HIGH-LEVEL MODELING OF BUILDING STRUCTURE USING OCTOGONAL CASTELLATED BEAM AND STEEL PLATE SHEAR WALL SYSTEM (SPSW)

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ABSTRACT

In reality, the development of a city or region is realized in the form of high-rise buildings. In the world of construction usually planner or executor of a project generally choose between two such material is steel or concrete. Concrete is a construction material that forms most often for current construction projects. In this thesis is exemplified how to choose the steel material in construction. steel profile is quite popular to use the castellated profile, by adding a steel plate shear wall (steel plate shear wall). The result of this structural modeling for building a dental hospital in Malang, get the dimensions of the roof joists with spans 7.2 m on the roof using WF profile 300 x 150 x 6.5 x 9 and on the floor with the original profile WF 300 x 200 x 8 x 14, then converted into a castellated beam profile octagonal 442.5 x 200 x 8 x 14. The dimensions of the transverse roof beam using a profile castellated beam octagonal 427.5 x 200 x 8 x 12 and longitudinal roof beam using octagonal profile castellated beam 570 x 200 x 8 x 13. b. Dimensions of the transverse floor beam profile using a profile octagonal castellated beam 427.5 x 200 x 8 x 12 and beam elongated floor using octagonal profile castellated beam 617.5 x 300 x 10 x 15. The dimensions of the column using a 1-4 floor King Cross profile 588 x 300 x 12 x 20, the dimensions of the floor columns 5-7 using a profile King Cross 450 x 200 x 9 x 14.

Keywords :Building Structure, Modeling, Castellated Beam, Steel Plate Shear Wall.

INTRODUCTION

Rise buildings constructed based on the limited use of land, especially in urban areas is also high demand for space for different types of activities. Humans possible to build increasingly high-rise buildings. State building higher and higher, allowing it to require strength in the planning structure. A planner need a material in its construction. The material often used of concrete or steel. Steel material at this time many variations, including a fairly popular use is castellated profile. Castellated profile has various types of openings are hexagonal, octagonal

and round. In this thesis, we planned a multi-story building using octagonal castellated beams and paired a steel plate shear walls.

From the above background, this thesis has several formulation issues such as:

1. How to determine a preliminary design castellated steel beam cross-sectional profile?
2. How to plan a secondary structure include joist, floor plate and the roof and the stairs?
3. How to calculate the load acting on the structure of the building?

LITERATURE REVIEW

1. Castellated Steel Profile

Castellated steel profile is a solid profile (profile WF) which is split into two equal parts in a straight line along the span, with a certain pattern in accordance with the shape of openings to be created. The shape of the openings were varied from a hexagon (hexagonal), segidelapan (octagonal), or rounded (circular) wherein the shape and size of openings customized needs. (Hutabarat and Syahrizal, 2017)

Figure 1. Castellated with various openings

2. Steel Plate Shear Wall

Steel plate shear wall is a lateral load resisting system consisting of a solid vertical steel plates connecting beams and columns around which installed along the height of the structure so as to form a buttress. (Seilie and Hooper, 2005)

Figure 2. Steel Plates Shear Wall

Figure 3. Model of Steel Plates Shear Wall

RESEARCH METHODS

Figure 4. Flow Chart Method Final Settlement

RESULTS AND DISCUSSION

1. Collecting Data

General Data Building

Building names	: Dental Hospital of Brawijaya University.
Building location	: Veteran Street, Malang, East Java
Building functions	: Hospital.
Floors	: 7 floors.
Building height	: 29, 35 meters.
Main structure	: Conventional Concrete

Modification Data Building

Building names	: Dental Hospital of Brawijaya University.
Building location	: Veteran Street, Malang, East Java.
Building functions	: Hospital.
Floors	: 7 floors.
Building height	: 29, 35 meters.
Main structure	: Profiles Octogonal Castellated Beam and King Cross Column.
Structure System	: Steel Plate Shear Wall.

2. Secondary planning

- Plates Planning

On the roof and floor plate is planned to use floor deck with 0.75 mm thickness and quality of concrete (fc): 25 Mpa. Having its own weight of 10.1 kg.m² concrete plates.

