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ANALYSIS OF STRENGTH OF LIFT FRAME STRUCTURE ON LIFT LOAD WEIGHT OF 320 KG AND LIFT LOAD WEIGHT OF 450 KG USING ETABS SOFTWARE (CASE STUDY: PONDOK INDAH TOWNHOUSE PROJECT)

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ABSTRACT

The lift frame is a system that provides physical support to the lift. The steel material used is hot rolled steel (WF and H-Beam). In this research, to prevent damage due to earthquakes, it is necessary to carry out earthquake analysis including structural irregularities, intersections between levels, and increased forces due to irregularities following SNI 1726-2019. This research aims to determine the specifications of an elevator frame that can withstand a load of 320 kg and analyze the axial force, moment, and shear in the elevator structure using ETABS Software. Apart from that, to find out the results of the strength of the lift frame on a floor building if a load force of 450 kg is applied. The results obtained in this research are as follows, the weight of the lift load of 320 kg working on the 200x100x5.5x8 WF support beam is 1726.6 kg, and the weight of The lift load of 450 Kg working on the 200x100x5.5x8 WF Support Beam of 1925 Kg. In earthquake load analysis in the South Jakarta area, deformation in building structures was 3,064 mm in the X direction and 1,722 mm in the Y direction, so the elevator frame structure is safe.

Keywords: *Lift frame; ETABS, Earthquake Spectrum, Internal Loadings.*

1. PRELIMINARY

In the construction of a building, it is necessary to have transportation that can facilitate the transportation of loads from the lower floor to the next floor [1], In the Pondok Indah Townhouse Project with a capacity of 8 floors has an elevator construction, of course, what must be taken into account here is the strength of the structure of the elevator frame, the elevator frame is a system that functions to provide Physical Support to the elevator or it can also be called an arrangement or a unity of the elevator frame iron rods, iron plates, and other materials that form an elevator frame structure. [1]. The type of material used is of course steel material with IWF steel profile type and H Beam steel profile, to analyze how strong the steel structure of the elevator frame is, it is necessary to know the earthquake analysis in an area (Pondok Pinang, South Jakarta) [4], If you already know the type of steel and the earthquake spectrum, then to analyze whether the steel structure of the elevator frame is strong or not, it is necessary to have software that can reach stability in terms of the feasibility of a structure, here I use ETABS software [2]. In this study, the steel material used has different functions and dimensions, for WF steel as a stacker with dimensions of WF 200 × 100 × 5.5 × 8 and H-beam steel profiles as columns with dimensions H 200 × 200 × 8 × 12, the research I conducted used a comparison of elevator load capacity, of course, the weight of the elevator load is 320 kg (including the engine, equipment and passengers) with an elevator load weight of 450 kg (including engine, equipment and passengers), for the load capacity used is 320 kg.

In this design, a 15-meter high elevator structure will be located in South Jakarta and assumes standing on medium ground. To analyze the parameters, it must follow the latest SNI 1726-2019 earthquake regulations which we can get on the following website, https://rsa.ciptakarya.pu.go.id/2021/ [3]. In the process of making an elevator frame structure, we also need to know the loading that works on the elevator frame structure, such as static and dynamic loads, from these two loads we can design and find the stability of an elevator frame structure.

ETABS (Extended Three-Dimensional Analysis of Building Systems) is one of the programs used to analyze and design building structures quickly and accurately [2]. The ETABS software in terms of analyzing structural calculations is very fast and precise and that's why I use this software.

The elevator frame built in this beautiful townhouse project uses WF steel material with dimensions of WF 200 × 100 × 5.5 × 8 which works as a stacking beam and H-beam steel with dimensions of H 200 × 200 × 8 × 12 which works as columns. Concrete iron is planted in the ground using cement so that the elevator can stand firmly with the foundation made. Based on these problems, it is necessary to conduct a case study that aims to find out more clearly the strength of the elevator frame with a load variation of 320 kg (weight of the load used) with a weight of 450 kg (comparative load weight) and lift it in an undergraduate assignment with the title "Analysis of the Strength of the Elevator Frame Structure to the Weight of Elevator Load of 320 Kg and Weight of Elevator Load of 450 Kg using ETABS Software (Case Study: Pondok Indah Townhouse Project)" so that the strength of the frame on the elevator can be calculated.

The general purpose of this study is to find out the specifications of the elevator frame that can withstand a load of 320 kg and to analyze the axial force, moment, and shear on the elevator structure using ETABS Software. In addition, to find out the results of the strength of the elevator frame on the floor building if given a load force of 450 kg.

2. RESEARCH METHODOLOGY

Place and Time of Research Place

The place where the research was carried out was carried out in the Pondok Indah townhouse construction project located on Jalan Deplu Raya, Pondok Pinang, South Jakarta.

Research Time

The time for conducting the research was carried out after obtaining approval from the supervisor.

Table 1. Research Implementation Time

No	Activities	Time (Months)			
		12	234	56	78
1	Title Submission				

2	Equipment Provision				
3	Literature Studies				
4	Designing the elevator frame using ETABS software				

Tools

a. Laptops with specifications
b. Processor Intel(R) Core(TM) i5-7200U CPU @ 2.50GHz 2.70 GHz.
c. Memory 8 GB.
d. Sistem operasi Windows 10, 64-bit.

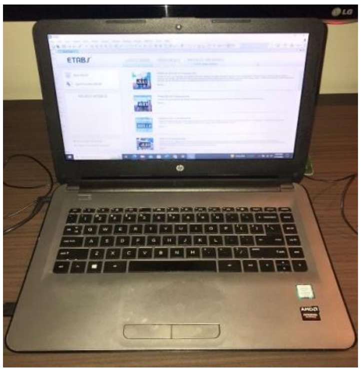

Figure 2. Laptop hp

Software ETABS 20.1.0

ETABS (Extended Three dimension Analysis of Building System) is one of the computer software programs used to design and analyze multi-story building structures., ETABS is one of the software made by CSI Berkeley [2]. The usefulness of the program can help our process of making designs. Thus, in addition to the reduced costs incurred, the market time from objects can also be accelerated. ETABS are made based on the theory contained in the formulation of the finite element method.

