Design of Beam in the Six Floors Building Based On Building Information Modelling (BIM) Using Autodesk Revit and Autodesk Robot Structural Analysis Professional

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Design of Beam in the Six Floors Building Based On Building Information Modelling (BIM) Using Autodesk Revit and Autodesk Robot Structural Analysis Professional

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Abstrak

Dengan berkembangnya industri Architecture, Engineering and Construction (AEC) banyak sofware yang dikembangkan untuk memenuhi kebutuhan industri konstruksi dengan tujuan untuk meminimalisir human eror dikarenakan pengolahan data secara konvensional. Revit dan Robot Structural Analysis Profesional adalah sebuah software penunjang metode BIM yang diterbitkan oleh Autodesk dan saling terintegrasi satu sama lain. Autodesk Revit merupakan software yang digunakan untuk desain 3D, perencanaan scheduling dan perencanaan anggaran biaya, sedangkan Robot Structural Analysis Profesional merupakan software yang digunakan untuk analisis struktur. Tujuan dari penelitian ini adalah untuk mengetahui bagaimana penerapan metode BIM dalam perencanaan sebuah gedung dan menggali keuntungan apa saja yang dapat diperoleh dalam penerapan BIM. Metode dalam penelitian ini dilakukan dengan merencanakan ulang salah satu gedung fasilitas pendidikan yang ada di Kota Surabaya menggunakan Autodesk Revit dan Autodesk Robot Structural Analysys Profesional. Penelitian ini menghasilkan desain optimum elemen balok serta perbandingan terhadap metode BIM dan metode konvensional. Dari hasil analisis dan pembahasan dapat disimpulkan bahwa penggunaan software penunjang metode BIM lebih efisien daripada konvensional, BIM memfasilitasi proses desain dan konstruksi terintegrasi untuk mencapai hasil yang lebih baik. Namun, penggunaan metode BIM perlu dilakukan pengecekan ulang terhadap SNI dalam mendesain sebuah bangunan.

***Kata Kunci** : Autodesk Revit, Autodesk Robot Structural Analysis Profesional (RSAP), Building Information Modelling (BIM), Integrasi.*

Abstract

With the development of the Architecture, Engineering and Construction (AEC) industry, a lot of software has been developed to meet the needs of the construction industry with the aim of minimizing human error due to conventional data processing. Revit and the Professional Structural Analysis Robot are software supporting the BIM method published by Autodesk and integrated with each other. Autodesk Revit is software used for 3D design, scheduling planning and budget planning, while Robot Structural Analysis Professional is software used for structural analysis. The purpose of this study is to find

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out how to apply the BIM method in planning a building and explore what advantages can be obtained in implementing BIM. The method in this study was carried out by re-planning one of the educational facility buildings in the city of Surabaya using Autodesk Revit and Autodesk Professional Structural Analysys Robot. This research resulted in the optimum design of the beam elements as well as comparisons with the BIM method and conventional methods. From the results of the analysis and discussion it can be concluded that the use of supporting software for the BIM method is more efficient than conventional, BIM facilitates integrated design and construction processes to achieve better results. However, the use of the BIM method needs to be re-checked against SNI in designing a building.

***Keywords**: Autodesk Revit, Autodesk Robot Structural Analysis Profesional (RSAP), Building Information Modelling (BIM), Integration.*

1. BACKGROUND

With the development of the Architecture, Engineering and Construction (AEC) industry, a lot of software has been developed to meet the needs of the construction industry with the aim of minimizing human error due to conventional data processing. This requires the Indonesian people to evaluate construction management methods in their implementation [1]. Building Information Modeling (BIM) is a paradigm shift to replace conventional CAD [2]. Building Information Modeling (BIM) is able to simulate all project information or data processing in 3 dimensions. The use of BIM provides many advantages in implementing a project. As is the case with BIM technology, accurate virtual models can be created digitally. BIM enables integrated design and construction processes to achieve better results, lower project costs and timeframes. BIM can also improve and perfect project development as needed starting from the planning stage, field implementation, to completion and maintenance stages

Revit is software for modeling, where each building element is identified based on its function, including technical data and price. *Revit* can create 3D modeling that includes the physical properties and interactions between construction components. Such as when making changes or modifications to a view, these changes will affect other displays and will automatically change. Meanwhile, *Autodesk Robot Structural Analysis Professional* is a new structural design and analysis software designed to simplify the process of calculating structural loading.

