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Comparison of Real Response Modification Factors and Performance of SMRSF Structure with OMRSF Structure Using Pushover Method

Friska Damayanti[1], Resmi Bestari Muin[2]

[1]Civil Engineering Post-graduate Program – Universitas Mercu Buana, Jakarta
email: friskadamayanti96@gmail.com
[2]Civil Engineering Post-graduate Program – Universitas Mercu Buana, Jakarta
email: resmi.bestari@mercubuana.ac.id

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Abstract

The value of the earthquake response modification factor (R) affects the results of the story drift in the SMRSF structure, where the smaller the R-value, the larger the deviation and the need for longitudinal reinforcement will be more and more. For structures that do not comply with the SMRSF provisions, in some locations the need for reinforcement is less than that of structures that use the SMRSF provisions. The performance of a structure can be analyzed using the pushover method. The research was conducted with a 4-story and 8-story configuration, with soft soil and medium soil conditions and using SMRSF and OMRSF. From research analysis results, the cross-sectional dimensions of the columns and beams of the ordinary moment building structure system with soft soil type were the largest cross-sectional dimensions compared to the others. Under the provisions of ATC-40, the structure was included in the Damage Control (DC) category level, which means the building was still able to withstand the force of the earthquake, and the risk of fatalities humans were very small. The real R-value of the structure with SMRSF is not much different from the R in the provisions of SNI 1726:2019.

Keywords: *Response Modification Value; SMRSF; OMRSF; Structural Performance; Pushover Analysis.*

INTRODUCTION

The design of earthquake-resistant buildings, has developed an approach to reduce building damage due to earthquakes (Arif, F., & Pariatmono, P. 2022).

According to geographical conditions, Indonesia has regulations for designing earthquake force resisting structures, especially in areas with moderate to high earthquake values. SNI 2847-2019 chapter 18.2 states that Special Moment Resisting Space Frames (SMRSF), special structural walls or a combination of both are used in structures with Seismic Design Category (SDC) D, E, or F areas. While the Ordinary Moment Resisting Space Frames (OMRSF) is used in the SDC area B or C.

One of the steps in the performance-based earthquake engineering methodology is to determine the seismic response of the structure with proper accuracy, For this purpose, pushover analysis is a method that can be used in assessing structural performance (Tarbali, K., & Shakeri, K. 2014). Structural performance is the level of performance of a structure in response to its design earthquake. This level is known by looking at the level of the collapse of the structure when an earthquake occurs for a certain return period.

Hasan, R, et. al. (2002) argue that pushover analysis is an analysis based on the conventional displacement method of elastic analysis. With the planning of structural elements, it will be adjusted progressively to take into account non-linear static pushover analysis through constant gravity loads and gradually increasing lateral loads.

The analysis is carried out by assigning a static lateral pattern to a structure, which is then gradually increased by a multiplier until a lateral displacement target from a reference point is reached. Usually, this point is a point on the roof, or rather the center of mass of the roof (Dewobroto, 2005).

The behavior of the building structure that is reviewed includes the response of the structure in the form of the basic shear force, the period of vibration of the structure, the total deviation and the deviation between levels (Muin, R. B. & Hidayat, R. 2019).

Wardhani, et al. (2019) explain that the performance of a structure can be analyzed using the approach known as pushover method. Pushover analysis can be used as a method in designing earthquake-resistant building structures, but observations are needed because the nature of the loading of this pushover analysis is monotonic static.

A. Mondal et al. (2013) state that most of the current seismic design codes use the linear response of a structure implicitly through the response modification factor (R). This reduction is carried out if a pure elastic design is carried out which results in a large structural requirement, which in turn will cause a higher the construction cost. For this reason, SNI allows a reduction. The higher the value of the response modification factor (R), the more difficult the details of the reinforcement will be, so it is necessary to know the effect of the response modification factor on the system (Tangahu B. R. et al, 2019).

RESEARCH METHOD

The analysis of this research will be limited to structural components with non-linear static analysis using computer assistance and the ETABS program. Non-linear static analysis is pushover analysis in terms of studying the failure mechanism of a structure. An important feature of a structure is its nonlinearity, which is largely due to the nonlinearity of the material and its component geometries (Muin, R.B. 2010).In addition, this study also uses the ATC-40, 1996 method. According to ATC-40 (1996), the performance-based building structure is determined by the shear force limits that have been set, according to **Table 1**.

The performance level of a structure is obtained based on the results of the pushover analysis. The level of performance of a building structure due to the planned earthquake load is referred to as Life Safety. At this level, the structure may suffers severe damage, but the safety of the occupants should be maintained and the building should not collapse, this level can be seen in **Figure 1**.