Figure 3. ETABS 20 Software

Research Flow Chart

To make it easier to see the structure of the thesis report.

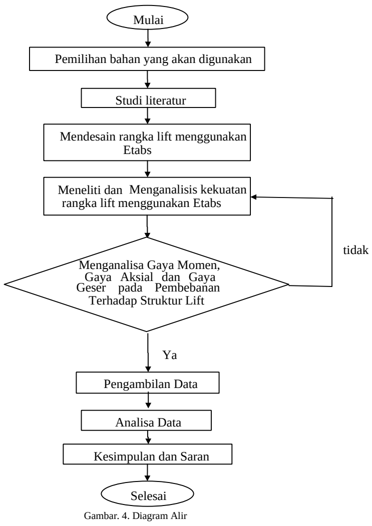

Figure 4. Research Flow Chart

Structural Modeling

Elevator Frame Structure in a building by having a frame structure separate from the main building structure. The planning system with SRPMM (Medium Moment Bearing Frame Structure) with the consideration that the location of the building is in a relatively light earthquake zone so that the calculated earthquake load can be reduced with a full reduction factor (R = 8) so that the building has a larger deviation in receiving the earthquake load which works by forming plastic joints at the ends of the beam with the principle of strong column weak beam. [3]

Modeling the structure to be done with the ETABS 20.1.0 Program is shown in the following Figure.

Figure 5. Elevator Frame Structure Modeling Plan

Structure Material

The Elevator Structure is designed using steel materials with quality and requirements following the following existing regulatory standards:

a. Concrete material
   1) Compressive strength of concrete 28 days. Floor Plate, Column, Beam, and Sloof are K-300 (f'c = 24,9 MPa).
   2) The modulus of elasticity (Ec) of K-300 is 23.452 MPa.
   3) Poisson ratio (υ) is 0,2.

b. Steel material
   1) Yield strength and tensile strength of profile steel are BJ 41 (fy = 360 MPa, fu = 490 MPa)
   2) Steel Reinforcement is Threaded reinforcement using U-40 (fy = 400 Mpa).
   3) Plain reinforcement using U-24 (fy = 240 Mpa.

Structural Element Details

The elements used in elevator planning are shown as follows:

a. The structure type is profile steel.
b. The beam code is B1-WF 200.100.5,5.8 (fastening beams, opening beams, & amp; elevator stacking beams).
c. The column code is P1-HB 200.200.8.12 (main column).

The cross-sectional details of the beams used are shown in the following figure.

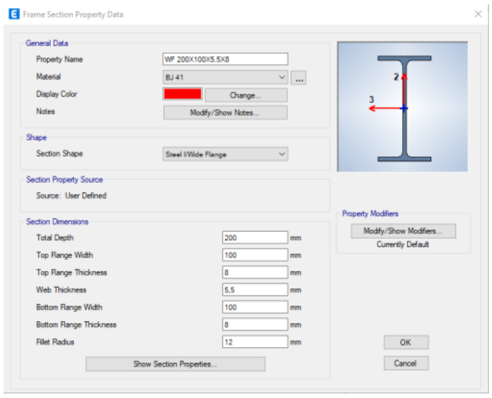

Figure 6. Input Profil Balok B1 – WF 200.100.5,5.8

The cross-sectional details of the columns are used in the following figure.

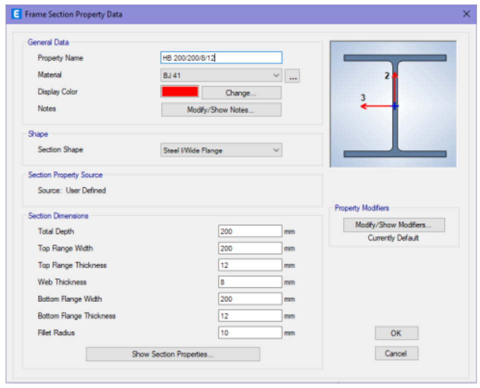

Figure 7. Input Profil Column P1 – HB 200.200.8.12

The floor plate is modeled as a shell, so that apart from receiving vertical forces due to dead and live loads, the plate is also assumed to receive horizontal/lateral forces due to earthquakes. The data input can be shown in the following figure.

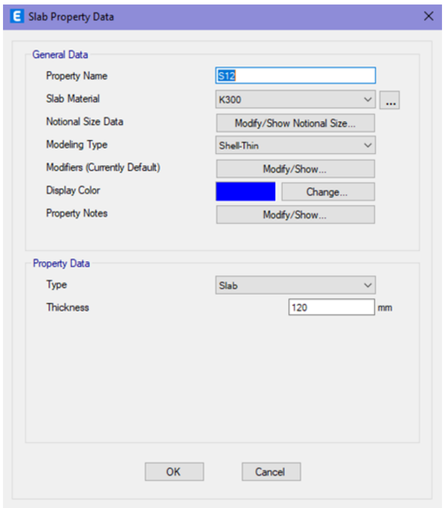

Figure 8. Data Plat S12

Modeling of structural elements.

The modeling of the elevator structure is carried out in 3D by modeling all the elements of beams, columns, and plates.

a. The floor has the same block plan (typical), and can be done with the Similar Story option, while for cases where the floor is designed differently from other floors, the One Story option can be used.

Figure 9. Plan of Beam B1

b. Column Element Modeling

The floor has the same column plan (typical) and can be done practically with the Similar Story option, while for cases where the floor is designed differently from other floors, the One Story option can be used.

Figure 10. Plan of Column P1

c. Plate Modeling

Because there are floors that have the same type of plates (typical), it can be done practically with the Similar Story option, while for cases where the floor is designed differently from other floors, the One Story option can be used.