Table 1. Table of Plates Planning

Plates Element	Useful load (kg / m ²)	Span (m)	Plates Thick (cm)	Negative Reinforcement (cm ² / m)	Reinforcement
Roof	200	8	9	1.968	Ø10-200
Floor	500	8	9	2,199	Ø12-250

- Secondary Beams Planning

On the secondary beams are planned using WF profile on the roof and octagonal castellated on the floor plate of the building.

Table 2. Table of Secondary Beams

Element of Beam	Type	Interaction Equation (requirement <1.0)		deflection	
				f (permission)	f (max)
Roof	WF 300.200.8.12 CB	0.54	OK	2 cm	1,85cm
Floor	442,5.200.8.14	0.78	OK	2 cm	1,25cm
<i>Elevator</i>	WF 400.200.8.13	0.24	OK	1 cm	0.39 cm

- Stairs Planning

Here are the results obtained for planning the steps of:

Table 3. Table of Stairs Planning

Element	Type	Mu (kg m)		Deflection	
		Mu	ØMn	f ' °	f °
Stairs	4 mm steel plate	17.05	139.5	0.083	0.052
Rung	L 65.65.8	117.39	179.33	0:43	0.32
Bracing	Plates Steel 9 mm	489.63	706.22	0.47	0.32
Stairs Landing	WF 100.50.5.7	450.12	945	0.43	0.2
Beams of Stairs Landing				1.23	0.80

Main	WF	2973.	6862.		
Beam	250.125.5.8	33	5		
Stairs					
Fulcrum	WF	4731.	6862.		
Beam	250.125.5.8	24	5	1	0.86
Stairs					

3. Control Structure Design and Modeling

In modeling the structure using the SAP 2000 program assistance, then controlled by restriction analysis results according to the rules SNI 03-1726-2012 restrictions on earthquake resilience planning procedures for building and non-building structures of buildings. The goal is that the system is being planned structure becomes more feasible.

Figure 5. Structure of Building Modeling Planned

- Mass Participation Control

Control of mass participation should include sufficient amount of variance in order to get the mass participation of at least 90% of the actual mass in the horizontal direction orthogonal to the response to be reviewed.

Table 4. Ratio Mass Participation

OutputCase	StepType	StepNum	Period	SumUX	SumUY
text	text	Unitless	Sec	unitless	unitless
MODAL	Mode	18	0.26432	0742	0919
MODAL	Mode	19	0.21806	0919	0919

- Natural Shakes Time Control Fundamentals

Control of natural shakes fundamental time (T_a) in seconds, can be determined by the following formula equation:

$$T_a = C_t \cdot h_n^x$$

$$C_t = 0,0488$$

$$x = 0,75$$

$$h_n = 29.4 \text{ m}$$

$$T_a = 0.0488 \times 29,40,75 = 0.616 \text{ sec}$$

SD1 value = 0.383, with $C_u = 1.4$ obtained from table rules SNI 03-1726-2012

So the structures that permitted period;

$T = T_a \cdot C_u = 0.616 \cdot 1.4 = 0.8626 \text{ sec}$

Table 5. Period and Frequency Building Structure

OutputCase Text	StepType text	StepNum unitless	Period Sec	Frequency Cyc / sec
MODAL	Mode	1	0.811471	1.232329506
MODAL	Mode	2	0.811471	1.232330644
MODAL	Mode	3	0.753497	1.327144532
MODAL	Mode	4	0.739337	1.352562521
MODAL	Mode	5	0.738095	1.354838833
MODAL	Mode	23	0.092806	10.77520708
MODAL	Mode	24	0.089164	11.21526172

- End Value Response Spectrum Control

Based on ISO 1726-2012, the final value of the dynamic response of building structures in the specified direction can not be less than 85% of the value of the static response or ($V_{dynamic} \geq 0.85 V_{static}$).

Table 6. Base Reaction of Structure Building

Output case	V dynamic (kg)	V static (kg)	V dynamic $\geq$ V static
Earthquake Directions X	758,067.93	758,066.887	OK
Earthquake Directions Y	758,226.65		OK

- Control deviation (drift)

Calculation of the deviation between the floor (Δ) is calculated in order to distinguish the deflection at the center of mass at the top and bottom are reviewed.