Table 1. Structural performance level

Structural performance level	Limit Story Drift	
	Maximum total drift	Maximum inelastic drift
Immediate Occupancy	0,01	0,005
Damage Control	0,01 – 0,02	0,005 – 0,015
Life Safety	0,02	No limit
Structural Stability	$0,33\frac{V_i}{P_i}$	No limit

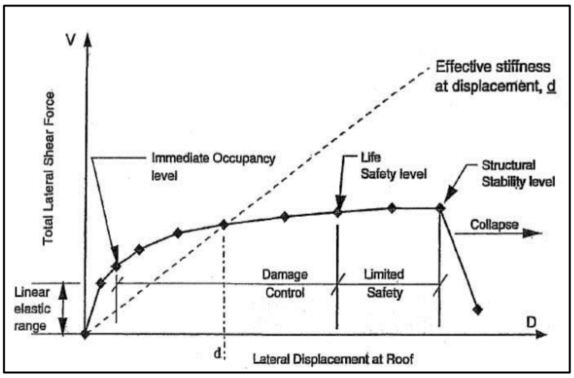

Figure 1. Building Collapse Level

The planned structural system is reinforced concrete with an SMRSF and an OMRSF on a 4-story and 8-story building structure that is intended as an office building. The quality of reinforcing steel uses 420 MPa while the quality of concrete uses 25 MPa for beams and slabs; 35 MPa for columns. The layout of the building structure planning can be seen in **Figure 2** until **Figure 4**. other structural data can be seen in **Table 2.**

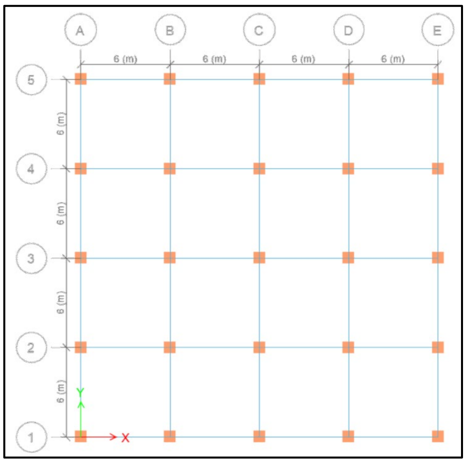

Figure 2. The layout of structure planning

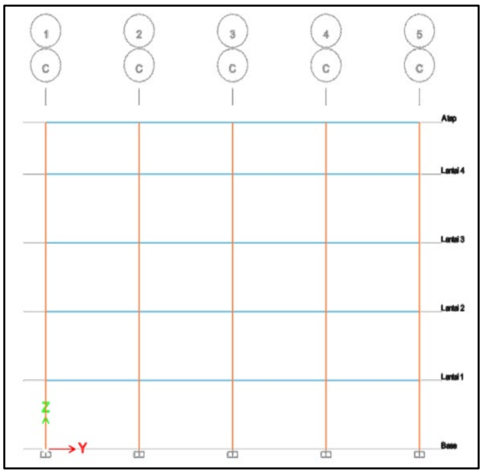

Figure 3. Side view of the 4-story structure

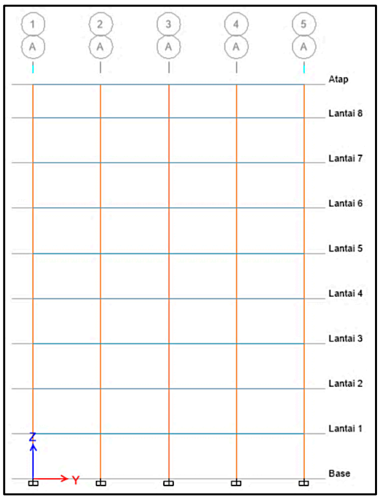

Figure 4. Side view of the 8-story structure

The steps carried out in this study is described in the research flow chart as shown in **Figure 5.**

Table 2. Building structure data

Description		Structure data
Structure Type	:	Reinforced concrete
Building Type	:	Structure-Function
Structure Function	:	Office building
Building Location	:	DKI Jakarta
Loc. Coordinates	:	-6.126276, 106.823025
Type of Soil	:	Medium soil & soft soil
X-direction length	:	24 meters
Y-direction length	:	24 meters
Height Between Floors	:	4 meters
Foundation Depth	:	3 meters
Foundation Type	:	Pinpoint assumption
Structural System	:	SMRSF and OMRSF

RESULTS AND ANALYSIS

The initial planning calculations are carried out on the structural components of the building. These components include slabs, columns, and beams. Firstly, beams are grouped into main beams, sub-beams, and cross-sectional beams. Calculation of beam dimensions and slab thickness h should not less than the minimum stated in SNI 2847:2019 Table 9.3.1.1.

The initial design of the floor slab dimensions refers to the ratio of the long span (L_y) to the short span (L_x). If the ratio ($\beta = L_y/L_x$) between the two values is greater than 2,0 then the floor slab is categorized as one-way slab. Otherwise, if $1{,}0 \leq \beta \leq 2{,}0$ the slab is considered as a two-way slab.

The cross-sectional dimensions of beams, floor slabs, and columns that have been calculated are initial sizes based on requirements specified by SNI 2847:2019. Then these dimensions are used as inputs to ETABS. If the dimensions of the building components do not meet the required sizes according to ETABS, then the dimensions are enlarged and adjusted so that the structure can withstand the load. The results of the calculation of the dimensions of each of these elements can be seen in **Table 3** to **Table 9**.