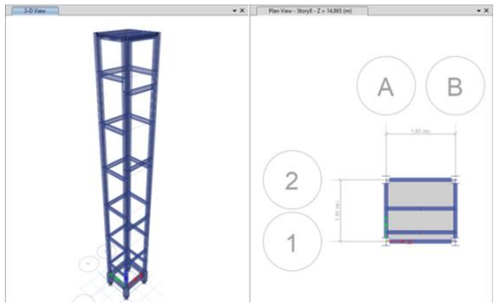

Figure 11. Floor Plate Plan R. Elevator Machine

d. Foundation Modeling

Foundation modeling is assumed to be a clamp, because of the foundation design that uses Pilecap, so the position of the foundation is considered not to undergo rotation and translation. Modeling of the pedestal can be done by clicking all the joint points of the column on the floor.

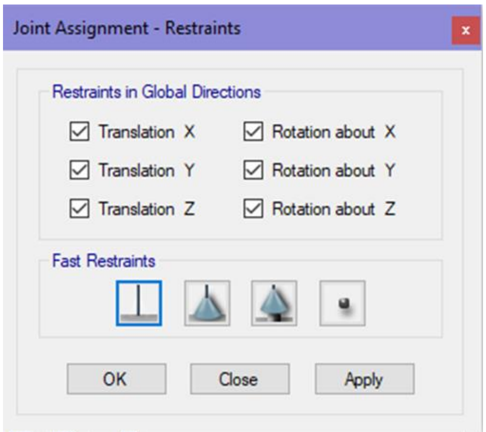

Figure 12. Determining the type of foundation support as a clamp

3. RESULTS AND DISCUSSION

Structural Data

General data Planning is:

a. The Main Material of the Structure is Steel.
b. The form Category is Regular.
c. The Building Function is a Passenger Elevator.
d. SNI used are SNI 1729-2020 (Steel), and SNI 1726-2019 (Earthquake).
e. Building Height is 14,865 m.
f. Capacity is 320 kg (4 people), and 450 kg (6 people).
g. Elevator Dimensions are 850 x 1100 mm.
h. Sliding Space Dimensions is 1650 x 1850 mm.
i. The empty Weight of the Elevator is 650 Kg.

Loading Data

Types of loads acting on structures include:

a. Self Weight Includes beams, columns, and plates
b. Superimposed Dead Load Includes Elevator cabin load and equipment.
c. Live Load Includes load area per m^2 reviewed based on building function.
d. Earthquake Load Covering equivalent static earthquake load.

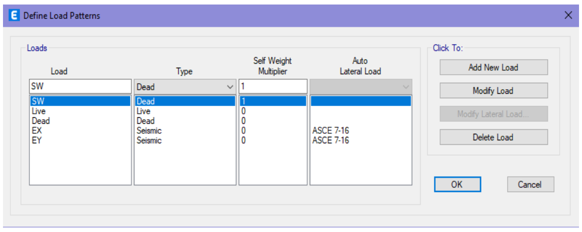

Figure 13. Types of loads acting on the elevator structure

Combination of Loading

The elevator structure is designed to withstand dead, live, and earthquake loads following SNI Earthquake 1729-2019.

The combination of loading used is as follows:

Combination 1 is 1.4 D

Combination 2 is 1.2 D + 1.6 L

Combination 3 is 1.2 D + Lr + 1 E

Dead Load Calculation

Dead load is the load of all permanent elevator elements

a. Self-Dying Load
   1) Self-Die Load of Steel Structure 78.50 kN/m3.
   2) Self-Dying Load of Concrete Structure 24.00 kN/m3
b. Additional Dead Load

Loads on Elevator Stacking Beams 320 Kg and 450 Kg.

As a planned load, the load of the tap must be taken by multiplying it by a shock coefficient determined by the following formula:

$\psi=(1+k\_1.k\_2.v)\geq 1.15$ (1)

So the load working on the elevator stacker beam is

$P = \sum R.\psi$; $P = (320 + 650) \times (1+0,6 \times 1,3 \times 1) = 1726,6$ Kg ....(320 Kg)

$P = \sum R.\psi$; $P = (450 + 650) \times (1+0,6 \times 1,3 \times 1) = 1925$ Kg .... (450 Kg)

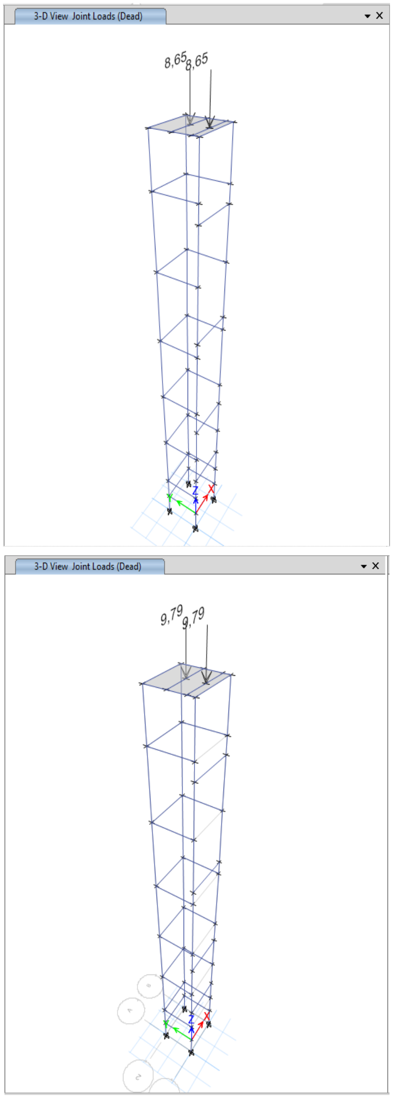

Figure 16. Centralized load of the elevator machine on the 320 kg and 450 kg support beams

c. Live load

A live load is a load that acts on the floor of the building depending on the function of the space used.