Table 7. Inter-Floor Control Deviation Charges Due Earthquake Directions X

Floor	h_i (Mm)	δ_{xe} (Mm)	Δx (Mm)	$\Delta = \delta_{xa} - \delta_{xb}$ (Mm)	Δa (Mm)	$\Delta a / \rho$ (Mm)	$\Delta < \Delta a$ / ρ
1 (Basic)	0	0	0	0	0	0	OK
2	4200	3,585	341	14 341	63	48	OK
3	4200	8442	769	19 428	63	48	OK
4	4200	889	557	21 788	63	48	OK
5	4200	501	004	22 447	63	48	OK

		25	102				
6	4200	550	200	24 196	63	48	OK
		31	124				
7	4200	060	239	22 039	63	48	OK
		35	141				
8	4200	269	077	16 839	63	48	OK
roof		36	144				
beams	1800	157	628	3,551	27	21	OK
		36	145				
Upstairs	1100	329	315	0687	17	13	OK

Table 8. Inter-Floor Control deviation Expenses Due to Earthquake Directions Y

Floor	hi (Mm)	δx_e (Mm)	Δx (Mm)	$\Delta = \delta x_a - \delta x_b$ (Mm)	Δa (Mm)	$\Delta a / \rho$ (Mm)	$\Delta < \Delta a$ / ρ
1 (Basic)	0	0	0	0	0	0	OK
			17				
2	4200	4,424	695	17 695	63	48	OK
			39				
3	4200	9834	337	21 642	63	48	OK
			61				
4	4200	15 409	635	22 298	63	48	OK
			82				
5	4200	20 595	380	20 745	63	48	OK
			110				
6	4200	27,500	001	27 622	63	48	OK
			133				
7	4200	33 482	927	23 925	63	48	OK
			148				
8	4200	37 007	027	14 101	63	48	OK
roof			153				
beams	1800	38 410	642	5,614	27	21	OK
			161				
Upstairs	1100	40 358	430	7788	17	13	OK

4. Primary Structure Planning and Connections

- Primary Structure Planning

In the calculation and planning of the building to the main structure used octogonal castellated beams on the lengthwise and crosswise direction and the column used kingcross profile.

Table 9. Calculation of Main Beams Recap

Type column	L m	Dimension Mm	Strong Bending Moment $\phi M_n < M_u$ (kg.m)	Strong Slide $\phi V_n < V_u$ (Kg.m)	Deflection $f' > f''$	Interaction Equation
CB 1	8	CB.617,5x 300x10x15	75622.06 <28091.39	23224.12 <14592.98	2.22 <0.57	0.36 > 1
CB 2	8	CB.580x20 0x8x13	43452.72 <4350.70	17287.06 <2797.74	2.22 <0.01	0.80 > 1
CB 1a	7.2	CB.427,5x 200x8x12	27835.35 <14251.89	12223.86 <9942.44	2 < 0.48	0.01 > 1

Table 10. Calculation Column Recap

Type column	L m	Dimension Mm	Analysis Structure			Nominal Moment Control $\phi M_n < M_u$ (kg.m)	Interaction Equation
			P_u (kg)	M_{ux} (kg m)	M_{uy} (Kg.m)		
Column lt. 1-4	4.2	KC.588x30 0x12x20	291,983. 99	152.7 3	10816. 51	97209> 152.73	0.927 > 1
Column lt. 5-7	4.2	KC.450x20 0x9x14	106,350. 31	311.3 2	8462.0 8	35 370> 311.32	0.912 > 1

- Steel Plate Shear Wall Planning

SAP2000 analysis results obtained from the shear force on a steel plate shear wall that is:

$$V_u = 53\,497,85 \text{ kg}$$

Using a steel material BJ 37

$$f_y = 2400 \text{ kg / cm}^2 \text{ and}$$

$$f_u = 3700 \text{ kg / cm}^2$$

Dimension of Steel Plate Shear Wall = 3.6 mx 2.1 m

Steel Plate Shear Wall Thickness

Assumptions of SPSW pull angle of 30 ° from the VBE.