Table 3. The cross-sectional dimensions of 4-story soft and medium soil SMRSF

Floor	L Beams		T Beams		Column		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Roof	250	500	250	500	550	550	550
1 – 4	300	600	300	600	650	650	650

Table 4. The cross-sectional dimensions of 8-story soft soil SMRSF

Floor	L Beams		T Beams		Column		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Atap	250	500	250	500	550	550	550
5 – 8	300	600	300	600	650	650	650
1 – 4	325	650	300	600	650	700	700

Table 5. The cross-sectional dimensions of 8-story medium soil SMRSF

Floor	L Beams		T Beams		Column		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Roof	250	500	250	500	550	550	550
5 – 8	300	600	300	600	650	650	650
1 – 4	300	600	300	600	650	700	700

Table 6. The cross-sectional dimensions of 4-story soft soil OMRSF

Floor	L Beams		T Beams		Column		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Roof	275	550	275	550	600	600	600
1 – 4	350	700	350	700	750	750	750

Table 7. The cross-sectional dimensions of 4-story medium soil OMRSF

Floor	L Beams		T Beams		Column		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Roof	275	550	250	500	600	550	600
1 – 4	325	650	300	600	700	650	700

Table 8. The cross-sectional dimensions of 8-story soft soil OMRSF

Floor	L Beams		T Beams		Kolom		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Roof	275	550	275	550	600	600	600
5 – 8	350	700	350	700	900	900	900
1 – 4	400	800	400	800	1000	1000	1000

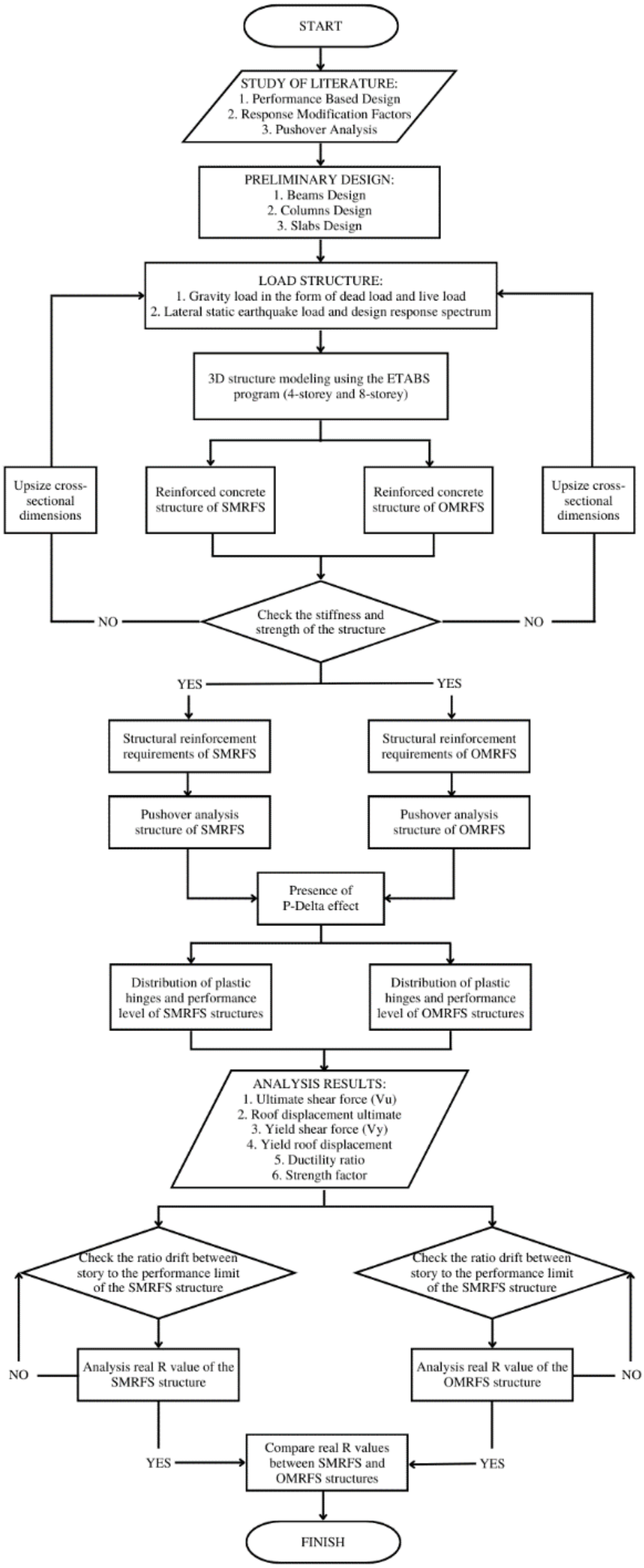

Figure 5. Research flow chart

Table 9. The cross-sectional dimensions of 8-story medium soil OMRSF

Floor	L Beams		T Beams		Column		
	b	h	b	h	Corner	Middle	Edge
	mm	mm	mm	mm	mm	mm	mm
Roof	250	500	250	500	550	550	550
5 – 8	325	650	300	600	800	800	800
1 – 4	325	650	300	600	900	900	900

