structure with a new R value, so that savings can be made, but of course still maintain the deformation capacity of the cross section in plastic conditions.

CONCLUSION

Based on the analysis and results that have been carried out in the discussion in the previous chapter regarding Comparison of Real Response Modification Values of Special Moment Structures to Ordinary Moment Structures Using the Pushover Method with soft and medium soil conditions in the DKI Jakarta area with KDS D, it can be concluded as follows: 1). the analysis results obtained with the provisions of SRPMK and SRPMB are as follows: a) the real R value obtained in the SRPMK structure varies between 9.4 and 11.3. Structures that have a real R value of 9.4 (above a real R value of 8) are in soft soil conditions, namely beam B1 325 x 650 mm2 and column 700 x 700 mm2, B2 300 x 600 mm2 and column 650 x 650 mm2 and B3 275 x 550 mm2 and column 550 x550 mm2. Structures that have a real R value of 11.3 (above a real R value of 8) are in medium soil conditions, namely beam B1 300 x 600 mm2 and column 700 x 700 mm2, B1 300 x 600 mm2 and column 650 x 650 mm2 and B2 250 x 500 mm2 and column 550 x550 mm^2, b) the real R value obtained in the SRPMB structure varies between 3.4 and 4.7. Structures that have a real R value of 3.4 (above the real R value of 3) are in soft soil conditions, namely beam B1 400 x 800 mm2 and column 1000 x 1000 mm2, B2 350 x 700 mm2 and column 900 x 900 mm2 and B3 275 x 550 mm2 and column 600 x600 mm^2, c) structures that have a real R value of 4.7 (above the real R value of 3) are in medium soil conditions, namely beam B1 325 x 650 mm2 and column 700 x 700 mm2, B1 325 x 650 mm2 and column 650 x 650 mm2 and B2 250 x 500 mm2 and column 550 x550 mm^2, d) design re-planning or follow-up can be done using the real R value. If in the SRPMK structure the real R value is greater than the design R, then the planner can save reinforcement by re-analyzing the structure using real R, e) with the results of this research analysis, it can be concluded that the SRPMK structure with horizontal irregularities at the Jakarta location, produces a real response modification (R) value (referring to the ATC-40 limit on the ratio of deviations between floors and the rotational capacity of structural components) which is greater than the maximum value requirement. specified in SNI. 2) when the real modified response (R) value is smaller than the applicable regulations, this can indicate that the structure may not meet the desired performance level in a particular earthquake situation. In this case it may be considered unsafe because the structure may not provide sufficient protection to human life or property in an earthquake situation. In this study, the R value was greater than the maximum value stipulated in SNI. In situations where the real response modification value (R) is greater than the planned R value, it can indicate that the structure has a better level of stiffness or bearing capacity than predicted in the initial planning. However, an R value greater than planned does not always guarantee absolute safety. Although a larger R value indicates the potential for better performance in earthquake conditions. In this study, in accordance with the provisions of ATC-40, all structural configurations are included in the Damage Control (DO) category level, which means that the transition between Immediate Occupancy (IO) SP-1 and Life Safety (LF) SP-3, the building is still able to withstand earthquake forces that occurs, with very little risk of human loss. Only SRPMB's 8-story medium ground structure is included in the Life Safety (LF) category level SP-3, 3) structural optimization has been carried out in each building configuration, but it was found that the cross-sectional dimensions of the SRPMB columns and beams in soft soil conditions were the largest cross-sectional dimensions compared to the others. Although the level of structural performance obtained in the SRPMB structure is still at the permitted level, structures with this system will require much larger cross-sectional dimensions and require more reinforcement than SRPMK.

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