

Evaluation Of Structure Performance On Store Building With Spectrum Response Analysed Based On Etabs Software v.2013 Hotel Harris Batam Center

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ABSTRACT

Indonesia is earthquake-prone countries with different levels of seismic activity in each region. The earthquake area in Indonesia is divided into 6 (six) earthquake zones according to SNI- 1726 - 2002. Batam is included in the region zone 1 (one) with a low level of seismicity, the high-rise building structure is planned for earthquakes that have been regulated in SNI 03-1726-2002 and SNI 03-2847-2002. Therefore, this study discusses the design of earthquake load-bearing structures with ordinary moment resisting frame systems with the aim of getting the best structural system in terms of strength, stiffness, durability and structural economy in high-rise buildings. The design of the building structure used the 2013 ETABS program with the adjustment of the strength parameters of the material used. Quality of concrete ($f_c = 30\text{MPa}$) & quality of reinforcing steel ($f_y = 400\text{MPa}$). From the structural design analysis, it is found that the stiffness.

Keyword: Earthquake 2013 ETABS, Performance of Ordinary Moment Resistant Frame Structures and Systems

1. INTRODUCTION

Indonesia is the largest archipelagic country in the world compared to other archipelagic countries which consist of 13,487 islands and has an area of 1,904,569 km². And geographically, Indonesia is located between two oceans, namely the Pacific Ocean and the Indian Ocean, and two continents, namely the Asian continent and the Australian continent. In addition, Indonesia is also located on three tectonic plates, including the Pacific plate, the Eurasian plate, and the Indo-Australian plate. The existence of these plates results in tectonic and volcanic activities so most of Indonesia is prone to earthquakes.

An earthquake is a vibration or movement that occurs on the earth's surface due to the sudden release of energy from within. There will be vibrations called seismic waves when this shift occurs and causes damage to building structures and casualties if these waves propagate in all directions away from the epicenter. In Indonesia, earthquakes often occur which result in very large damage and losses, therefore it is necessary to develop an earthquake analysis of the structure.

Several methods are often used in earthquake calculations including, Equivalent static analysis, a method of structural analysis in which the effect of an earthquake on the structure is considered as a horizontal static load obtained by only takes into account the response of the first variety of vibrations. Dynamic analysis is a structural analysis in which the distribution of seismic shear forces across levels is obtained by taking into account the dynamic influence of soil motion on the structure. Dynamic analysis is divided into 2, namely. Analysis of the spectrum response variance where the total response is obtained through the superposition of the responses of each type of vibration. Time history analysis is a dynamic analysis where the structural model is given a record of earthquake records and the response of the structure is calculated step by step at certain intervals. According to Widodo (2001), time history analysis is the closest method for predicting the parameter response of structures due to earthquakes. However, performing a time history analysis, takes a lot of calculations and takes a long time.