The purpose of this research is to find out how to apply the BIM method in planning a building and to explore what advantages can be obtained in implementing BIM. The reason for choosing the Building Information Modeling (BIM) based method is so that the implementation of a construction work becomes more effective and efficient. By using the BIM method, construction companies can save processing time, costs and the required manpower. It can also minimize errors in the implementation of a development by using a technology in the field of construction that has covered all disciplinary aspects of the field of construction work using Building Information Modeling (BIM) technology.

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2. RESEARCH METHODOLOGY

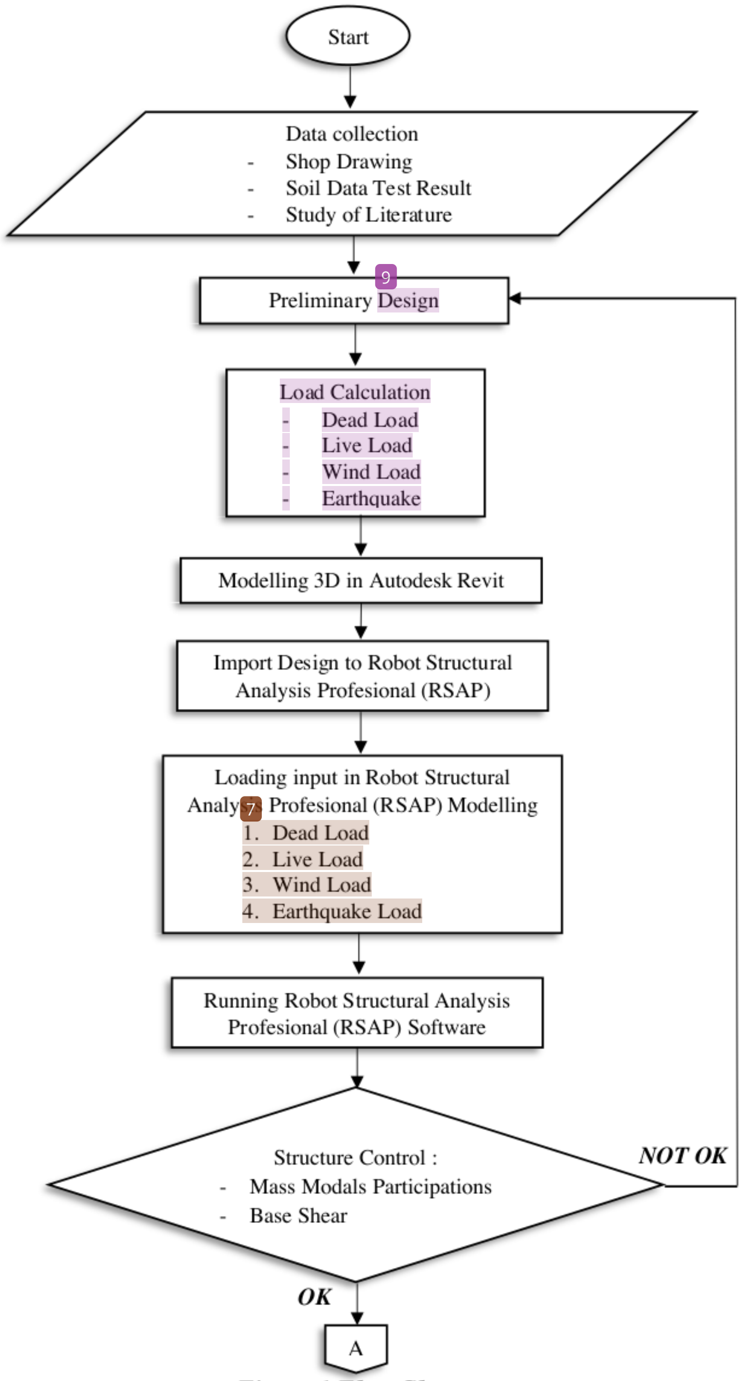

Figure 1 Flow Chart

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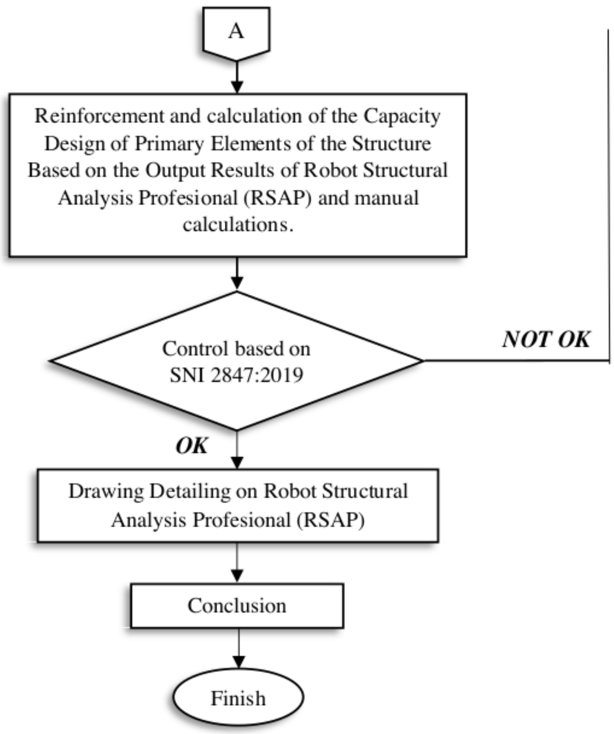

Figure 2 Flow Chart (Continued)

2.1 Loading Calculation Data

2.1.1 Gravity Load

a. Dead Load

Dead Load in the form of the Building Structure load itself will be modeled into the *Robot Structural Analysis Profesional* software and will automatically be calculated by the software itself.

b. Super Dead Load

Super Dead Load is a dead load that is not modeled but needs to be inputted directly into the software in the form of load values in the Indonesian Loading Regulation for Buildings 1983 (PPIUG 1983) as follows :

Table 1 Dead Load based on PPIUG 1983

Load Type	Weight (kg/m^2)
Reinforcement Concrete	2400