From Table 4.2 the working live load is as follows:

Elevator machine floor live load = 1 kN/m2

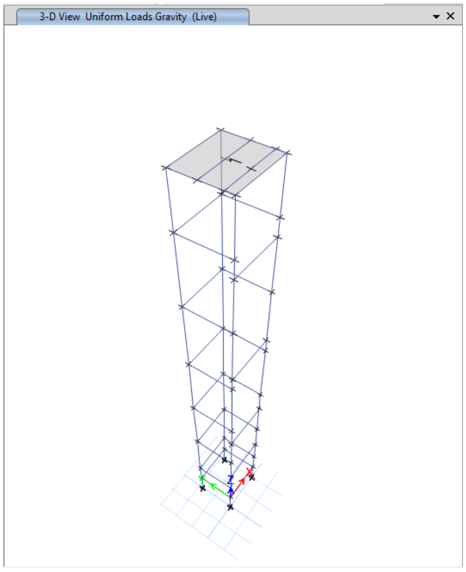

Figure 17. Floor live load on the lift machine base

Earthquake Parameters Plan In this design, a 15-meter high elevator structure will be located in South Jakarta and assumes standing on medium ground. Earthquake parameters following the latest earthquake regulations SNI 1726 2019 can be obtained on the following website [4] :

https://rsa.ciptakarya.pu.go.id/2021/

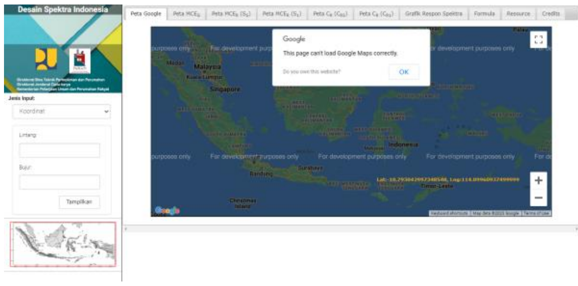

Figure 18. Indonesian Spectra Design

In the Input type section, select City Name or Coordinates, and then click View Results.

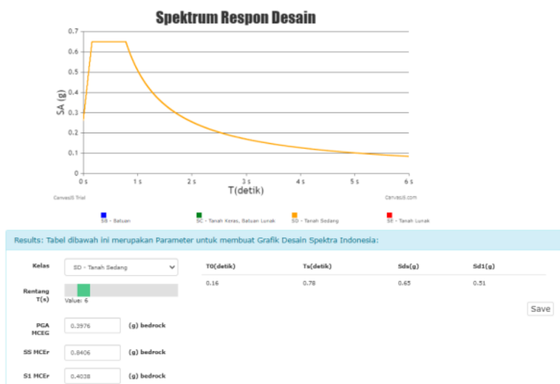

Figure 19. Parameters of the SD (Medium Soil) site class

By using the web we immediately automatically get complete data of the spectral parameters needed for earthquake planning.

Automatic Static Earthquake Loading ETABS

Before starting the automatic equivalent static earthquake input with the ETABS program, then select the Define – Load Patterns – Lateral Force Input Direction X(EX) menu as shown in the following image.

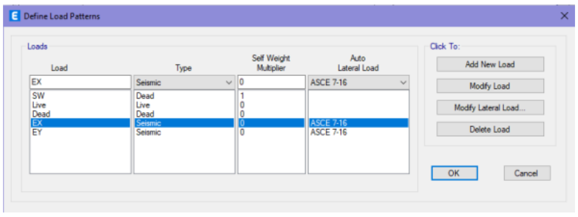

Figure 20. EX Lateral Force Input

Then click modify lateral load so that a dialog box appears as below.

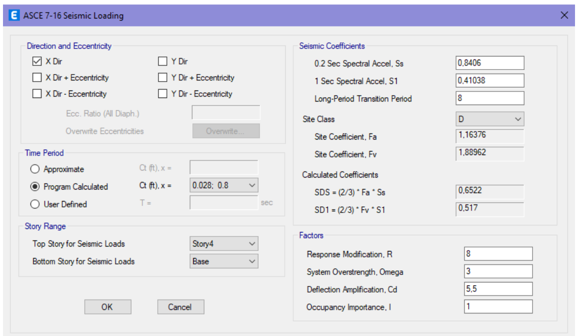

Figure 21. ASCE 7 – 16 Seismic Loading X-Direction (Time Program Calculated)

Do the same to make the earthquake load static – Y direction

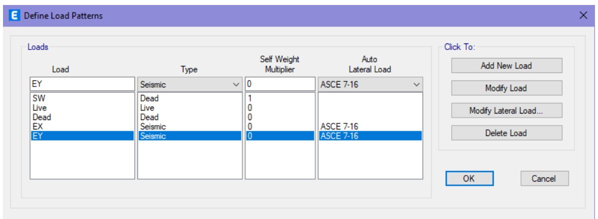

Figure 26. EY Lateral Force Input

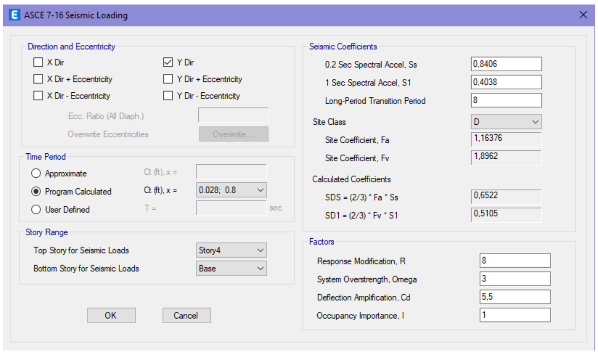

Figure 22. ASCE 7 – 16 Seismic Loading Y-Direction (Time Program Calculated)

After the input of EX and EY loads through the automatic program, perform the analysis by selecting the Analyze – Set Load Cases To Run – Run Now menu. After the run analysis process is complete, select Display – Show tables – Analysis – Results – Reactions – check Base Reaction – OK.