2. RESEARCH METHOD

2.1. Flow Chart System.

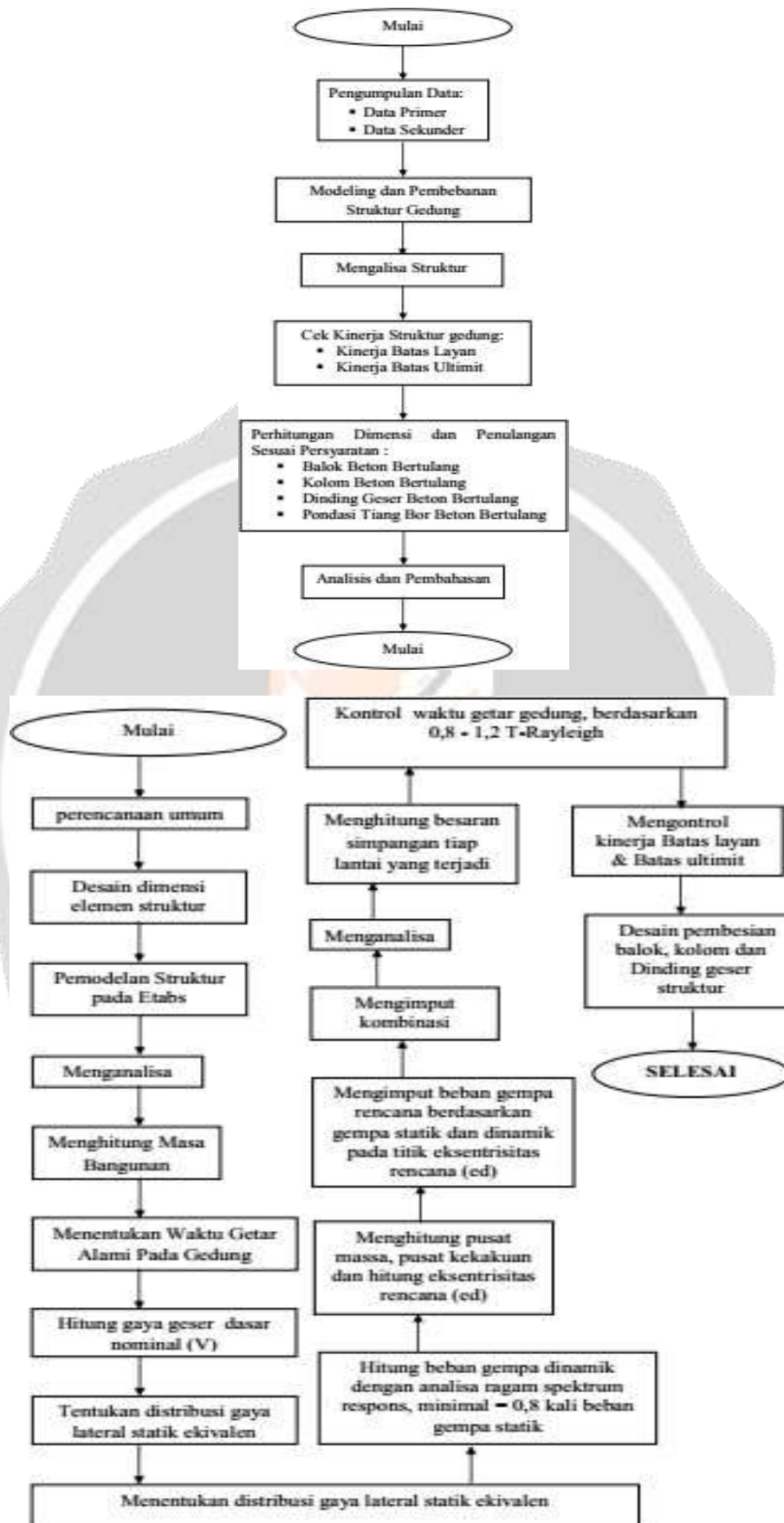


Figure 1. Research flow chart
ijarie.com

2.2. PLANNING DATA

Planning location	: Batam City - Indonesia
Earthquake area	: Earthquake Region 1 (Low Seismic Risk)
Type of soil	: Medium ground Building function: Hotel
Number of floors	: Basement + 10 Floors + Dak Roof
Total height	: 36,630 Meters
Structure type	: Reinforced concrete
Structural system	: Ordinary Moment Resistant Frame System (SRPMB)
Beam Length	: L1 = 7.6 m 6.5 m
Column Height	:
Basement Floor	: 3.20 m
1st floor	: 6.00 m
2nd floor to 10th floor	: 3.20 m
Rooftop	: 3.43 m
Basement Lt Plate Thickness	: 0.20m
Lt Plate Thickness 1 to 10	: 0.12m
Roof plate thickness	: 0.10m

2.3. Structural Material Quality

Reinforced concrete structures have two materials that have different properties, namely concrete and reinforcing steel. In this planning the quality of the material is selected based on the provisions stipulated in SNI 03-2847-2002, namely:

- Concrete quality (f_c) = 30 MPa (minimum 20 MPa for earthquake resistant design)
- Steel quality (f_y) = 400 MPa (Based on SNI-2847-2002)

2.4. Beam Dimensioning

The dimensions of the main beam that carry the load due to the earthquake have the following requirements:

The height of the beam depends on the stretch, namely:

$h = l_n/12 = 7.6m/12 = 0.633m$ $0.7m = 700$ mm The ratio of the width and height of the beam is required not to be less than 0.3 and the width is not less than 250mm or 0.25m.