$$\phi V_n = 0.90 \times 0.42 \times f_y \times t_w \times L_{cf} \times \alpha$$

$$53497.85 = 0.90 \times 0.42 \times 2400 \times t_w \times 360 \times \sin(2 \times 30^\circ)$$

$$t_w = 0.189 \text{ cm, then use } t_{w \min} = 0.3 \text{ cm}$$

Pull angle Actual accordance thickness SPSW

$$\alpha = \tan^{-1} \sqrt[4]{\frac{1 + \frac{t_w L}{2 A_c}}{1 + t_w h \left[\frac{1}{A_b} + \frac{h^3}{360 I_c L} \right]}}$$

$$\alpha = \tan^{-1} \sqrt[4]{\frac{1 + \frac{0.3 \times 360}{2 \times 385}}{1 + 0.3 \times 210 \left[\frac{1}{84.12} + \frac{210^3}{360 \times 127020 \times 360} \right]}}$$

$$\alpha = 4180^\circ \text{ qualify } 30^\circ < \alpha < 55^\circ$$

Scroll strength Actual SPSW

$$\phi V_n = 0.90 \times 0.42 \times f_y \times \sin(2) t_w L_{cf} \alpha$$

$$\phi V_n = 0.90 \times 0.42 \times 2400 \times 0.3 \times 360 \times \sin(2 \times 41.80^\circ)$$

$$\phi V_n = 97\,366,79 \text{ kg} > 53497.85 \text{ kg} \dots (\text{OK})$$

- Joint Planning

Joint with the planned use bolts of quality:

Profile BJ 41, $f_u = 410 \text{ MPa} = 4100 \text{ kg / cm}^2$

BJ bolt 50, $f_u = 500 \text{ MPa} = 5000 \text{ kg / cm}^2$

Table 11. Connection Planning Recap

Element		Elbow Profile	D (mm)	n (bh)
Secondary Floors	Secondary Beams body	L60.60.6	12	3
Beam – Main Beam joint	Main Beams body	L60.60.6	12	3
Secondary Roof Beam – Main Beam joint	Secondary Beams body	L40.40.4	12	3
	Main Beams body	L40.40.4	12	3
Main Stairs beam – Fulcrum Stairs Beam joint	Main Beams Stairs body	L40.40.4	8	2
	Fulcrum Stairs Beam body	L40.40.4	8	2
	Fulcrum Stairs Beam body	L40.40.4	8	2
Beam – Columns joint	Column Wing	L40.40.4	8	2

CONCLUSIONS AND SUGGESTION

1. Conclusion

From the calculation and analysis has been done, it can be concluded as follows:

1. The results of calculation of secondary structure:

- Planning for the roof and floor slab hospitals use floor deck of PT. Lysaght Bondek with 0.75 mm thick and 90 mm thick concrete slab and negative reinforcement are installed 10-200 for roof plate and negative reinforcement for floor slabs 12-250. $\phi \phi$
- Dimensions of roof joists with spans of 7.2 m on the roof using WF profile 300 x 150 x 6.5 x 9 and on the floor with the original profile WF 300 x 200 x 8 x 14, then converted into a castellated beam profile octogonal 442.5 x 200 x 8 x 14.

- c. Dimensions of the lift beam using WF profile 400 x 200 x 8 x 13.
- d. Thick plates used 4 mm stairs and risers angled stiffener dimensions 65 x 65 x 8.
- e. Landing slab thickness used 9 mm and the dimensions of the beam landing using WF profile 100 x 50 x 5 x 7.
- f. Dimensions main stairs beam and fulcrum stairs beam using WF profile 250 x 125 x 5 x 8.

2. The results of calculation of primary structure:

- a. Dimensions of the transverse roof beam using octogonal profile castellated beam 427.5 x 200 x 8 x 12 and longitudinal roof beam using octogonal profile castellated beam 570 x 200 x 8 x 13.
- b. Dimensions of the transverse floor beam using castellated beam profile octogonal profile 427.5 x 200 x 8 x 12 and beam elongated floor using octogonal profile castellated beam 617.5 x 300 x 10 x 15.
- c. 1-4 floor column dimensions using a profile King Cross 588 x 300 x 12 x 20 dimension columns 5-7 floor using a profile King Cross 450 x 200 x 9 x 14.
- d. Used steel plate shear wall with 3mm thick

3. Suggestion

Based on the description and discussion in the previous chapter, it can be given suggestions as follows:

- a. In order to do the analysis and recalculation control well for the secondary structure, primer and calculation of connections. If required the calculation of the foundation.
- b. Need for analysis of rigidity in the structure of the building.
- c. It is expected that the need for a study to learn about the calculation of castellated beams octagonal also planning to use a steel plate shear wall (steel plate shear wall) more deeply by considering various things about the technical, economic and aesthetic.

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