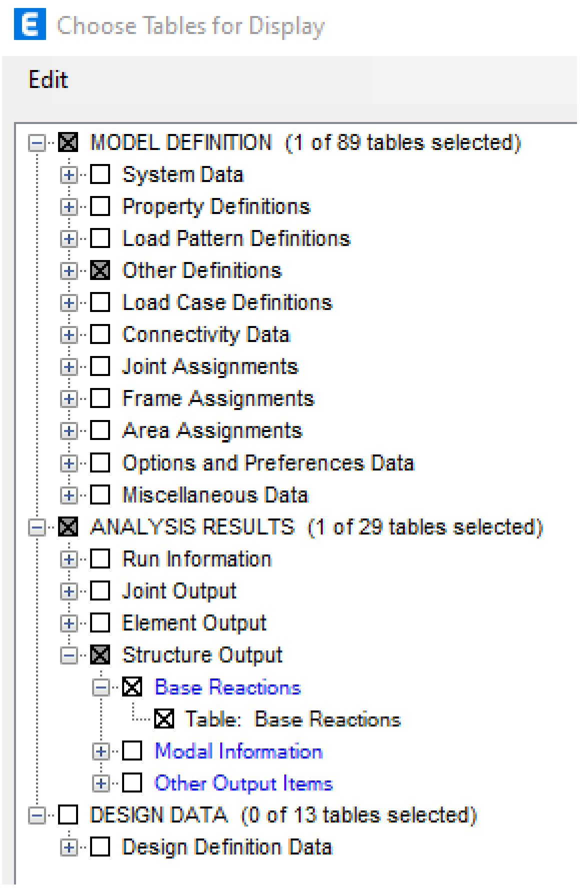

Figure 23. Output Base Reactions

Tabel 2. Base Reactions Time Period Program Calculated

Output case	Case type	Step type	Step number	Fx kN	Fy kN				
SW	Linstatic			0	0				
Live	Linstatic			0	0				
Dead	Linstatic			0	0				
EX	Linstatic			-2,7354	0				
EY	Linstatic			0	-2,7354	0	13,3274	0	-2,5302

EY Linstatic 0 -2.7354 0 13.3274 0 -2.5302

From the results of the program analysis using ASCE 7 – 16 based on the period Program Calculated method, it is obtained:

Vx = 2.7354 kN

Vy = 2.7354 kN

Automatic Dynamic Earthquake Loading ETABS

Dynamic earthquake loading of spectral response can also be done by using the spectrum response curve automatically in the ETABS program. The spectrum response curve can also be done using the ASCE 7 – 16 method by menu Define – Functions – Response Spectrum – in the Choose Function Type to Add section, select ASCE 7 – 16.

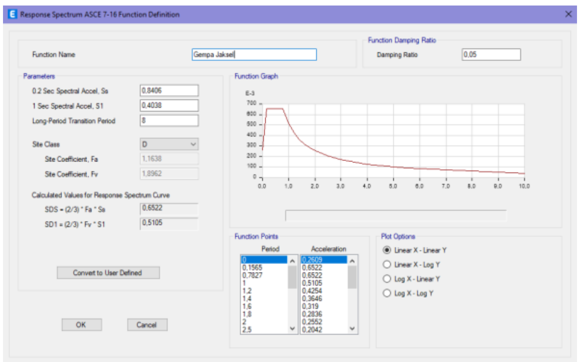

Figure 24. Spectrum Response with ASCE 7 – 16

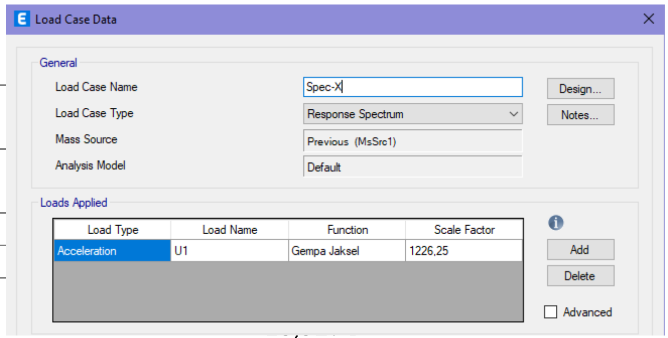

Figure 25. Input Function ASCE 7 – 16 X direction

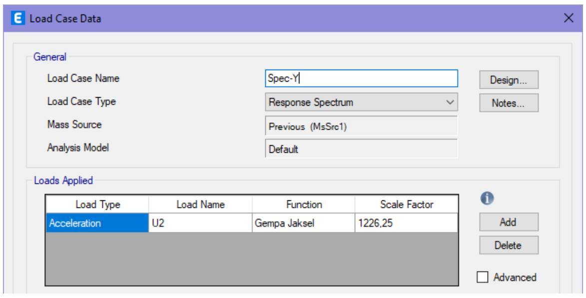

Figure 26. Input Function ASCE 7 – 16 Y direction

Table 3. Automatic Spectrum Dynamic Shear Force

Outcase	**FX**	**FY**	**FZ**
	kN	kN	kN
Spec-X	2,8418	5,088E-07	0
Spec-Y	0	2,9362	0

VSPEC-X = 2,814 kN

VSPEC-X = 2,936 kN

The dynamic sliding force of each floor can be seen from the output of ETABS by selecting the Display menu – Story Response Plot – a Story Response dialog box will appear as shown below.