$b/h \geq 0.3$ $b = hx$ $0.3 = 0.7m \times 0.3 = 0.21$ m Because the result of the beam width in the calculation does not reach 0.25 m, the width of the beam is taken as 300 mm or 0, 3 m to avoid beams that are too thin anticipating shear and torsion hazards that occur. So that the requirements for the ratio of width and height as well as the minimum width of the beam are met.

The dimensions of the sub-beams that function as stiffeners for the main portal as well as load dividers from the slab to the main-port where the sub-beams are considered to be beams with two simple supports to the main beam. So the dimensions of the children's beams are as follows:

The height of the beam depends on the stretch, namely:

$h = l_n/16 = 7.6m/16 = 0.475m$ $0.5 = 500mm$ The ratio of width and height of the beam is taken as 0.5 from the height (h), then the width of the child beam is:

$b = 1/2 h$ $b = 2/3 h$ $1/2 h = 1/2 \times 0.5 = 0.25$

$2/3 h = 2/3 \times 0.5 = 0.333$ 0.25 b

0.333

Take the width of the beam (b) = 0.3m = 300mm

2.5. Column Dimensioning

The initial column dimensions are assumed through dead load and live load approaches that work with a tributary area, so that the approximate dimensions of the column dimensions on the ground floor are obtained. Because the spans between columns vary, one column can be considered as a limitation the maximum size of the column to be used, which has the largest tributary area and is considered the heaviest working load. Then the calculation of the working load is described as follows:

Dead Load

Basement Floor Plate Weight up to 1

$$= 7.6\text{m} \times 6.5\text{m} \times \text{hx} \times \text{c}$$

$$= 49.5\text{m}^2 \times 0.20\text{m} \times 2400 \text{ kg/m}^3 = 23712 \text{ kg Weight of Floor Slabs 1 to 10th Floor}$$

$$= 7.5\text{m} \times 6.5\text{m} \times \text{hx} \times \text{c}$$

$$= 49.5\text{m}^2 \times 0.12\text{m} \times 2400 \text{ kg/m}^3 = 14256 \text{ kg Weight of Dak Roof Plate}$$

$$= 7.5\text{m} \times 6.5\text{m} \times \text{hx} \times \text{c}$$

$$= 49.5\text{m}^2 \times 0.10\text{m} \times 2400 \text{ kg/m}^3 = 11880 \text{ kg Total Weight}$$

$$= (23712\text{kg}) + (10 \times 14256 \text{ kg}) + 11880\text{kg}$$

$$= 178152 \text{ kg}$$

Finishing Weight + Hanger:

1st floor to 10th floor

$$= 10 (7.5\text{m} \times 6.5\text{m} \times 125 \text{ kg/m}^2)$$

$$= 10 (6093.75\text{kg}) = 60937.5 \text{ kg}$$

Dak Roof

$$= 7.5\text{m} \times 6.5\text{m} \times 38 \text{ kg/m}^2 = 1852.5 \text{ kg}$$

$$\text{Total Weight} = 60937.5 \text{ kg} + 1852.5 \text{ kg} = 62790 \text{ kg Wall Weight (cellcon10)}$$

$$= \text{Height} \times \text{Length} \times \text{Weight per m}^2$$

$$= 2.5\text{m} \times 7.5\text{m} \times 115 \text{ kg/m}^2 = 2156.25 \text{ kg}$$

$$\text{Total Weight} = 10 \text{ Floors} \times 2156.25 \text{ kg} = 21562.5 \text{ kg Total Weight Dead Load}$$

$$= 178152 \text{ kg} + 62790 \text{ kg} + 21562.5 \text{ kg}$$

$$= 262504.5 \text{ kg}$$

Live Load

Basement floor (parking)

$$= 7.5\text{m} \times 6.5\text{m} \times 400 \text{ kg/m}^2 = 19500 \text{ kg Floor 1 to Floor 10}$$

