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Design of Steel Structure Elementary School Building Sdn 05 Pagi in Cibubur

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ABSTRACT

The compressive strength of concrete can be used to increase the strength of steel beams, especially in the positive moment region. From the composite action that occurs it is expected to reduce the size of the steel profile to be used. This thesis compiles a plan using Composite Steel Beams and End Plate Connections, using the SAP2000v23 program for static calculations, and calculation of beam and column dimensions as well as connection and base plate planning. To analyze the dimensions of the required WF Steel Profiles for Columns, Composite Beams, beam-column connections, main beams-joists, and floor slabs. From the analysis results, the dimensions for main beams are WF 400x200x8x13 and WF 450x200x9x14, for joists using WF 300x150x8x13, and for columns using WF 350x350x12x19. The design of the connection on the flanged beams uses an End Plate with a plate thickness of 18 mm and the number of bolts is 8 Ø 24 mm. The connection design for the web beam-column connection uses an End Plate with a thickness of 10 mm and a total of 8 Ø 20 mm bolts. The connection design for the main beam-subbeam and the joist beams uses an angled profile of 80x80x8 and the number of bolts is 4 Ø 22 mm. The required base plate size is 550x550x45mm using 8 Ø 19 mm anchors with a length of 800 mm.

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1. INTRODUCTION

The development of the times in Indonesia has increasingly encouraged growth in the construction of buildings, facilities, and infrastructure to be further improved. The lack of available land is one of the problems in infrastructure development so one alternative is to build multi-story buildings in response to the needs of building facilities and infrastructure (Rionaldo Wantania, Banu Dwi Handono, Ronny Pandaleke 2019). One of the most important factors in designing a high-rise building structure is the strength of the building structure, where this factor is closely related to the safety and durability of the building to withstand the loads acting on the structure (Al Amin, Najib 2014).

The rapid development of structures using steel materials has prompted civil engineers, especially in steel construction, to innovate, such as modifying the shape of steel profiles and new methods that aim to produce buildings that are more economical but do not leave the safety factor of the structure, one of which is the use of composite beams. Prior to the discovery of shear connectors for composite design, the concrete slabs with steel girders were analyzed separately, each acting independently in load bearing. However, with advances in civil technology, a shear connector is created to withstand the shear forces that occur. The shear connector is able to withstand the slip that occurs so as to provide the necessary interaction for the steel and concrete to work as a unit in supporting the load. The compressive strength of concrete can be used to increase the strength of steel beams, especially in positive moment areas where the concrete is compressed. From the composite action that occurs it is expected to reduce the size of the steel profile used (Muhammad Zulkifli, 2016)(Sugawa et al., 201).

The steel structure analysis method that has recently been commonly used besides the Allowable Stress Design method (ASD) is the Load and Resistance Factor Design method (LRFD) which is usually also called Limit State Design. The boundary state limit is a general term that means a condition in a building structure where the building cannot fulfill its function. In design boundary conditions, safety-related forces are prevented by multiplying a factor in the loading(Salmon and Johnson, 1996).

The building structure(Dewobroto, 2016) of Elementary School SDN 05 Pagi in Cibubur which is designed to use reinforced concrete material. In this research, the school building will be designed using steel material with the LRFD method, as an alternative other than Reinforced Concrete material. The purpose of this study is to calculate and analyze the structure of SDN 05 Pagi Elementary School Building in Cibubur using steel structures.

2. METHOD

The design was carried out at the SDN 05 Pagi Elementary School Building in Cibubur using a steel structure with a total of 4 stories with an area of each floor 35.1 x 20 = 702 m2 and a total area of 3,024 m2.