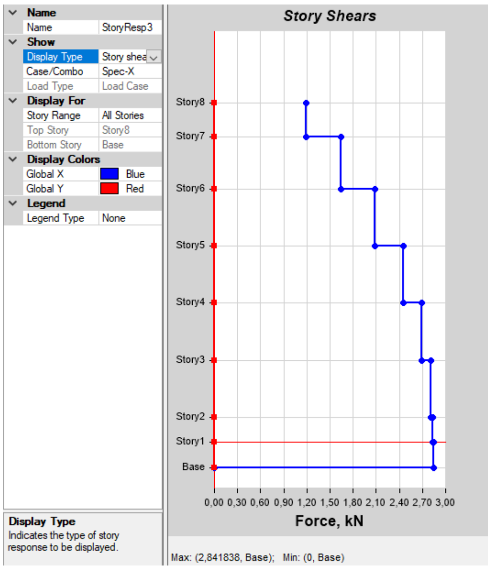

Figure 27. Dynamic Shear Force in X Direction

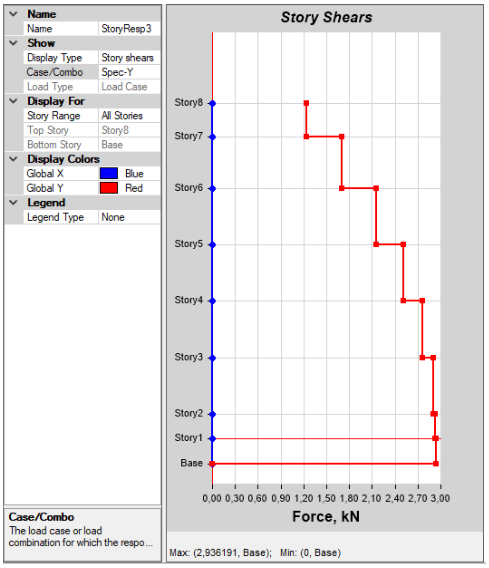

Figure 28. Dynamic Shear Force in Y Direction

Table 4. Dynamic Shear Force – X Each Floor

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
Story8	14,865	Top	1,1937	0
		Bottom	1,1937	0
Story7	13,38	Top	1,6462	0
		Bottom	1,6462	0
Story6	11,08	Top	2,0861	0
		Bottom	2,0861	0
Story5	8,6	Top	2,4496	0
		Bottom	2,4496	0
Story4	6,1	Top	2,6846	0
		Bottom	2,6846	0
Story3	3,6	Top	2,8154	0
		Bottom	2,8154	0
Story2	1,1	Top	2,8343	0
		Bottom	2,8343	0
Story1	0	Top	2,8418	0
		Bottom	2,8418	0
Base	-1,1	Top	0	0
		Bottom	0	0

Table 5. Dynamic Shear Force – Y Each Floor

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
Story8	14,865	Top	0	1,243
		Bottom	0	1.243
Story7	13,38	Top	0	1,7058
		Bottom	0	1.7058
Story6	11,08	Top	0	2,1528
		Bottom	0	2,1528
Story5	8,6	Top	0	2,5171
		Bottom	0	2,5171
Story4	6,1	Top	0	2,7668
		Bottom	0	2,7668
Story3	3,6	Top	0	2,9031
		Bottom	0	2,9031
Story2	1,1	Top	0	2,9229
		Bottom	0	2,9229
Story1	0	Top	0	2,9362
		Bottom	0	2,9362
Base	-1,1	Top	0	0
		Bottom	0	0

Lateral Earthquake Force Design

Previous analysis. The earthquake force on a floor is the difference from the shear force between the floors, so the value of each can be seen in the table below.

Table 6. Earthquake Style Design

	GAYA GESER DESAIN		F, GEMPA DESAIN	
	VX	VY	FX	FY
	(kN)	(kN)	(kN)	(kN)
Story8	1,194	1,243	1,194	1,243
Story7	1,646	1,706	0,453	0,463
Story6	2,086	2,153	0,440	0,447
Story5	2,450	2,517	0,364	0,364

Story4	2,685	2,767	0,235	0,250
Story3	2,815	2,903	0,131	0,136
Story2	2,834	2,923	0,019	0,020
Story1	2,842	2,936	0,008	0,013

Table 7. Earthquake Style Design

	F, GEMPA DESAIN		**F, GEMPA DESAIN**	
	FX	**FY**	**FX**	**FY**
	(kN)	**(kN)**	**(Kg)**	**(Kg)**
Story8	1,194	1,243	121,757	126,786
Story7	0,453	0,463	46,155	47,206
Story6	0,440	0,447	44,870	45,594
Story5	0,364	0,364	37,077	37,159
Story4	0,235	0,250	23,970	25,469
Story3	0,131	0,136	13,342	13,903
Story2	0,019	0,020	1,928	2,020
Story1	0,008	0,013	0,765	1,357

After obtaining the design earthquake force value, input these forces into the ETABS program in the following way:

a. Earthquake Force Design X Direction:

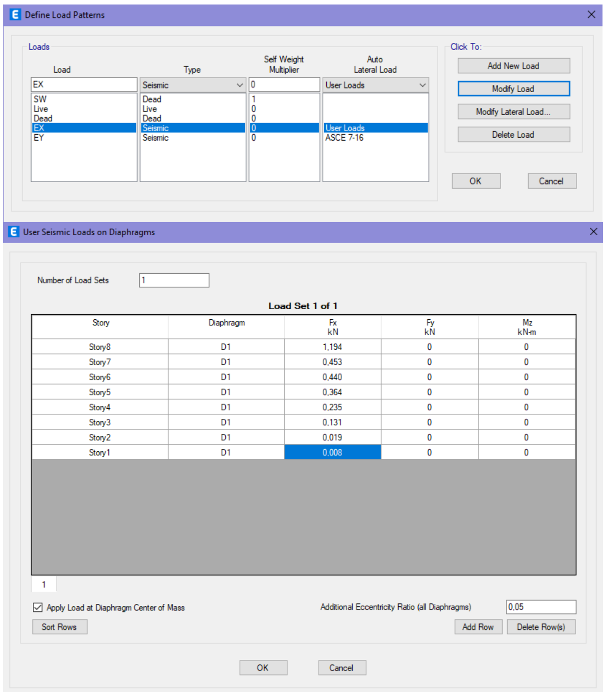

Figure 29. EX Earthquake User Loads and Fx Design Earthquake Force Input

b. Earthquake Style Design in Y Direction:

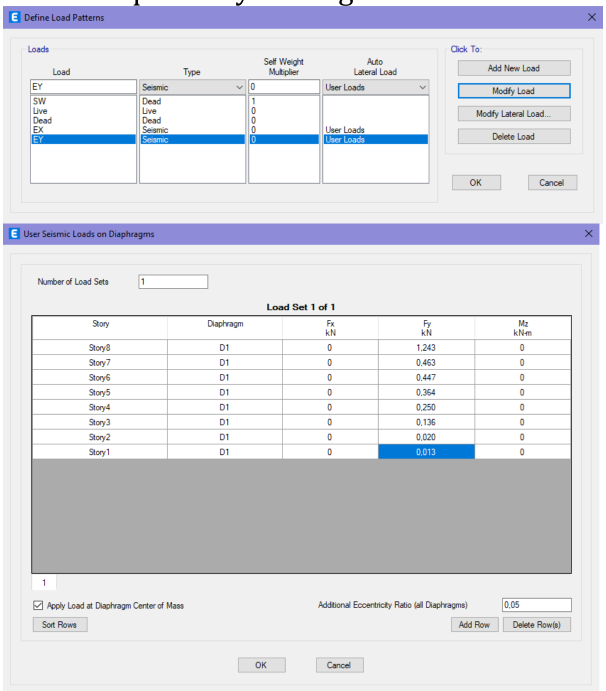

Figure 30. EY Earthquake User Loads and Fy Design Earthquake Force Input

Design Control

Structural design control is carried out on the checking of the boundary between floors regulated in articles 7.8.6 and 7.12.1.

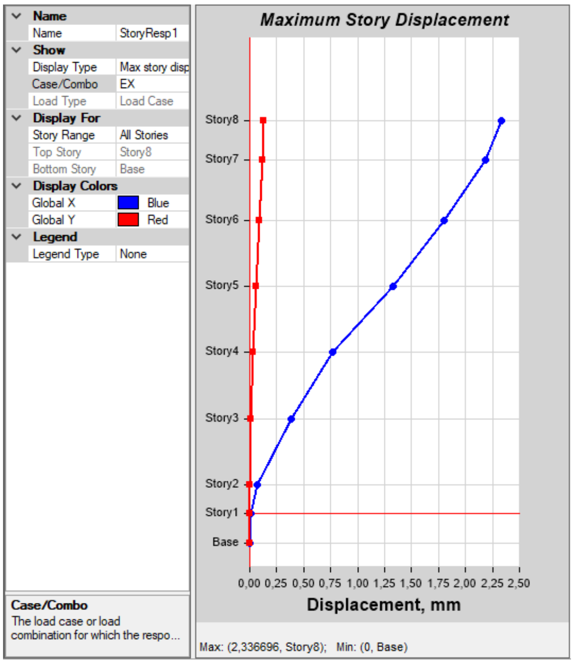

Figure 31. Maximum Story Displacement Due to the EX-Earthquake.

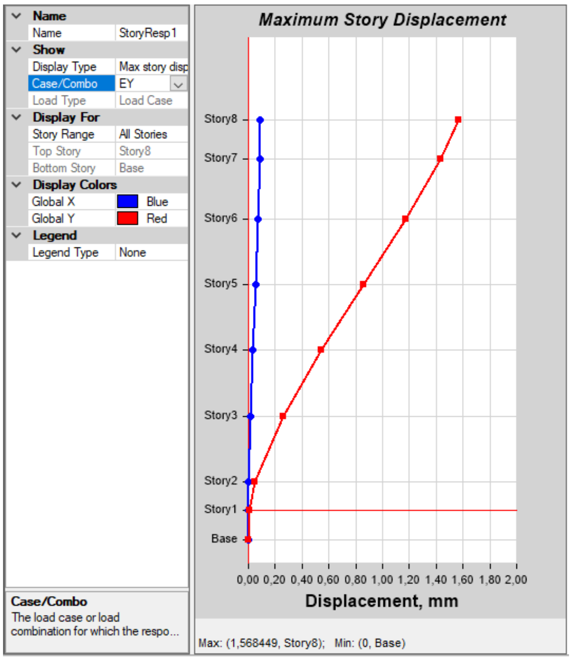

Figure 32. Maximum Story Displacement Due to the EY Earthquake

Table 8. Table 4.12 Maximum Floor Deviation Due to Earthquake in X Direction.

Story	Elevation m	Location	X-Dir mm	Y-Dir mm
Story8	14,865	Top	2.337	0,127
Story7	13,38	Top	2,189	0,113
Story6	11,08	Top	1,803	0,089
Story5	8,6	Top	1,329	0,06
Story4	6,1	Top	0,772	0,033
Story3	3,6	Top	0,38	0,013
Story2	1,1	Top	0,071	0,002
Stroy1	0	Top	0,007	0,0003456
Base	-1,1	Top	0	0

Table 9. Maximum Floor Deviation Due to Earthquake in Y Direction

Story	Elevation m	Location	X-Dir mm	Y-Dir mm
Story 8	14,865	Top	0,089	1,568
Story 7	13,38	Top	0,085	1,437
Story 6	11,08	Top	0,071	1,169
Story 5	8,6	Top	0,053	0,856
Story 4	6,1	Top	0,029	0,547
Story 3	3,6	Top	0,014	0,264
Story 2	1,1	Top	0,003	0,047
Stroy 1	0	Top	0,0002151	0,008
Base	-1,1	Top	0	0

Table 10. Deviations Between Permit Levels In Y Direction.