$$= 10 (7.5\text{m} \times 6.5\text{m} \times 250 \text{ kg/m}^2)$$

$$= 10 (12187.5 \text{ kg}) = 121875 \text{ kg}$$

$$\text{Roof Dak} = 7.5\text{m} \times 6.5\text{m} \times 100 \text{ kg/m}^2 = 4875 \text{ kg Total Weight Live Load}$$

$$= 19500 \text{ kg} + 121875 \text{ kg} + 4875 \text{ kg} = 146250 \text{ kg}$$

Factored load

$$= 1.2 \text{ DL} + 1.6 \text{ LL}$$

$$= 1.2 (262504.5 \text{ kg}) + 1.6 (146250 \text{ kg})$$

$$= 315005.4 \text{ kg} + 234000 \text{ kg} = 549005.4 \text{ kg}$$

The stress that occurs in the middle column on the ground floor is taken based on the quality of the concrete used at $f_c' = 30\text{Mpa}$, but the amount of allowable stress (stress that the concrete can bear) must be considered to experience a decrease in quality by taking the concrete strength of 40% to 40%.

60%. Then take a reduction of 50%, so $f_c = 30\text{MPa} \times 0.5 = 15 \text{ MPa}$.

$$= P/A \Leftrightarrow A = P/\sigma$$

$$A = (549005.4 \text{ kg}) / (15 \times 0.102 \text{ kg/mm}^2)$$

$$= 358827.05 \text{ mm}^2$$

Columns are required to have a minimum width of 300mm, but with consideration of the required column cross-sectional area the results of the above calculation. Then use a column width of 600mm so that the required length (h) of the column is:

$$A = b \times h \quad (\Leftrightarrow) \quad h = A/b$$

$$h = 358827.05\text{mm}^2 / 600\text{mm} \quad h = 600\text{mm} \quad 900\text{mm}$$

So the dimensions of the columns used on the ground floor are width (b) 600mm and length (h) 900mm.

The loads acting on the structure consist of live loads and dead loads. Dead load is the structure's own weight and additional dead load. The self-weight of the structure is calculated automatically by the program while

the additional dead load is inputted to the floor slab. The additional live and dead loads that are calculated are as follows:

Live load : 250 kg/m² (hotel function)

Additional slab dead load: 120 kg/m² (screed and mechanical load)

Architectural wall load : 115 kg/m² (cellcon10 wall)

3. EQUIVALENT STATIC EARTHQUAKE ANALYSIS

3.1. Building Weight Calculation

The total weight of the building (Wt) due to its own weight can automatically be calculated by ETABS which produces the weight of the building for each floor and the total weight of the building. By Display – Show Table – Building Data – Group – Table : Group Masses And Weights

Table 4.1. Building Weight and Mass Each Floor

Floor	Weight (kg)
BASEMENT	647419.297
STORY 1	690559.154
STORY 2	534031.541
STORY 3	534031.541
STORY 4	534031.541
STORY 5	534031.541

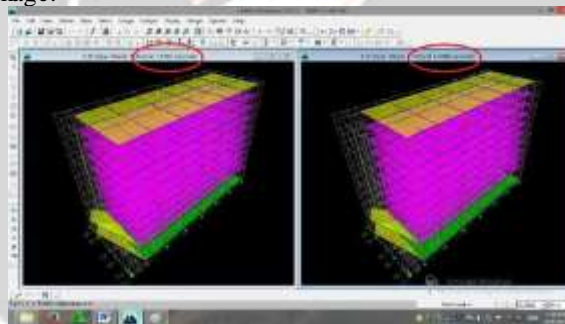
3.2. Natural Shake Time

From the results of ETABS analysis, the natural vibration time of the structure in the direction of x = 1.5762 and direction of y = 1.4988.

By means of Analyze - Run Analyze – Display

– Show Mode Shapes.

