38 Floor Apartment Design with Special Moment Frame System (SMF), With Performance Based Design Using SNI 1726: 2019 AND SNI 1729: 2015

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ABSTRACT

Apartments are an option for vertical housing. Currently, with the rapid development of technology, a person will tend to choose housing that can support their mobility. So it is planned that an apartment building structure is planned using a Special Moment Frame System using Performance Based Design referring to SNI 1729: 2015 and SNI 1726: 2019. Planned with columns HC 582x500x50x65 and HC 508x462x75x75 as well as WF beams 400x300x12x22 and WF 400x200x12x22. The results show that the columns and beams are strong but wasteful.

Keywords: Apartment, Special Momen Frame, Performance Based Design, SNI 1729, SNI 1726

1. INTRODUCTION

1.1. Overview

The very high population growth creates new problems in urban planning. This is based on the large number of urbanization of people from rural areas to urban areas, factors such as education, trade and technology support become the reason someone thinks of living in a big city. Adequate and appropriate occupancy is needed by paying attention to many aspects based on the local population. In today's digital era, residential needs are still a priority in life. Knowing this, the local government is certainly looking for a solution in future city planning considering the limited amount of land available. One solution that has been implemented is to limit residential construction horizontally, and to promote vertical housing development.

The apartment is one of the options for vertical housing. At present, with the rapid development of technology, someone will tend to choose a residence that can support their mobility, someone will tend to choose a residence that is located in the middle of the city and close to the economic center because their residence will be considered to have great value compared to housing in the suburbs. Apartments will be a solution to these problems considering that the land required for apartment construction is not as large as public housing. And now there are many apartments that offer convenience with locations that are in the same area as office buildings and shopping centers. Because of this, apartments are suitable as an alternative to people's needs for housing.

From some of the problems above, planning a steel building structure for an earthquake-resistant apartment plan with a Special Moment Frame System (SMF), engineering using Performance Based Design and SNI 1729: 2015 and SNI 1726: 2019 standards.

2. LITERATURE REVIEW

Structural performance is the level of performance of a structure against a planned earthquake. The level of structural performance can be determined by looking at the level of damage to the structure when it is hit by a planned earthquake with a certain return period. In performance-based design, the building structure is designed by considering the condition of the building during an earthquake and the safety of the building occupants.

There have been many developing methods of designing buildings, the most commonly used method is based on the ultimate force. The performance-based method is actually well known, but in Indonesia this method is relatively new and there is not much literacy that discusses this method when compared to the ultimate force-based method.

3. METHODOLOGY

3.1. Flow Chart

Picture 1. Flow Chart

4. RESULT AND DISCUSSION

4.1. Seismic Classification

4.1.1. Determining the Classification of Soil Sites

$$\begin{aligned}
 \bar{N} &= \sum_{i=1}^n d_i / \sum_{i=1}^n \frac{d_i}{N_i} \\
 &= \frac{55}{3.11} \\
 &= 17.68
 \end{aligned}
 \tag{1}$$

Based on the soil classification in SNI 1726: 2019 Table 5, the value of $\bar{N} = 17.68$ is categorized as a class of SD sites (medium soil).

4.1.2. Determining Risk Categories

The risk category is stated based on the function of the building itself, as the building function is an apartment, so based on SNI 1726: 2019 the risk category is stated in category II.

4.1.3. Determining Seismic Design Categories

The values of S_s (short period earthquake acceleration spectral response parameter 0.2 seconds) and S_1 (earthquake acceleration spectral response parameter short period 1 second) were determined using the application "Design Spectra Indonesia" from puskim.pu.go.id then the following results were obtained.

Table 1. Result Table "Design Spectra Indonesia"

Parameter	Medium Soil D
S_s	0.665
S_1	0.252
S_{MS}	0.844
S_{M1}	0.477
S_{DS}	0.562
S_{D1}	0.318

Source : <http://puskim.pu.go.id/>

With S_s and S_1 data in the table above and the requirements in tables 8 and 9 of SNI 1726: 2019), the earthquake design category can be determined as follows;

a. Medium Soil

$SDS = 0.562$

Seismic Design Category D for risk category II.