In SNI 1726:2019 chapter 7.9.1.1 it is stated that the analysis must include a sufficient amount of variance to obtain combined mass participation of variance of at least 90% of the actual mass in each of the orthogonal horizontal directions of the response reviewed by the model. The amount of mass participation can be known by displaying the Table: Modal Participating Mass Ratio on ETABS and then looking at the Sum UX and Sum UY columns. The following is the capital-output of the participating mass ratio for the configuration of the 4-story and 8-story ststructures with soft soil and medium soil conditions:

Table 10. Modal Participating Mass Ratio SMRSF

Modal Participating	Period SMRSF (s)			
	Soft		Medium	
	4 story	8 story	4 story	8 story
Mode 1	0,9970	1,8920	0,9970	1,917
Mode 2	0,9970	1,8920	0,9970	1,917
UX	0,7255	0,7433	0,7368	0,751
UY	0,7255	0,7433	0,7368	0,751
Sum UX	95,89%	92,58%	95,89%	92,59%
Sum UY	95,89%	92,58%	95,89%	92,59%

Table 11. Recapitulation Modal Participating Mass Ratio OMRSF

Modal Participating	Period OMRSF (s)			
	Soft		Medium	
	4 story	8 story	4 story	8 story
Mode 1	0,8000	1,3350	0,9470	1,508
Mode 2	0,8000	1,3350	0,9470	1,508
UX	0,6716	0,6989	0,7165	0,712
UY	0,6716	0,6989	0,7165	0,712
Sum UX	95,77%	91,23%	95,91%	91,31%
Sum UY	95,77%	91,23%	95,91%	91,31%

In the **Table 10** and **Table 11**, it can be seen that the structural system with special moment resisting produces a higher structural period value than the ordinary moment resisting system. Analysis of combined variances that is sufficient to obtain the combined mass participation of variance is required to be more than 90% in the X and Y directions.

The seismic response coefficient (C_S) should not be less than $0{,}044 S_{DS} I_e \geq 0{,}01$ and for building structures with a value of $S_1 \geq 0{,}6$g, then C_S should not be less than the ratio between $0{,}5 S_1$ with the response modification factor value compared to the building priority factor.

Table 12. Static base shear force SMRSF

	Soft		Medium	
	4 story	8 story	4 story	8 story
Cs (s)	0,089	0,075	0,085	0,060
V(kN)	2332,50	3701,21	2233,94	1199,589

Table 13. Static base shear force OMRSF

	Soft		Medium	
	4 story	8 story	4 story	8 story
Cs (s)	0,237	0,199	0,227	0,161
V(kN)	6804,39	12068,20	6112,61	7236,42

In the **Table12** and **Table 13**, it can be seen that the structural system with special moment resisting produces a smaller earthquake shear force value than the ordinary moment resisting system. 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.

Based on SNI 1726:2019 if the fundamental period exceeds $C_u T_a$, then the structure period (*T*) must be $C_u T_a$. With the combined base shear response (V_t) less than 100% of the calculated base shear (*V*) from the static equivalent method, it must be multiplied by V/V_t.

Table 14. Earthquake scale factor SMRSF

	Scale Factor	Check	SF Final
	(V_s/V_d)	V_d >100% V_s	(kN/m^2)
Soft soil of 4-story			
X Dir	1,32	NOT OK	1,62
Y Dir	1,32	NOT OK	1,62
Soft soil of 8-story			
X Dir	1,36	NOT OK	1,67
Y Dir	1,36	NOT OK	1,67
Medium soil of 4-story			
X Dir	1,31	NOT OK	1,61
Y Dir	1,31	NOT OK	1,61
Medium soil of 8-story			
X Dir	1,36	NOT OK	1,67
Y Dir	1,36	NOT OK	1,67

Table 15. Earthquake scale factor OMRSF

	Scale Factor	Check	SF Final
	(V_s/V_d)	V_d >100% V_s	(kN/m^2)
Soft soil of 4-story			
X Dir	1,34	NOT OK	4,38
Y Dir	1,34	NOT OK	4,38
Soft soil of 8-story			
X Dir	1,35	NOT OK	4,42
Y Dir	1,35	NOT OK	4,42
Medium soil of 4-story			
X Dir	1,31	NOT OK	4,29

	Scale Factor	Check	SF Final
	(V_s/V_d)	V_d >100% V_s	(kN/m^2)
Y Dir	1,31	NOT OK	4,29
Medium soil of 8-story			
X Dir	1,31	NOT OK	4,29
Y Dir	1,31	NOT OK	4,29

From the **Table 14** and **Table 15**, it is concluded that the dynamic shear force requirements have not been fulfilled by the provisions of SNI 1726:2019 chapter 7.9.1.4. that the dynamic shear force must be greater than 100% static shear force. If these requirements are not met, then the earthquake force scale is adjusted to the final earthquake scale factor.