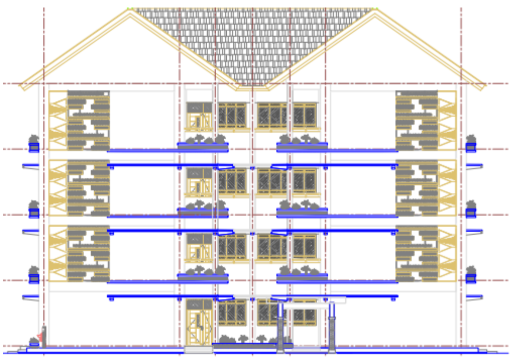

Figure 1 Front View

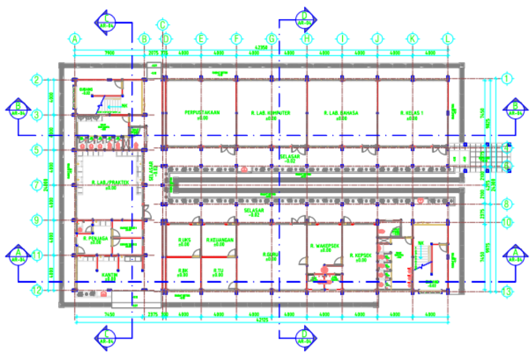

Figure 2 Building Plan

This design and analysis in this study use several structural design guidelines, namely Specifications for Structural Steel Buildings (SNI 1729:2020), Earthquake Resistance Design Procedures for Building and Non-Building Structures (SNI 1726:2012), Minimum Load for the Design of Buildings and Other Structures (SNI 1727:2020)(Rochman, 2012).

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The structure in this study is located in Cibubur City with a soft soil type. The structure has 4 floors and the building functions as a warehouse or production factory with the following structural data:

a) Steel
   Profile: ASTM A-36.
   Bolt: ASTM A-325
b) Drawing
   The drawings obtained in this research are shop drawings and architect drawings.
c) Material
   The material used in this study can be seen in the table below.

Table 1 Material Data

No	Code	Size	Info
1	K1	WF350X350X12X19	KOLOM
2	B1	WF400X200X8X13	BALOK INDUK
3	B1'	WF450X200X9X14	
4	B2	WF350X175X7X11	BALOK ANAK

From Figure 2, it is known that each floor of the building has a different function. Thus, for loads on the building(Setiawan, 2012), follow the loading layout following applicable regulations using SNI 1727-2020 regarding minimum loading. The steel structure design process in this research can also be seen as shown in the flowchart below.

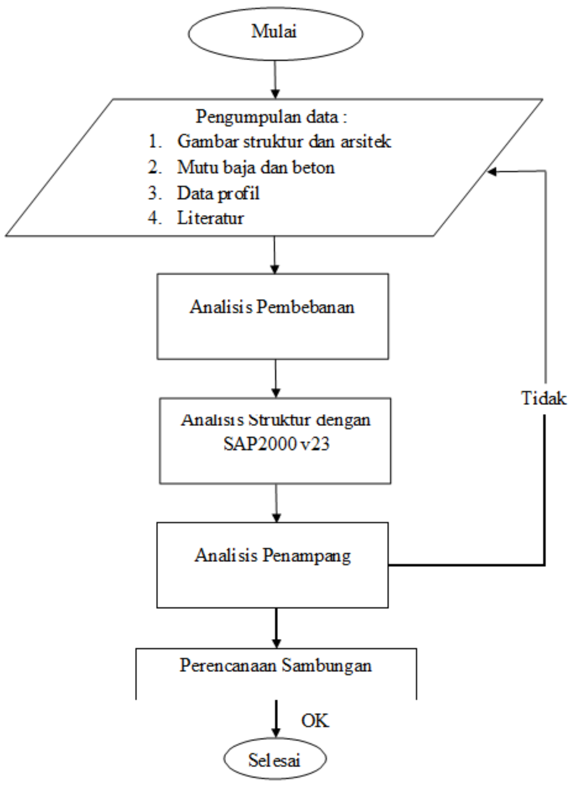

Figure 3 Flowchart

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3. RESULT AND DISCUSSION

The results of steel structure in this study also take into account the earthquake loads as lateral loads and gravitational loads, then combine those loads according to the requirements of SNI 1726-2012 and SNI 1729-2002, and analyze the internal forces using the LRFD method.

Table 2 Profile Selection For Column

Profile	**Axial**	**Bending**	**Info**
	$\frac{Pu}{\emptyset Pn}$	$\frac{Pu}{\emptyset Pn} + \frac{8}{9}\left(\frac{Mu}{\emptyset Mn}\right) < 1$	
WF350X350X12X19	Lantai 1 – 4		OK
	0.471 < 1	0.99 < 1	

Table 3 Profile Selection For Beam

Profile	**Moment**	**Shear**	**Info**
	$\emptyset M_n > M_u$	$\emptyset V_n > V_u$	
WF400X200X8X13	50479.08 > 1328.23	35458.56 > 1328.23	OK
WF450X200X9X14	44350.89 > 12790	40020.48 > 12790	OK
WF350X175X7X11	33405.08 > 30646.6	31104 > 30646.6	OK

3.1. Connection

After getting the appropriate steel profile for use in buildings. Then by using the forces in the structure, the required connections can also be calculated.