As shown in the following image:



Figures 2. Structure Natural Vibration Time

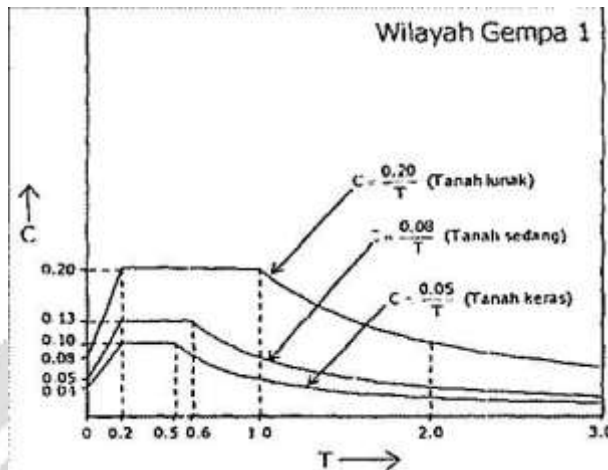
In Article 5.6 of SNI Earthquake, it is stated that the time of the fundamental natural vibration must be limited to prevent the use of a building structure that is too flexible with the requirements of $T_1 < \dots$, where n is the number of floors and the coefficient depends on the earthquake zone.

Tables 2. Coefficient which limits the fundamental natural vibration time of the building structure

Wilayah Gempa	ζ
1	0,20
2	0,19
3	0,18
4	0,17
5	0,16
6	0,15

The location of the building is in zone 1, then = 0.20 Then $T1 < xn$
 $1.5762 < 0.20 \times 11$
 $1.5762 < 2.2$ OK \rightarrow

The value of the earthquake response factor based on the earthquake area and soil type is determined as follows:



Figures 3. Image of SNI regulations for earthquake areas

Because the vibration time of the structure for the X and Y directions is different, the value of the earthquake response factor is also different.

- Earthquake direction X (Mode 1), $T1 = 1.5762$ seconds $C1 = 0.20/1.5762 = 0.1269$
- Y direction earthquake (Mode 2), $T1 = 1.4988$ seconds $C1 = 0.20/1.4988 = 0.1334$

3.3. Nominal Slide Style

The magnitude of the basic shear force due to static loads is calculated using the following equation:

$$V = (C \cdot I) / R \cdot W_t$$

The magnitude of the nominal shear force due to the weight of the building, the function of the building, and the earthquake area is calculated using the following equation:

$$V_x = (C \cdot I) / R \cdot W_t$$

$$V_x = ((0.1269)(1)) / 3.5 \times 6117736.252 \quad V_x = 221811.64 \text{ tons}$$

$$V_y = (C \cdot I) / R \cdot W_t$$

$$V_y = ((0.1334)(1)) / 3.5 \times 6117736.252 \quad V_y = 233173.15 \text{ tons}$$

The magnitude of the earthquake shear force coefficient for the X and Y directions can be calculated as follows:

$$\text{Direction X} = C1 \times I/R = 0.1269 \times 1/8.5 = 0.0149 \quad \text{Direction Y} = C2 \times I/R = 0.1334 \times 1/8.5 = 0.0157$$

3.4. Plan Eccentricity (ed)

The magnitude of the eccentricity is influenced by the center of mass and the center of rigidity of the structure. If the center of mass and the center of stiffness are in unequal coordinates, then there is eccentricity, so it is necessary to review article 5.4.3 of the Standard for Earthquake Resistance Planning for Buildings, SNI 03 – 1726 – 2002 regarding the eccentricity between center of mass and center of rotation to obtain the design eccentricity.

1). For $e < 0.3 b$, the formula is used:

$$ed = 1.5e + 0.05b \text{ or } ed = e - 0.05b$$

2). For $e > 0.3 b$, the formula is used:

$$ed = 1.33e + 0.1b \text{ or } ed = 1.17e - 0.1b$$

The center of mass and the center of stiffness are determined using the ETABS program, by means of Display – Print Table – Analysis Results – Building Output – Center Mass Rigidity.