$SD1 = 0.318$

Seismic Design Category D for risk category II.

From the results of the data above based on SNI 1726: 2019, the seismic design category is categorized as D for buildings with risk category II.

4.1.4. Determining the Priority Factors of the Earthquake

The earthquake priority factor is stated based on the building risk category, the apartment building risk category is II, so the earthquake priority factor I_e is 1.0.

4.1.5. Determining Site Coefficients

The F_a and F_v site coefficients follow table 6 SNI 1726: 2019 and S_s , S_1 from the calculation results of the "Indonesian Spectra Design" application, then interpolation is carried out as follows.

Table 2. F_a Site Coefficient

	$S_s = 0,5$	$S_s = 0,75$
SD	1,4	1,2

If $S_s = 0.665$ then,

$$F_a = 1.4 - \frac{0.085}{0.25} \times (1.4 - 1.2) = 1.332 \quad (2)$$

Table 3. F_v Site Coefficient

	$S_1 = 0,2$	$S_1 = 0,3$
SD	2,2	2,0

If $S_1 = 0.252$ then,

$$F_v = 2.2 - \frac{0.048}{0.1} \times (2.2 - 2.0) = 2.104 \quad (3)$$

4.2. Load Analysis

4.2.1. Dead Load

Table 4 : Total Dead Loads

Story	Total Loads (kN)
Total	
Story 1	19178.49972
Story 2	8068.586782
Story 3	11030.29782
Story 4	9393.861826
Story 5-7	30689.44106
Story 8	12404.6693
Story 9	1633.362501
Story 10	3504.027778
Story 11	4514.337249
Story 12-20	41772.48443
Story 21	3778.451789
Story 22-30	41772.48443
Story 31	4174.833969
Story 32-38	36664.54408
Roof	3195.787281
TOTAL	231775.67

4.2.2. Live Load

Table 5 : Total Live Loads

Story	Total Loads (kN)
Total	
Story 1	9997.9176
Story 2	3919.7136
Story 3	5607.492
Story 4	4693.4448
Story 5-7	15467.364
Story 8	6423.12
Story 9	607.3848
Story 10	1727.7744
Story 11	2303.2152
Story 12-20	20728.9368
Story 21	1822.2072
Story 22-30	20728.9368
Story 31	2040.2712
Story 32-38	16122.5064
Roof	748.4832
TOTAL	112938.768
TOTAL * ½ (reduction factor)	56469.384

4.2.3. Seismic Load

The effective seismic weight is taken from 1 total dead load + 0.5 total live load.

Table 6 : Effective Seismic Weight

Story	Dead Loads (kN)	Live Loads (kN)	Total Loads (kN)
Story 32-38	36664.54408	8061.2532	44725.7973
Story 31	4174.833969	1020.1356	5194.96957
Story 22-30	41772.48443	10364.4684	52136.9528
Story 21	3778.451789	911.1036	4689.55539
Story 12-20	41772.48443	10364.4684	52136.9528
Story 11	4514.337249	1151.6076	5665.94485
Story 10	3504.027778	863.8872	4367.91498
Story 09	1633.362501	303.6924	1937.0549
Story 08	12404.6693	3211.56	15616.2293
Story 05-7	30689.44106	7733.682	38423.1231
Story 04	9393.861826	2346.7224	11740.5842
Story 03	11030.29782	2803.746	13834.0438
Story 02	8068.586782	1959.8568	10028.4436
Story 01	19178.49972	4998.9588	24177.4585
Roof	3195.787281	374.2416	3570.02888
TOTAL	231775.67	56469.384	288245.054