According to provisions of SNI 1726:2019 chapter 7.12.1, the story drift limits that apply to structures risk category II is equal to 0,020h_{sx}. However, in chapter 7.12.1.1 it is stated that for the moment bearing system at SDC D, the story drift is not allowed to exceed Δ_a/ρ. The results of these calculations can be seen in **Table 16** and **Figure 6** for a 4-story structure and **Table 17** and **Figure 7** for an 8-story structure:

Table 16. Story drift of 4-story structure

Story	Story Drift (mm)			
	SMRSF		OMRSF	
	Soft	Medium	Soft	Medium
Roof	34,25	27,26	33,53	32,31
4th floor	45,79	36,37	42,10	42,84
3rd floor	56,26	44,68	51,07	52,01
2nd floor	53,23	42,33	47,90	48,65
1st floor	18,10	14,41	16,21	16,40

Table 17. Story drift of 8-story structure

Story	Story Drift (mm)			
	SMRSF		OMRSF	
	Soft	Medium	Soft	Medium
Roof	21,88	16,97	29,56	22,51
8th floor	30,66	23,48	36,06	27,83
7th floor	41,80	31,91	44,81	34,64
6th floor	52,32	40,17	52,01	41,49
5th floor	59,91	47,45	53,48	46,64
4th floor	62,76	51,13	50,27	47,26
3rd floor	63,64	51,90	47,08	43,78
2nd floor	53,62	43,45	36,55	32,57
1st floor	17,28	13,85	11,05	9,37

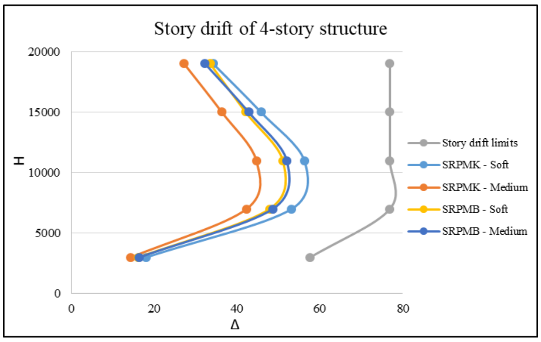

Figure 6. Graph Story drift of 4-story

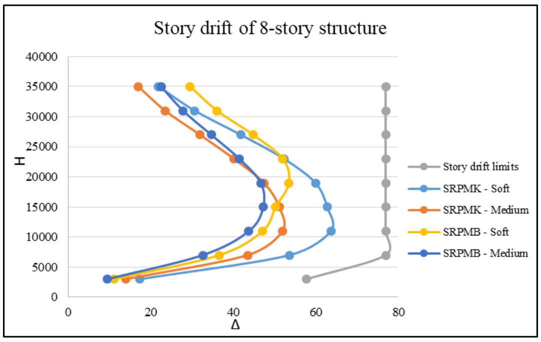

Figure 7. Graph Story drift of 8-story

According to provisions of SNI 1726:2019 chapter 7.8.7, the effect of P-Delta does not need to be taken into account if the stability coefficient (θ) is equal to or less than 0,10 and also cannot be more than θ_{max}. P-Delta effect, the parameters needed are dynamic shear force using the final earthquake scale factor, structure weight, story drift, earthquake priority factor, story height, and deflection enlargement factor then the results will be obtained in **Table 18** and **Table 19**, with the P-Delta graph in **Figure 8** and **Figure 9**.

Table 18. P-Delta of 4-story

Story	P-Delta 4-story (mm)			
	SMRSF		OMRSF	
	Soft	Medium	Soft	Medium
Roof	0,0019	0,0018	0,0014	0,0017
4th floor	0,0033	0,0033	0,0023	0,0031
3rd floor	0,0062	0,0062	0,0041	0,0056
2nd floor	0,0105	0,0105	0,0070	0,0095
1st floor	0,0099	0,0099	0,0066	0,0089

Table 19. P-Delta of 8-story

Story	P-Delta 8-story (mm)			
	SMRSF		OMRSF	
	Soft	Sedang	Soft	Sedang
Roof	0,0009	0,0009	0,0008	0,0009
8th floor	0,0015	0,0015	0,0012	0,0015
7th floor	0,0026	0,0026	0,0018	0,0023
6th floor	0,0043	0,0043	0,0027	0,0036
5th floor	0,0064	0,0067	0,0036	0,0054
4th floor	0,0093	0,0099	0,0048	0,0076
3rd floor	0,0138	0,0148	0,0067	0,0104
2nd floor	0,0198	0,0209	0,0090	0,0133
1st floor	0,0163	0,0171	0,0071	0,0098