So that the results of the ETABS output are then processed and can be seen as follows:

Table.3. Center of mass and center of stiffness

story	center of mass		Center of Rotation		Eccentricity	
	X	Y	X	Y	X	Y
BASE	26.037	8,291	24,568	8,372	1.469	0.081

1	25,947	8,303	24,831	8,274	1.116	0.029
2	27,198	8075	24,961	8,246	2.237	-
3	27,198	8075	25,362	8,214	1,836	-
4	27,198	8075	25,678	8.189	1.52	-
5	27,198	8075	25,907	8.171	1,291	-
6	27,198	8075	26.077	8.157	1.121	-
7	27,198	8075	26,206	8.146	0.992	-
8	27,198	8075	26,308	8.138	0.89	-
9	27,197	8075	26,392	8.13	0.805	-
10	27,203	8075	26,472	8.124	0.731	-

3.5. Structure Performance Analysis

1. Service Limit Performance (s)

Based on SNI-03-1726-2002 Article 8.1.2, to meet the requirements, s deviation between levels should not be greater than:

$s \leq 0.03/R \times h_i$ (High level)

or 30 mm (chosen the smallest)

To find the magnitude of the deviation, the results of the ETABS analysis are used, namely by Analyze – Run Analyze – Display – Show Story Response Plots .

$s_{\text{roof}} = \text{deviation of the roof floor} - \text{the deviation of the floor below it}$
 $= 16.48 - 15.93 = 0.55 \text{ mm}$

3.6. Ultimate Limit Performance (Δ_m)

Based on SNI-03-1726-2002 Article 8.2.2, the deviation and deviation between stories must be calculated from the deviation of the building structure due to loading nominal earthquake, multiplied by a factor as follows:

$m = s \times \text{multiplier factor}$

For a regular building structure = 0.7 R

Condition : $m \leq 0.02 \times \text{level height}$

$m_{\text{roof}} = s_{\text{roof}} \times 0.7R$

$= 0.55 \times 0.7 \times 3.5 = 1.35 \text{ mm}$

4. DESIGN OF STRUCTURAL COMPONENTS OF ORIGINAL MOMENT RESISTING FRAME SYSTEMS

Plate Planning

a. Determining the Plate Thickness

Length of span $I_x = 7600 \text{ mm}$ Length of span $I_y = 6500 \text{ mm}$

Height of beam (h) = 700 mm

beam width (b) = 300 mm

Plate thickness (h) = 120 mm

$I_x/I_y = 7600/6500 = 1.17 < 2$ (Two-way plate) So the type of plate is a two-way plate. $m = (E_{cb} I_b)/(E_{cs} I_s)$

$= (4700\sqrt{30} \times 1/12 \times 300 \times 700^2) / (4700\sqrt{30} \times 1/12 \times 7600 \times 120^2)$

$= 1.34 > 0.2$ but < 2

Based on SNI-03-2847-2002 for m greater than 0.2 but not more than 2.0, thickness plate

minimum must meet : $h = (\ln(1/m)(0.8 + f_y/1500)) / (36 + 5\beta(m - 0.2))$

and must not be less than 120 mm $h = (7300\sqrt{10}(0.8 + 240/1500)) / (36 + 5 \times 1(1.34 - 0.2))$

$= 129 \text{ mm}$

A plate thickness of 120 mm is used.

b. Calculating the Effective Height of the Plate (d)

Main reinforcement is used 10 d = h – t_s – 0,5D

$$= 120 - 20 - 5 = 95 \text{ mm}$$

c. Floor Plate Loading

The types of loads acting on the floor slabs are dead loads and live loads with the following calculations:

Dead load (DL)

- Plate self weight

$$= 0.12 \times 2400 = 288 \text{ kg/m}^2$$

- Plaster (2.5 cm)

$$= 0.025 \times 1600 = 40 \text{ kg/m}^2$$

- Ceramic (1 cm)

$$= 0.01 \times 2200 = 22 \text{ kg/m}^2$$

- M/E Installation

$$= 25 \text{ kg/m}^2$$

- Ceiling and hanging = 18 kg/m²

$$\text{Total dead load on floor slab} = 393 \text{ kg/m}^2 \quad \text{Live Load (LL)} = 250 \text{ kg/m}^2 \quad \text{Planned Load (qu)}$$