4.2.3.1. Slide the seismic base

$$C_s = S_{DS} / (R / I_e)$$

$$= 0.59 / (8 / 1)$$

$$= 0.07375 \quad (4)$$

$$V = C_s W$$

$$= 0.07375 \times 288245.054$$

$$= 21258.07 \quad (5)$$

4.2.3.2. Distribution of seismic forces

$$F_x = C_{vx} V \quad (6)$$

$$\text{and}$$

$$C_{vx} = w_x h_x^k / \sum_{i=1}^n w_i h_i^k \quad (7)$$

Table 7 : Total Seismic Loads

Story	H (m)	W (kN)	W.h _{xk}	C _{vx}	F _x
Roof	128.2	3570.029	58674281.5	0.046382341	198.4573
Story 38	124.8	6389.4	99515154.5	0.078667275	336.5957
Story 37	121.4	6389.4	94166715.9	0.074439305	318.5054
Story 36	118	6389.4	88966000.2	0.070328111	300.9147
Story 35	114.6	6389.4	83913007.4	0.066333692	283.8237
Story 34	111.2	6389.4	79007737.5	0.062456049	267.2323
Story 33	107.8	6389.4	74250190.6	0.058695183	251.1406
Story 32	104.4	6389.4	69640366.6	0.055051091	235.5485

Story	H (m)	W (kN)	W.hxk	Cvx	Fx
Story 31	101	5194.97	52993884.6	0.041891956	179.2442
Story 30	97.6	5792.995	55182677.8	0.043622209	186.6475
Story 29	94.2	5792.995	51404950	0.040635895	173.8699
Story 28	90.8	5792.995	47761156.3	0.037755456	161.5452
Story 27	87.4	5792.995	44251296.6	0.034980892	149.6737
Story 26	84	5792.995	40875371	0.032312205	138.2551
Story 25	80.6	5792.995	37633379.4	0.029749393	127.2895
Story 24	77.2	5792.995	34525321.9	0.027292456	116.7769
Story 23	73.8	5792.995	31551198.4	0.024941395	106.7174
Story 22	70.4	5792.995	28711008.9	0.02269621	97.11086
Story 21	67	4689.555	21051414.1	0.016641258	71.20338
Story 20	63.6	5792.995	23432432.1	0.018523466	79.25683
Story 19	60.2	5792.995	20994044.7	0.016595907	71.00934
Story 18	56.8	5792.995	18689591.4	0.014774224	63.21486
Story 17	53.4	5792.995	16519072.1	0.013058417	55.87339
Story 16	50	5792.995	14482486.9	0.011448485	48.98493
Story 15	46.6	5792.995	12579835.7	0.009944429	42.54949
Story 14	43.2	5792.995	10811118.5	0.008546248	36.56705
Story 13	39.8	5792.995	9176335.42	0.007253943	31.03764
Story 12	36.4	5792.995	7675486.34	0.006067514	25.96123
Story 11	33	5665.945	6170213.94	0.004877588	20.86986
Story 10	30	4367.915	3931123.48	0.003107575	13.29646
Story 9	27	1937.055	1412113.02	0.001116283	4.776269
Story 8	24	15616.23	8994948.08	0.007110556	30.42412
Story 7	21	12807.71	5648199.09	0.004464932	19.10422
Story 6	18	12807.71	4149697.29	0.003280358	14.03575
Story 5	15	12807.71	2881734.23	0.002278027	9.747052
Story 4	12	11740.58	1690644.13	0.001336463	5.718361
Story 3	9	13834.04	1120557.55	0.000885807	3.790125
Story 2	6	10028.44	361023.969	0.000285391	1.221112
Story 1	3	24177.46	217597.127	0.000172012	0.735991
TOTAL		288245.1	1265013368	1	4278.726

4.3. Frame Analysis

4.3.1. Plan Profile

Used HC 508x437x50x75 and HC 478x427x40x60 column profile based on previous calculation experiments. Also WF 400x200x12x19 and WF 200x100x5.5x8 based on previous calculation experiments.

Table 8 : Column and Beam Forces (from ETABS)

Frame	Function	Pu (kN)	Mu (kN)	Vu (kN)
HC 508x437x50x75	Column	13393.1	637.8	377.6
HC 478x427x40x60	Column	10092.5	747.4	328.46
WF 400x200x12x19	Beam	240.7	282.85	136
WF 200x100x5.5x8	Beam	0.14	35	26.68

Table 9 : Column and Beam Capacity

Frame	Function	Pu (kN)	Mu (kN)	Vu (kN)
HC 508x437x50x75	Column	17744	3885.1	2397.1
HC 478x427x40x60	Column	13903.7	4320.3	1917.7
WF 400x200x12x19	Beam	2002	410	581.7
WF 200x100x5.5x8	Beam	142.7	44.67	135.5

HC 508x437x50x75 Pu capacity / force	= 17744 / 13393.1
	= 1.32
HC 478x427x40x60 Pu capacity / force	= 13903.7 / 10092.5
	= 1.37
WF 400x200x12x19 Mu capacity / force	= 410 / 282.85
	= 1.44
WF 200x100x5.5x8 Mu capacity / force	= 44.67 / 35
	= 1.27

All beams and collums capacity / force rasio are OK.