STORY	h_{sx} (mm)	δ_e (mm)	Δ (mm)	Δi (mm)	$\Delta_{allowed}$ (mm)	Exp
Story8	1485	2,337	12,854	0,814	29,70	OK
Story7	2300	2,189	12,040	2,123	46,00	OK
Story6	2480	1,803	9,917	2,607	49,60	OK
Story5	2500	1,329	7,310	3,064	50,00	OK
Story4	2500	0,772	4,246	2,156	50,00	OK
Story3	2500	0,380	2,090	1,700	50,00	OK
Story2	1100	0,071	0,391	0,352	22,00	OK
Story1	1100	0,007	0,039	0,039	22,00	OK

Table 11. Deviations Between Y-Dir Permit Levels

STORY	Hsx (mm)	δe (mm)	Δ (mm)	Δi (mm)	Δallowed (mm)	Exp
Story8	1485	1,568	8,624	0,721	29,70	OK
Story7	2300	1,437	7,904	1,474	46,00	OK
Story6	2480	1,169	6,430	1,722	49,60	OK

Story5	2500	0,856	4,708	1,700	50,00	OK
Story4	2500	0,547	3,009	1,557	50,00	OK
Story3	2500	0,264	1,452	1,194	50,00	OK
Story2	1100	0,047	0,259	0,215	22,00	OK
Story1	1100	0,008	0,044	0,044	22,00	OK

SNI 1726-2019 permit for the type of structure that is included in the type of all other structures and is in category II, the deviation limit between the floors of the permit is 0.020 hsx, where hsx is the height between the levels. So from the calculation above, it is obtained:

Δallowed = 0.020 x h_sx

Δallowed = 0.020 x 1485 = 29.70 mm

Then $\Delta_8 < \Delta_{allowed}$ .... OK

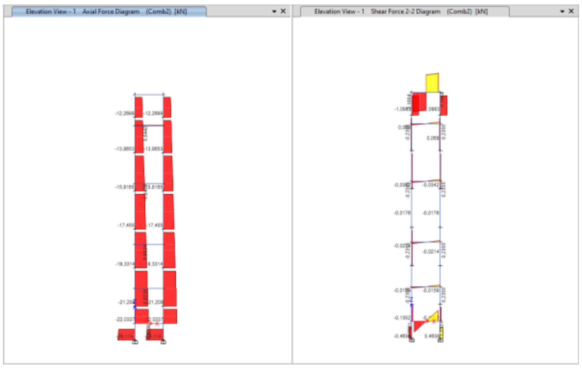

Figure 33. Axial Force and Shear Force Analysis Output Lift Capacity 320 Kg

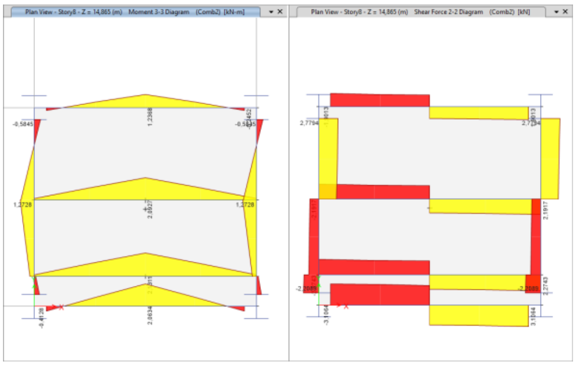

Figure 34. Output of Analysis of Moment Force and Shear Force of Supporting Beam with Elevator Capacity 320 Kg

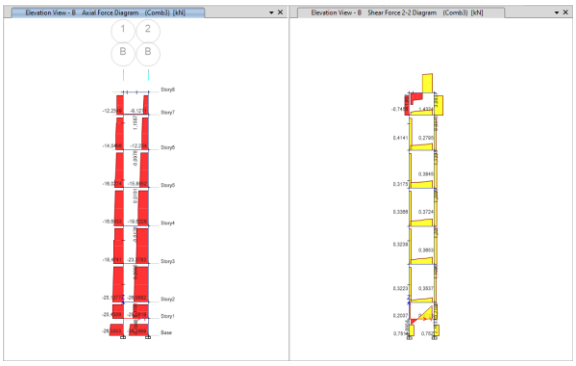

Figure 35. Axial Force and Shear Force Analysis Output with Lift Capacity 450 Kg

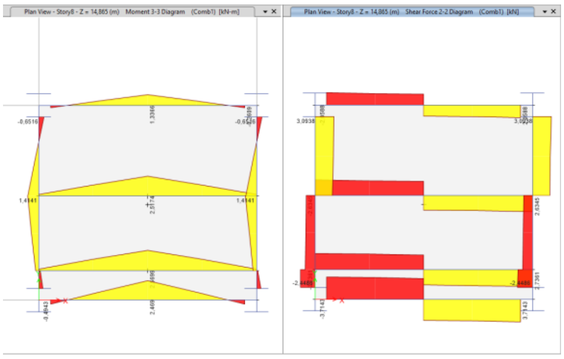

Figure 36. Output of Moment Force and Shear Force Analysis of Stacking Beam Elevator Capacity 450 Kg

4. CONCLUSION

The results of the Elevator Frame Structure Analysis are carried out by entering the earthquake spectrum in the ETABS Software which aims to obtain the behavior of the structure to the loads acting on the elevator structure. The following are the outputs obtained:

a. Lift Load Weight 320 Kg (including engine, equipment, and passengers) works on WF 200x100x5.5.5x8 Stacker Beam of 1726.6 Kg and Lift Load Weight 450 Kg (including engine, equipment and passengers) works on WF 200x100x5.5x8 Stacker Beam of 1925 Kg.

b. Earthquake load analysis in the South Jakarta area provides deformation in the building structure of 3,064 mm for the X direction and 1,722 mm for the Y direction. So the structure of the elevator frame is safe.

c. The results of axial, moment, and shear forces on a 320 Kg capacity Elevator structure working on the 200x200x8x12 H Column respectively are 28.113 kN < 173.2 kN (safe), 0.417 kNm < 79 kNm (safe), 0.594 kN < 933.1 kN (safe), and The results of moment and shear forces on the 320 Kg capacity Lift structure acting on the WF200x100x5.5x8 Beam respectively are 2,131 kNm, and 56.1 kNm (safe), 2,274 kN < 237.6 kN (safe).

4. The results of axial, moment, and shear forces on a 450 Kg capacity Elevator structure working on a 200x200x8x12 H Column are 36.187 kN < 173.2 kN (safe), 0.431 kNm < 79 kNm (safe), 0.752 kN < 933.1 kN (safe). The results of the moment and shear forces on a 450 Kg capacity Elevator structure working on the WF200x100x5.5x8 Beam are 2.57 kNm < 56.1 kNm (safe), 2.736 kN < 237.6 kN (safe) respectively.

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