Spent	21
Ceramics	24
a Half Brick Wall	250
Ceiling	11
Ceiling Hanger	7
Instalation of MEP	25

(Source : PPIUG 1983)

c. Live Load

The loading of the live load to be calculated refers to the regulation SNI 1727:2020 concerning Minimum Load for the Design of Buildings and Other Structures, as follows :

Table 2 Minimum evenly distributed live load, L_0 and minimum centralized live load

Occupancy or Use	**Evenly, L_0 (kN/m^2)**	**Centralized (kN)**	**Evenly, L_0 (kg/m^2)**	**Centralized (kg)**
School				
Class Room	1,92	4,45	195,78	453,77
Above the first floor Corridor	3,83	4,45	390,55	453,77
First floor corridor	4,79	4,45	488,44	453,77
Roof				
Roof for a gathering place	4,79		488.44	

(Source : SNI 1727:2020 Chapter 4.3)

2.1.2 Wind Load

In the calculation of wind load, the data used adjusts to geographical and climatological conditions at the project location. The basic wind speed data to be used in the calculation of wind load using data from the Central Statistics Agency (BPS) in the two-year data range from 2019 to 2020, get the wind speed value is V = 33 m/s.

2.1.3 Earthquake Load

Earthquake load analysis used spectrum response analysis which is analyzed using *RSA2019* software with Building Risk Category is IV dan Soil Site Classification is SE / Soft Soil. Get the graph of spectrum response analysis as follows :

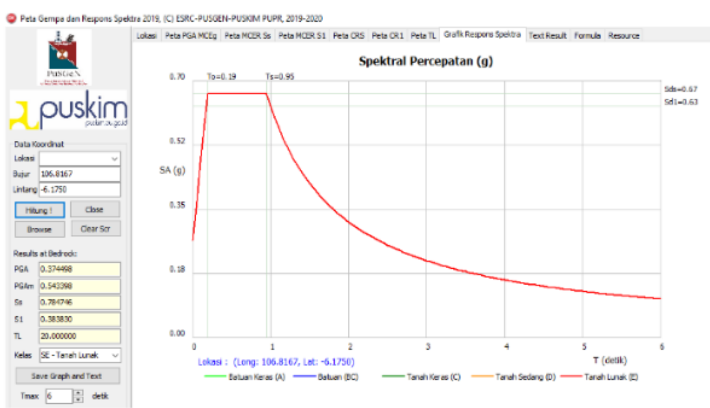

Figure 3 Spectral Values Design

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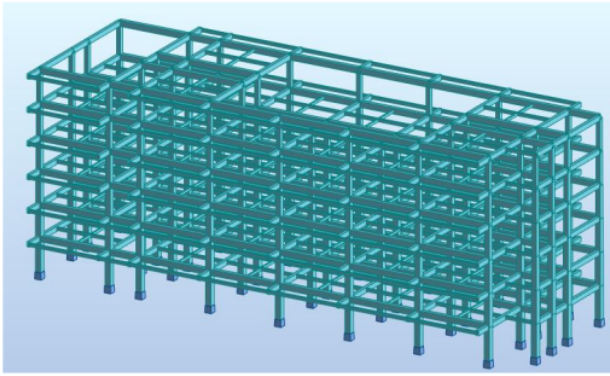