Table 4 Beam – Column Flange Connection

Type	Moment	Shear	Sum (pcs)	Ø (mm)
	$\emptyset M_n > M_u$	$\emptyset V_n > V_u$		
Flange	40780.91 > 21108	12626.7 >2638.61	8	24

Table 5 Beam – Column Web Connection

Type	Shear	Sum (pcs)	Ø (mm)
	$\emptyset V_n > V_u$		
Web	17537.37 > 508.95	8	24

3.2. Shear Connector

For joists, two shear connectors are attached to the flange with a distance of 80 mm between the other shear connectors. As for the main beam, two shear connectors are installed on the flange with a distance of 100 mm from the other shear connectors(Asroni, 2015).

3.3. Modelling

Based on architectural drawings consisting of plans per floor and sections in the X and Y directions, a 3D model was created using the SAP2000 program. The loading is adjusted to the function of each room on each floor as shown in Figure 2. The configuration model of the building plan for each floor can be seen in Figure 4. The configuration of the X and Y directions respectively can be seen in Figures 5 and 6.

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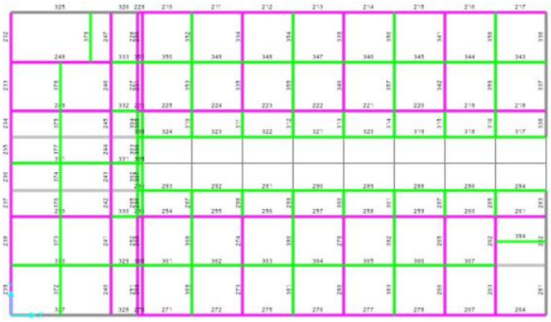

Figure 4 X – Y Configuration Plan

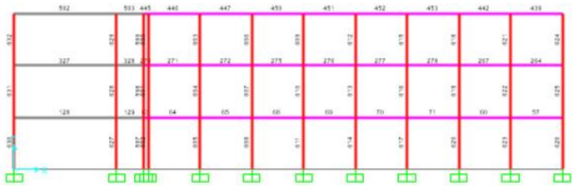

Figure 5 Y – Z Configuration Plan

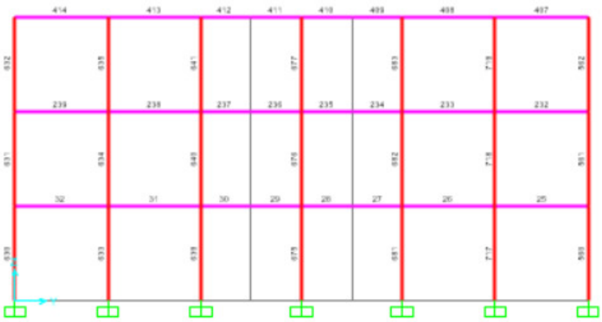

Figure 6 X – Z Configuration Plan

3.4. Response Spectrum

The average N-SPT value is below > 50 which means it is a soft soil type with a seismic design coefficient D (SNI 1726-2012).

Table 6 Response Spectrum Data

Variable	Value
SS(g)	0,749
S1(g)	0,317
FA	1,000
FV	1,000
SMS (g)	0,749

Variable	Value
SM1(g)	0,317
SDS(g)	0,499
SD1(g)	0,211
T0	0,499
Ts	0,499

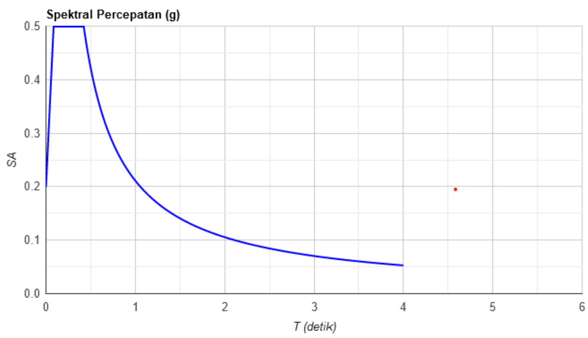

Figure 7 Response Spectrum of Cibubur

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3.5. Mass Participation

Mass participation is the total mass of the building carried by each mode of vibration. Following SNI 1726-2012, the accumulative mass participation of the building for the three DOF directions (x translation and y translation) must exceed 90%. The value of mass participation can be seen in Table 7 below.