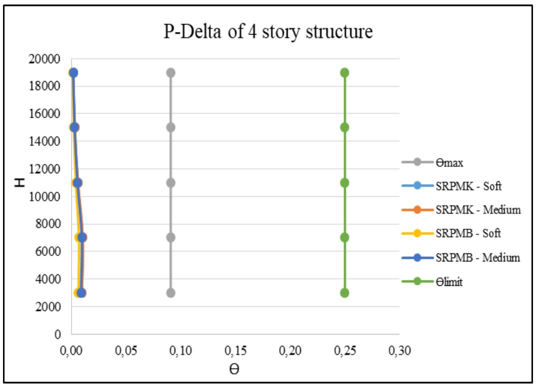

Figure 8. Graph P-Delta of 4-story

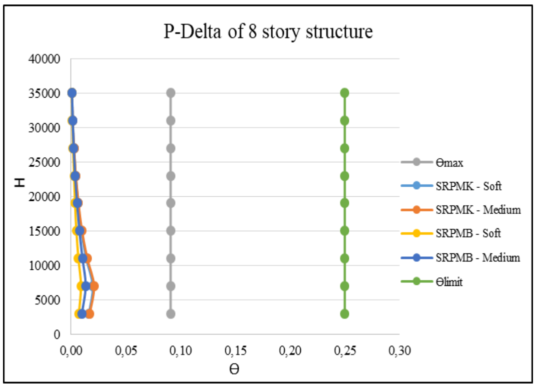

Figure 9. Graph P-Delta of 8-story

SNI 2847-2019 chapter 18.6.2.1 stipulates that the SMRSF flexural structural component must meet several requirements, namely the clear span of the structural component, not less than 4 times its effective height; the ratio of the width to the height of the beam should not be less than 0,3. Component width cannot be less than 250 mm and exceed the width of the supporting member. Reinforcement requirements for beams are briefly presented in the **Table 20** and **Table 21.**

Table 20. Requirements beam reinforcement

Soft soil of 4-story structure		
SMRSF		
Location	BL300X600	BT300X600
Pedestal	3D22	4D22
Field	2D22	2D22
Confinement	2D10-100	2D10-100
OMRSF		
Location	BL350X700	BT350X700
Pedestal	6D25	6D29
Field	2D25	2D29
Confinement	3D10-100	3D10-100
Medium soil of 4-story structure		
SMRSF		
Location	BL300X600	BT300X600
Pedestal	3D22	4D22
Field	2D22	2D22
Confinement	2D10-100	2D10-100
OMRSF		
Location	BL350X700	BT350X700
Pedestal	5D25	6D25
Field	2D25	2D25
Confinement	2D10-100	3D10-100

Table 21. Requirements beam reinforcement

Soft soil of 8-story structure		
SMRSF		
Location	BL300X600	BT300X600
Pedestal	3D22	4D25
Field	2D22	2D25
Confinement	2D10-100	2D10-100
OMRSF		
Location	BL350X700	B400X800
Pedestal	8D25	6D32
Field	3D25	2D32
Confinement	2D19-150	3D13-100
Medium soil of 8-story structure		
SMRSF		
Location	BL300X600	BT300X600
Pedestal	3D22	4D22
Field	2D22	2D22
Confinement	2D10-100	2D10-100
OMRSF		
Location	BL325X650	BT325X650
Pedestal	5D25	6D25
Field	2D25	2D25
Confinement	3D10-100	3D10-100

Column principal recurrence is generally checked based on interaction diagrams where the value of $M_u < ØM_n$ is based on a combination of maximum and minimum. In checking the main reinforcement with interaction diagrams, the SP Column program will be used. According to SNI 2847-2019 chapter 18.7.4.1 reinforcement ratio ρ_g was determined not to be less than 1% and no more than 6%. The minimum spacing between parallel bars in a layer shall be d_b and remains not less than 25 mm. The column reinforcement requirements are briefly presented in the **Table 22** and **Table 23.**

Table 22. Requirements column reinforcement

Soft soil of 4-story structure			
Structure	Location	K550	K650
SMRSF	Longitudinal	24D25	24D25
	Confinement	4D13-100	5D13-100
	Field	2D13-120	2D13-120
Structure	Location	K600	K750
OMRSF	Longitudinal	24D25	28D36
	Confinement	4D13-100	6D16-100
	Field	2D13-120	2D16-120
Medium soil of 4-story structure			
Structure	Location	K550	K650
SMRSF	Longitudinal	24D29	24D29
	Confinement	4D13-100	4D13-100
	Field	2D13-120	2D13-120
Structure	Location	K550	K600
OMRSF	Longitudinal	20D25	20D25

	Confinement	6D13-100	6D13-100
	Field	2D13-150	2D13-120
Structure	Location	K650	K700
OMRSF	Longitudinal	24D32	28D32
	Confinement	6D13-100	6D13-100
	Field	2D13-120	2D13-120

Table 23. Requirements column reinforcement

Soft soil of 8-story structure				
Structure	Location	K550	K650	K700
SMRSF	Long.	28D25	24D29	16D22
	Confi.	4D13-100	5D13-100	4D13-100
	Field	2D13-100	2D13-150	2D13-120
Structure	Location	K600	K900	K1000
OMRSF	Long.	24D22	28D32	24D32
	Confi.	4D16-100	5D16-100	4D19-100
	Field	2D16-120	2D16-120	2D19-150
Medium soil of 8-story structure				
Structure	Location	K550	K650	K700
SMRSF	Long.	24D25	16D19	20D19
	Confi.	4D13-100	4D13-100	4D13-100
	Field	2D13-150	2D13-100	2D13-100
Structure	Location	K550	K800	K900
OMRSF	Long.	20D22	24D22	24D22
	Confi.	4D13-100	5D13-100	5D13-100
	Field	2D13-100	2D13-100	2D13-100

From the **Table 22** and **Table 23**, 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 dimension and the location of the elements. Broadly speaking, the reinforcement requirements from the previous analysis on beam elements required 6D25 reinforcement for the top and 3D25 for the bottom.