Figure 4 Structural Modelling in Robot Structural Analysis Profesional

3. RESULT AND DISCUSSION

3.1 Preliminary Design

From the calculations of beam preliminary design, the results of the dimensions beam will be used in the design as follows :

Table 3 Beam Preliminary Design Result

No	Element	Dimensions (cm)	
		b	h
1.	Elongated Main Beam (BI1)	40	60
2.	Transverse Main Beam (BI2)	35	50
3.	Elongated Joist (BA1)	25	35
4.	Transverse Joist (BA2)	20	30

Checking the Beam Dimension Requirements According to SNI 2847:2019 Chapter 18.6.2.1 Page 377, for the checking example used one of elongated main beam, as follows :

1. Clean Span Requirement (ln ≥ 4d)
   - X Direction Clean Span Check
     lnx ≥ 4d
     $8250 \text{ mm} \geq 4 \times 539 \text{ mm} = 8250 \text{ mm} \geq 2156 \text{ mm}\ (Qualify)$
   - Y Direction Clean Span Check
     lny ≥ 4d
     $6450 \text{ mm} \geq 4 \times 539 \text{ mm} = 6450 \text{ mm} \geq 2156 \text{ mm}\ (Qualify)$
2. Cross Section Width Requirement (bw)
   - Requirements 1 : bw ≥ 0,3h
     $400 \text{ mm} \geq 0{,}3 \times 600 \text{ mm} = 400 \text{ mm} \geq 180 \text{ mm}\ (Qualify)$
   - Requirements 2 : bw ≥ 250 mm
     $400 \text{ mm} \geq 250 \text{ mm}\ (Qualify)$
3. Requirements for the width of the beam to the width of the column
   $c_1 \geq \text{bw} \leq 0{,}75 \times c_2$
   $750 \geq 400 \leq 0{,}75 \times 750 = 750 \geq 400 \text{ mm} \leq 562{,}5 \text{ mm}\ (Qualify)$

3.2 Mass Modals Partisipations

From the output of the *Autodesk Robot Structural Analysis Professional*, mass participation reaches more than 90%, for the X direction it is in mode 12 and for the Y direction it is in mode 10 with a maximum period of 0,99 Sec and a maximum frequency of 5,9 Hz . It can be concluded based on the provisions of SNI 1726:2019 Chapter 7.9.1 Page 77 that mass modals participation has met the requirements.

3.3 Base Shear

From the output of the *Autodesk Robot Structural Analysis Professional* get the base shear check as follows :

X Direction Base Shear Check :

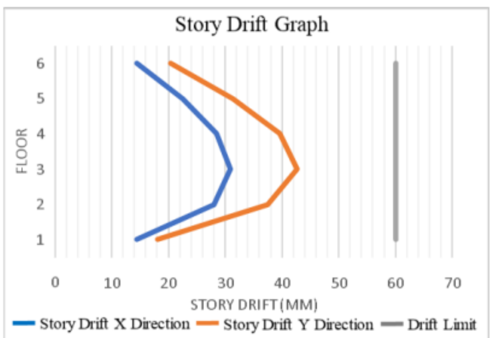
$$\text{V Dinamic} > 100\% \times \text{V Static}$$
$$524259{,}33 > 100\% \times 524259{,}33$$
$$524259{,}33 > 524259{,}33\ (Qualify)$$

Y Direction Base Shear Check :

$$\text{V Dinamic} > 100\% \times \text{V Static}$$
$$524259{,}33 > 100\% \times 524259{,}33$$
$$524259{,}33 > 524259{,}33\ (Qualify)$$