4.4. Pushover

In pushover analysis, ETABS 17 is used and the following results are obtained . At the maximum displacement an assumption is used of 2% of the building height.

- Non Linear Case "GRAVITY"

Create a new load case of nonlinear static type. At this stage it is assumed that the scale factor for dead load is 1 and for live load is ½.

- Non Linear Case "PUSHX"

Create a new load case of nonlinear static type. Use load type acceleration UX with a scale factor of -1.

In the load application data input is as follows. The result of 2,564 m is assumed to be 2% of the building height. The 2431 joint label is obtained at the point closest to the center of the diaphragm on the top floor.

- Non Linear Case "PUSHY"

Similar to PUSH X, it creates a new load case of type nonlinear static. Use load type acceleration UY with a scale factor of -1.

In the load application data input is as follows. The result of 2,564 m is assumed to be 2% of the building height. The 2431 joint label is obtained at the point closest to the center of the diaphragm on the top floor.

- Hinge Assign

For defining plastic joints that occur in each element as follows.

- Column = P-M2-M3

In the column defining the plastic hinge it is only used on the ground floor column only. In each assign plastic hinge, relative distance 1 and 0 are used.

○ Beam = M3

In each assign plastic hinge, relative distance 1 and 0 are used.

The next step is to run the ETABS 17 program on the nonlinear load case "GRAVITY", "PUSHX", "PUSHY" and get the following results.

Picture 12. Graphic Displacement X direction

Table 10 : Result Table Displacement X

TABLE: Base Shear vs Monitored Displacement												
Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
	m	kN										
0	0	0	12340	0	0	0	0	12340	0	0	0	12340
1	0.256232	9380.9765	12340	0	0	0	0	12340	0	0	0	12340
2	0.512464	18761.9022	12340	0	0	0	0	12340	0	0	0	12340
3	0.650146	23802.5745	12339	1	0	0	0	12340	0	0	0	12340
4	0.910199	32997.5329	12293	47	0	0	0	12340	0	0	0	12340
5	1.117115	38629.8446	12224	116	0	0	0	12339	1	0	0	12340
6	1.177139	39556.0535	12197	143	0	0	0	12334	6	0	0	12340
7	1.234714	40005.646	12187	153	0	0	0	12329	11	0	0	12340
8	1.292865	40255.6117	12177	163	0	0	0	12329	11	0	0	12340
9	1.30465	40279.0073	12175	165	0	0	0	12323	17	0	0	12340
10	1.340129	40295.8137	12171	169	0	0	0	12310	29	0	1	12340
11	1.377395	40330.2606	12168	172	0	0	0	12285	53	0	2	12340
12	1.409855	40344.9873	12164	176	0	0	0	12272	66	0	2	12340
13	1.414774	40349.9646	12164	175	1	0	0	12270	68	0	2	12340
14	1.415434	40373.664	12164	175	1	0	0	12270	68	0	2	12340

In X direction pushover, it can be seen that almost the entire structure is still able to withstand the force.