$$= 1.2DL + 1.6LL$$

$$= (1.2 \times 393) + (1.6 \times 250) = 871.6 \text{ kg/m}^2$$

d. Finding the Moment Value

plate weight

$$qD = 0.12 \times 2400 = 288 \text{ kg/m}^2$$

Load need

$$qu = 1.2 \cdot qD + 1.6 \cdot qL$$

$$= (1.2 \times 399) + (1.6 \times 250) = 871.6 \text{ kgm}$$

Fully clamped plate support condition, $I_y/I_x = 7.6/6.5 = 1$

From the plate table (PBI-1971) it is obtained

$Cl_x = 25$, $Cl_y = 21$, $Ct_x = 59$ and $Ct_y = 54$. Moments need:

$$MI_x(+) = 0.001 \cdot Cl_x \cdot qu \cdot I_x^2$$

$$= 0.001 \times 25 \times 871.6 \times 7.62 = 1258.59 \text{ kgm} \quad MI_y(+) = 0.001 \cdot Cl_y \cdot qu \cdot I_x^2$$

$$= 0.001 \times 21 \times 871.6 \times 7.62 = 1057.21 \text{ kgm}$$

$$Mt_x(-) = 0.001 \cdot Ct_x \cdot qu \cdot I_x^2$$

$$= 0.001 \times 59 \times 871.6 \times 7.62 = 2970.27 \text{ kgm}$$

$$Mt_y(-) = 0.001 \cdot Ct_y \cdot qu \cdot I_x^2$$

$$= 0.001 \times 54 \times 871.6 \times 7.62 = 2718.55 \text{ kgm}$$

e. Plate reinforcement

Reinforcement area:

US

$$= (1/4 \cdot \pi \cdot D^2 \cdot S) / s = (1/4 \cdot \pi \cdot 6^2 \cdot 1000) / 115 = 245.864$$

mm² $\geq A_s(s,b,u)$ (OK) So use :

$$\text{principal reinforcement } A_s = D10-70 = 1121.43 \text{ mm}^2 \quad \text{reinforcement for } A_{sb} = D6-115 = 245.864 \text{ mm}^2$$

5. CONCLUSION

Based on the results of the analysis and planning that has been carried out, several conclusions are obtained regarding the planning of industrial buildings (workshops) that carry crane loads as follows:

1. The stresses and deflections that occur in the runway beams are less than the allowable stresses and deflections by using a combination of WF and Channel profiles.
2. The analysis of runway beams which are considered as continuous beams actually results in a more economical design, but the application in the field with perfectly clamped position conditions is still not convincing so that considerations of safety take precedence over economic considerations.
3. The shock coefficient contained in the 1984 Indonesian Steel Building Planning Regulations should be included in the calculation because it has a large enough value, namely an increase in moment of 15%, from the initial value of 34.15tm to 39.27tm.

6. REFERENCES

Agus Setiawan, 2008, Steel Structure Planning with LRFD Method (Based on SNI 03-1729-2002), Erlangga, Jakarta.

- Joseph E. Bowles, 1985, *Structural Steel Design*, Erlangga, Jakarta.
- Salmon Charles G, and Johnson John E, 1994, *Steel Structure Design and Behavior 1*, PT. Gamedia Pustaka Utama, Jakarta.
- S. Aryza,, Irwanto, M., Lubis, Z., Siahaan, A. P. U., Rahim, R., & Furqan, M. (2018). A Novelty Design Of Minimization Of Electrical Losses In A Vector Controlled Induction Machine Drive. In *IOP Conference Series: Materials Science and Engineering* (Vol. 300, No. 1, p. 012067). IOP Publishing.
- Salmon Charles G, and Johnson John E, 1994, *Steel Structure Design and Behavior 2*, PT. Gamedia Pustaka Utama, Jakarta.
- SNI 03-1729-2002, *Procedures for Designing Steel Structures for Buildings*, Ministry of Public Works.
- SNI-03-2847-2002, *Procedure for Calculation of Concrete Structures for Buildings*, Ministry of Public Works.
- Ir. Oentoeng, 2000, *Steel Construction*, LPPM Petra Christian University Surabaya and ANDI.