3.4 Story Drift Analysis

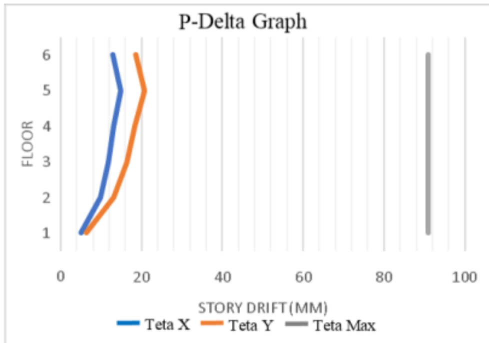
Based on the calculation checking of story drift analysis against SNI requirements 1726:2019 Chapter 7.12.1 Page 88, the results obtained meet the requirements for each floor. With a greatest displacement in X direction is 30,87 mm and greatest displacement in Y direction 42,61 mm, with the following graphic as follows :



Graph. 1 Story Drift

3.5 Effect of P-Delta Analysis

Based on the calculation checking Effect of P-Delta analysis against SNI requirements 1726:2019 Chapter 7.8.7 Page 76, the results obtained meet the requirements for each floor. With a greatest P-Delta in X direction is 14,81 mm and greatest P-Delta in Y direction 20,67 mm, with the following graphic as follows :



Graph. 2 Effect of P-Delta Analysis

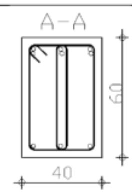
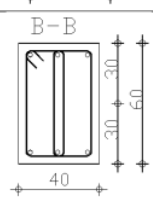
(Source : Author's Review, 2022)

3.6 Beam Reinforcement

3.6.1 Beam Reinforcement Detail (BI1-291/X Direction)

The following is a table of reinforcement output recapitulation obtained from RSAP which is then checked against SNI regulations 2847:2019 Chapter 10.5.1.1 Page 214 that ø Mn ≥ Mu.

Table 4 Recapitulation of flexural beam reinforcement calculations (BI1-291/X Direction)

Area	Reinforcement (RSAP)			Mn (N.mm)	Mr (N.mm)	Mu (N.mm)	Check
	$øT = 22$ mm	As	A's	$(As \times fy) \times \left(d - \frac{a}{2}\right)$	$ø \times Mn$	RSAP Output	Mr ≥ Mu
Support		6	3	441447088	397302379	365877304	*Qualify*
Span		3	3	246798226	222118403	216677448	*Qualify*

1. Support Beam Flexural Reinforcement Checked

- Reinforcement Ratio Check

Given :

$$Rn = 3{,}498 \text{ Mpa} \rightarrow \rho_{needed} = \frac{0{,}85Fc}{Fy} \times \left(1 - \sqrt{1 - \frac{2Rn}{0{,}85Fc}}\right)$$

$$\rho_{needed} = \frac{0{,}85 \times 30}{420} \times \left(1 - \sqrt{1 - \frac{2 \times 3{,}498}{0{,}85 \times 30}}\right) = 0{,}00899$$

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Minimum reinforcement ratio :

$$\rho \min 1 = \frac{0{,}25\sqrt{Fc}}{Fy} = \frac{0{,}25\sqrt{30}}{420} = 0{,}00326$$

$$\rho \min 2 = \frac{1{,}4}{Fy} = \frac{1{,}4}{420} = 0{,}00333$$

$$\rho \min = 0{,}00333\ (Determined)$$

Check Reinforcement Ratio is Necessary :

$$\rho \text{ needed} > \rho \min = 0{,}00899 > 0{,}00333\ (Qualify)$$

- Spacing Check based on SNI 2847:2019 Chapter 24.3.2 Page 550

Given :

$$S_{clean} = \frac{b - (2 \times ts) - (2 \times øs) - (n \times øT)}{n - 1}$$

$$S_{clean} = \frac{400 - (2 \times 40) - (2 \times 10) - (3 \times 22)}{3 - 1}$$

$$S_{clean} = 117 \text{ mm} > 40 \text{ mm}\ (Ok)$$

Reinforcement is installed in 2 layers.

$$Cc = ts + øs = 40 + 10 = 50 \text{ mm} \ / \ Fs = \frac{2}{3} \times Fy = \frac{2}{3} \times 420 = 280 \text{ Mpa}$$

$$S = 380 \times \left(\frac{280}{Fs}\right) - (2{,}5 \times Cc) < 300 \times \left(\frac{280}{Fs}\right)$$

$$S = 380 \times \left(\frac{280}{280}\right) - (2{,}5 \times 50) < 300 \times \left(\frac{280}{280}\right)$$

$$S = 255 \text{ mm} < 300 \text{ mm}\ (Qualify)$$

$$S \text{ available} = S_{clean} < S = 117 \text{ mm} < 255 \text{ mm}\ (Qualify)$$