Compared with the analysis of this study, the need for reinforcement in A. Mondal (2013) research is more, both for the upper and lower supports. Meanwhile, for the column elements, 12D25 reinforcement is needed for the inner and outer columns. Compared to the analysis of this study, the need for reinforcement from the research of A. Mondal (2013) is less with the same diameter of reinforcement used, namely 25 mm.

The performance level of the structure is determined according to the ATC-40 method. The level of structural performance globally can be determined based on the ratio of the roof displacement value at the performance point to the total building height.

Table 24. Structure performance level results

Structure	Push over	Max. total drift	Max. inelastic drift	Perform. level
4-story		Ratio	Ratio	
Soft soil SMRSF	X	0,01452	0,01202	Damage Control
	Y	0,01452	0,01202	
Medium Soil SMRSF	X	0,01452	0,01202	Damage Control
	Y	0,01452	0,01202	
Soft soil OMRSF	X	0,00806	0,00670	Damage Control
	Y	0,00806	0,00670	
Medium Soil OMRSF	X	0,01964	0,01714	Life Safety
	Y	0,01964	0,01714	
8-story		Ratio	Ratio	
Soft soil SMRSF	X	0,01256	0,01006	Damage Control
	Y	0,01256	0,01006	
Medium Soil SMRSF	X	0,01093	0,00843	Damage Control
	Y	0,01093	0,00843	
Soft soil OMRSF	X	0,01366	0,01116	Damage Control
	Y	0,01366	0,01116	
Medium Soil OMRSF	X	0,01262	0,01012	Damage Control
	Y	0,01253	0,01003	

So by 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 earthquake force that occurs, with the risk of casualties. the human soul is very small. However, from **Table 24** the results of this nonlinear pushover analysis where the structural system with ordinary moments uses large cross-sectional dimensions of columns and beams and the number and dimensions of reinforcement used are also very large. The capacity curve of the results of this research can be seen in **Figures 10** to **Figures 13.**

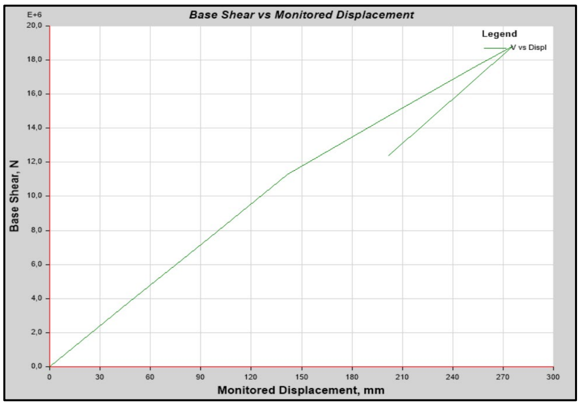

Figure 10. The capacity curve of 4-story soft soil SMRSF

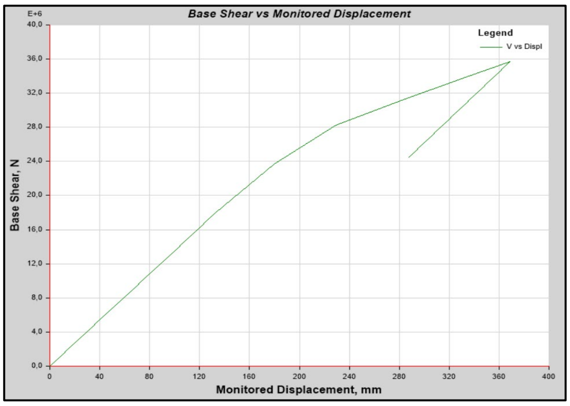

Figure 11. The capacity curve of 4-story soft soil OMRSF

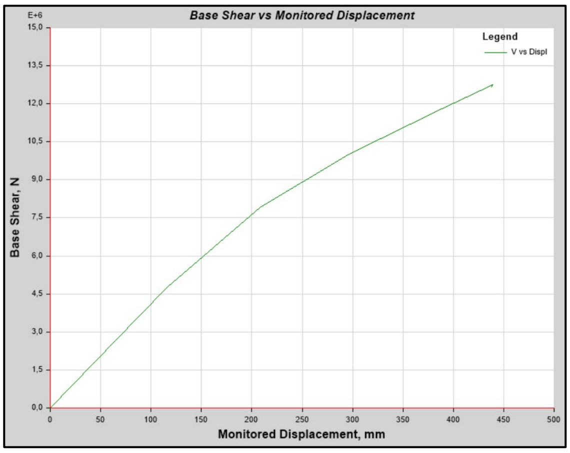

Figure 12. The capacity curve of 8-story soft soil SMRSF

Figure 13. The capacity curve of 8-story soft soil OMRSF

Based on SNI 1726:2019, the parameters needed to obtain the response modification factor value (R) real is ultimate shear force (V_u), design shear force (V_d), elastic shear force (V_e), and redundancy (ρ). The following is a table of these parameters:

Table 25. Real ***R*** value obtained

Structural system	Soil condition and number of floors	*R* (SNI 1726:2019)	Real *R*
SMRSF	Soft soil of 4-st.	8	7,957
	Medium soil of 4-st.		8,515
	Soft soil of 8-st.		7,218
	Medium soil of 8-st.		8,129
OMRSF	Soft soil of 4-st.	3	10,276
	Medium soil of 4-st.		8,317
	Soft soil of 8-st.		5,081
	Medium soil of 8-st.		6,486

In the **Table 25**, it is found that the real *R* value in the structure with SMRSF is not much different from the *R* in the provisions of SNI 1726:2019. However, in the structure with OMRSF the real *R* value looks significantly different compared to the provisions.

Table 26. *R*-value of previous research

Condition	Configuration	*R* (IS 13920)	Real *R*
ATC-40	2-Story	5	4,96
	4-Story		4,97
	8-Story		4,56
	12-Story		4,23
Plastic Hinge Capacity	2-Story		8,48
	4-Story		6,54
	8-Story		5,46
	12-Story		7,09

The results of the analysis of the overall configuration can be seen in **Table 26.** with some descriptions as follows:

1. The real *R* value obtained in the SMRSF structure varies between 7,218 – 8,515. The results of the analysis are not significantly different from the existing provisions, and in soft soil the value is smaller than the OMRSF structure. The resulting real *R* is less than the provision (*R* = 8), causing the value of the received earthquake force to be greater. The smallest real *R* value (7,218) of the design *R* is the maximum value that can be used based on this research. So that planners need to analyze and redesign the planned structure using this real *R* value. On the other hand, the planner does not have to re-analyze the structure for a real *R* value > 8, and the details can be looser, but of course through a reliable analysis.
2. The real *R* value obtained in the SMRSF structure also varies between 5,081 – 10,276. The results of this analysis are very different from the provisions (*R* = 3) that exist in both soft and medium soil conditions. This means that the planner can redesign the structure with a new *R* value, so that savings can be made, but of course still maintain the capacity of the deformed cross section in the OMRSF plastic condition.

3. Re-design or further planning can be done using the real R value to calculate the maximum reinforcement detail as well as the most optimum level of structural performance, if the real R value of the SMRSF structure is greater than the design R, the planner can save reinforcement by reanalyzing the structure using real R which is obtained.
4. However, it cannot be denied that the real R value obtained is influenced by the use of the amount of reinforcement carried out based on the area of reinforcement that needs the design results, as stated by A. Mondal et al. (2013) that the real R value obtained depends on the detailing of the real reinforcement that is carried out. For example, in an 8-storey structure with soft soil SMRSF beam type BL250X500 span B16 floor roof at right support the area of tensile reinforcement (A_s) needs 396,516 mm^2 and the area of compressive reinforcement (A_s') needs to be 332,712 mm^2, so A_s'/A_s needs to be = 0,83. Then the area of tensile reinforcement (A_s) and area of compressive reinforcement (A_s') is 567,057 mm^2, so A_s'/A_s pairs = 1,0. And on the left support the area of tensile reinforcement (A_s) needs to be 384.071 mm^2 and the area of compression reinforcement (A_s') needs to be 312.81 mm^2, so A_s'/A_s needs to be = 0,81. Then the area of tensile reinforcement (A_s) and area of compressive reinforcement (A_s') is 567,057 mm^2, so A_s'/A_s pairs = 1,0. Therefore, the ratio of the compression reinforcement to the tension reinforcement attached to the reinforcement ratio needs to be very influential on this real R value.

CONCLUSION

Based on the analysis and results that have been carried out regarding the Comparison of Real Response Modification Values and Performance of SMRSF Structures with OMRSF Structures Using the Pushover Method with soft soil and medium soil conditions in the DKI Jakarta area with SDC D, it can be concluded as follows:

1. The results of the analysis obtained with the provisions of the SMRSF and OMRSF are as follows:
   a. The real R value for the SMRSF structure varies between 7,218 – 8,515. The results are not significantly different from the existing provisions;
   b. The real R value for the OMRSF structure varies between 5,081 – 10,276. These results are very different from the existing provisions for both soft and medium soil conditions;
   c. So the provisions in SNI 1726:2019 that SDC D with the OMRSF structure will require stricter and more complicated details.
2. In accordance with the provisions of ATC-40, all structural configurations are included in the level of the Damage Control (DO) category, which means the building is still able to withstand the force of the earthquake, with a very small risk of human casualties. Only the OMRSF 4-story medium soil structure is included in the Life Safety (LF) category level SP-3;
3. Structural optimization has been carried out in each building configuration, but the cross-sectional dimensions of the OMRSF columns and beams in soft soil conditions are the largest cross-sectional dimensions compared to the others. Although the level of structural performance obtained in the OMRSF structure is still at the permitted level, the structure with this system will require much larger cross-sectional dimensions and require more reinforcement than the SMRSF.

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