Picture 13. Graphic Displacement Y direction

Table 11 : Result Table Displacement Y

Step	Monitored Displ m	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	12340	0	0	0	0	12340	0	0	0	12340
1	-0.000052	11372.7558	12340	0	0	0	0	12340	0	0	0	12340
2	-0.00015	25573.4938	12340	0	0	0	0	12340	0	0	0	12340
3	-0.000155	25983.9145	12339	1	0	0	0	12340	0	0	0	12340
4	-0.000168	27925.4748	12336	4	0	0	0	12340	0	0	0	12340
5	-0.000168	28970.5859	12332	8	0	0	0	12340	0	0	0	12340
6	-0.000169	29790.5746	12329	11	0	0	0	12340	0	0	0	12340
7	0.000027	40473.3768	12204	136	0	0	0	12340	0	0	0	12340
8	0.000106	41879.98	12185	155	0	0	0	12340	0	0	0	12340
9	0.000131	42151.4399	12182	158	0	0	0	12339	0	0	1	12340
10	0.000152	42593.8069	12172	168	0	0	0	12339	0	0	1	12340
11	0.000175	42835.1576	12170	170	0	0	0	12339	0	0	1	12340
12	0.000184	43032.8022	12167	173	0	0	0	12339	0	0	1	12340
13	0.000206	43352.512	12163	177	0	0	0	12339	0	0	1	12340
14	0.000467	45102.6558	12119	221	0	0	0	12338	0	0	2	12340
15	0.000545	45336.4238	12111	229	0	0	0	12338	0	0	2	12340
16	0.000612	45722.1943	12104	236	0	0	0	12338	0	0	2	12340
17	0.00071	45963.4398	12097	243	0	0	0	12338	0	0	2	12340
18	0.000773	46294.6035	12091	249	0	0	0	12338	0	0	2	12340
19	0.000861	46456.7591	12083	257	0	0	0	12336	2	0	2	12340
20	0.00093	46715.1292	12077	263	0	0	0	12336	2	0	2	12340
21	0.001155	47198.2462	12067	273	0	0	0	12334	3	0	3	12340
22	0.001155	47198.4096	12067	273	0	0	0	12334	3	0	3	12340

TABLE: Base Shear vs Monitored Displacement												
Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
	m	kN										
23	0.001155	47198.8926	12067	273	0	0	0	12334	3	0	3	12340
24	0.001155	47199.1705	12067	273	0	0	0	12334	3	0	3	12340
25	0.001156	47220.1641	12067	273	0	0	0	12334	3	0	3	12340
26	0.001156	47220.4347	12067	273	0	0	0	12334	3	0	3	12340
27	0.001156	47220.9267	12067	273	0	0	0	12334	3	0	3	12340
28	0.001156	47220.9439	12067	273	0	0	0	12334	3	0	3	12340

From the table above it can be seen that most structures can withstand loads in the Y direction, but some structures that experience collapse can have a major effect on other structures.

4.5. Performance Structure

After obtaining the results from the pushover calculation, the structure performance level is determined based on the ATC-40.

Table 12 : Structure Performance Level ATC-40

Deviation Limits Between Levels	Structure Performance Level			
	Immediate Occupancy	Damage Control	Life Safety	Strucutral Stability
Maximum Total Deviation	0.01	0.01-0.02	0.02	0.33 Vi / Pi
Maximum Inelastic Deviation	0.005	0.005-0.015	No limits	No limits

Source : ATC-40,1996 Table 11-2

Table 13. Rasio X Direction

D (m)	H (m)	Rasio
1.415	128.2	0.011037441

Table 14. Rasio Y Direction

D (m)	H (m)	Rasio
0.001	128.2	7.80031E-06

5. CONCLUSIONS

From the table of the ratio of the X direction and Y direction, the level of performance of the structure in the X direction is Damage Control, while for the Y direction it is Immediate Occupancy. With this the performance level of the structure for security has been reached. It is necessary to continue with a more detailed study to obtain an accurate design, so that the design can be like the conditions in the field with suitable results.

In the column, column HC 582x500x50x65 has a capacity to withstand a force of 18799 kN a moment of 4320.3 kN and a shear force of 3026 kN, column HC 508x462x75x75 has a capacity to withstand a force of 20475 kN a moment of 3885 kN and a shear force of 3595.7 kN. In a beam, a WF 400x300x12x22 beam has a capacity to withstand a force of 3502.8 kN a moment of

641.7 kN and a shear force of 572.1 kN, a WF 400x200x12x22 beam has a capacity to withstand a force of 2225.4 kN a moment of 456 kN and a shear force of 572.1 kN.

In conclusion, the planned columns and beams are strong but quite wasteful.

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