From Table 7, in the 1st vibrational pattern the number of mass participation in the x direction is equal to 92%, and on the 2nd vibration pattern in the y direction is 92%. The value of both has exceeded the minimum value of 90%. Based on the table below, mass participation has reached more than 90% in the second mode which has fulfilled the requirements specified in the SNI

Table 7 Mass Participation

Mode	Period	Sum UX	Sum UY
1	2,457	92%	0%
2	1,514	92%	92%
3	1,251	92%	92%
4	0,897	99%	92%
5	0,796	99%	92%
6	0,789	99%	92%
7	0,762	99%	92%
8	0,733	99%	92%
9	0,716	99%	92%
10	0,696	99%	92%
11	0,655	99%	92%
12	0,647	100%	92%

3.6. Story Drift

Determination of the story drift (Δ) must be calculated as the difference in deviation at the center of mass above and below the level under review (see figure 8).

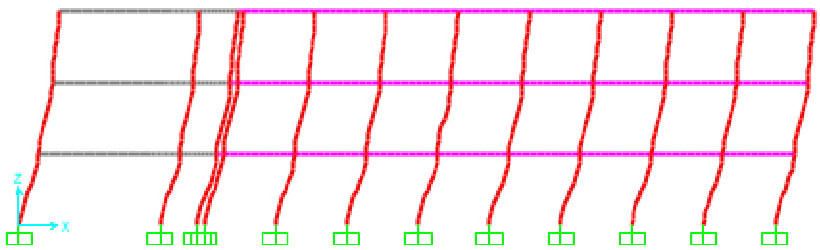

Figure 8 Story Drift

The story drift between floors must be calculated as an effort to find out the largest difference from the deviation of points aligned vertically along one edge of the structure from top to bottom of the level under consideration. According SNI 1726 – 2012, deflection of the center of mass at level x (δx) is calculated according to Equation 1 below.

$$\delta_x = \frac{C_d \delta_{xe}}{I_e} \qquad \textbf{(1)}$$

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The center of mass deflection at level x (δx) is calculated by multiplying the value of Cd which is the amplification factor of the deflection of 5.5 with the value of δxe which is the deflection at the required location by elastic analysis and then divide it by the value of Ie of 1.5 which is the priority factor of the earthquake based on building function and risk category.

Based on SNI 1726-2012, the deflection that occurs must be smaller than the allowable deflection. The story drift based on the results of the SAP2000 program are shown in the table below. From Table 8 and Figure 8, it is known that the deviation between levels of the structural model is still below the allowable drift.

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Table 8 Story Drift for Each Floor

Story	X direction		Y direction		Drift Limit (mm)	Info
	δ_{xe} (mm)	δ_x (mm)	δ_{ye} (mm)	δ_y (mm)		
4	0.0099	0.0363	0.0064	0.0235	57.3	OK
3	0.021	0.0916	0.0141	0.0283	57.3	OK
2	0.029	0.0297	0.0185	0.1612	57.3	OK

The story drifts in the y direction has a smaller value than the story drifts in the x direction. This is because the building plan in the x direction is longer than the building plan in the y direction so it provides greater lateral strength to withstand earthquake forces in the y direction. This causes the structure in the y direction to be stiffer than the x direction. From Table 8 it can also be seen that there is quite a large difference between the deviations that occur and the allowable deviation limits, this indicates that the structure is too rigid.

4. CONCLUSION

The design results of the steel structure elementary school building *SDN 05 Pagi* in Cibubur using the Load and Resistance Factor Design (LRFD) method can be concluded as follows:

1. The story drifts in the y direction has a smaller value than the story drifts in the x direction because the building plan in the x direction is longer than the building plan in the y direction which provides greater lateral strength to withstand earthquake forces in the y direction.
2. The story drift of the structural model is still below the allowable story drift with quite a large difference. In other words, the building structure is still quite rigid with the size of the steel profile used.
3. The dimensions of the steel profile required for composite main beams are WF 400x200x8x13 and WF 450x200x9x14, and for composite joists use WF 350x175x7x11. While the dimensions of the steel profile for the column use WF 350x350x12x19.

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The connection design for the flange beam-column connection uses an End Plate with a plate thickness of 18 mm, with a total of 8 Ø 24 mm. Meanwhile, the connection design for the web beam-column connection uses an End Plate with a plate thickness of 10 mm, with a total of 8 Ø 20 mm bolts. The connection design between the main beams and joists and between joists uses an angled profile of 80x80x8, with a total of 4 Ø 22 mm bolts. The design base plate size required is 550x550x45 mm using 8 Ø 19 mm anchor length 800 mm.

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