2. Span Beam Flexural Reinforcement Checked

- Reinforcement Ratio Check

Given :

$$Rn = 2{,}072 \text{ Mpa} \rightarrow \rho_{needed} = \frac{0{,}85Fc}{Fy} \times \left(1 - \sqrt{1 - \frac{2Rn}{0{,}85Fc}}\right)$$

$$\rho_{needed} = \frac{0{,}85 \times 30}{420} \times \left(1 - \sqrt{1 - \frac{2 \times 2{,}072}{0{,}85 \times 30}}\right) = 0{,}00515$$

Minimum reinforcement ratio :

$$\rho \min 1 = \frac{0{,}25\sqrt{Fc}}{Fy} = \frac{0{,}25\sqrt{30}}{420} = 0{,}00326$$

$$\rho \min 2 = \frac{1{,}4}{Fy} = \frac{1{,}4}{420} = 0{,}00333$$

$$\rho \min = 0{,}00333\ (Determine)$$

Check Reinforcement Ratio is Necessary :

$$\rho \text{ needed} > \rho \min = 0{,}00515 > 0{,}00333\ (Qualify)$$

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- Spacing Check based on SNI 2847:2019 Chapter 24.3.2 Page 550

  Given :

  $$S_{clean} = \frac{b - (2 \times ts) - (2 \times øs) - (n \times øT)}{n - 1}$$
  $$S_{clean} = \frac{400 - (2 \times 40) - (2 \times 10) - (3 \times 22)}{3 - 1}$$
  $$S_{clean} = 117 \text{ mm} > 40 \text{ mm } (Ok)$$

  Reinforcement is installed in 1 layers.

  $$Cc = ts + øs = 40 + 10 = 50 \text{ mm} \ / \ Fs = \frac{2}{3} \times Fy = \frac{2}{3} \times 420 = 280 \text{ Mpa}$$
  $$S = 380 \times \left(\frac{280}{Fs}\right) - (2{,}5 \times Cc) < 300 \times \left(\frac{280}{Fs}\right)$$
  $$S = 380 \times \left(\frac{280}{280}\right) - (2{,}5 \times 50) < 300 \times \left(\frac{280}{280}\right)$$
  $$S = 255 \text{ mm} < 300 \text{ mm } (Qualify)$$
  $$S \text{ available} = S_{clean} < S = 117 \text{ mm} < 255 \text{ mm } (Qualify)$$

3. Beam Shear Reinforcement

   Based on the RSAP output, shear reinforcement is 4D22-260 mm in the plastic hinge area and 4D22-270 mm in the critical hinge area. As in the following picture :

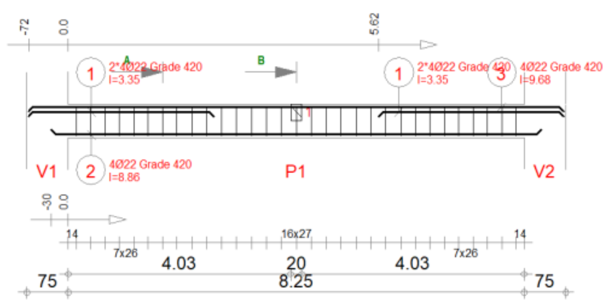

Figure 5 Beam Shear Reinforcement BI1-291
(Source : Autodesk Robot Structural Analysis Profesional, 2022)

Given :

$$Vu = 267732 \text{ N (RSAP Output)}$$
$$Vc \text{ Support} = 0{,}17\sqrt{Fc} \times bd = 0{,}17 \times \sqrt{30} \times 400 \times 508 = 189205{,}28$$
$$Vc \text{ Span} = 0{,}17\sqrt{Fc} \times bd = 0{,}17 \times \sqrt{30} \times 400 \times 539 = 200751{,}27$$

Vs Support Area Analysis

$$Vn = Vc + Vs$$
$$\frac{Vu}{ø} = Vc + Vs$$
$$189205{,}28 + Vs = \frac{267732}{0{,}9}$$
$$Vs \text{ support} = 108274{,}72 \text{ N}$$

Vs Span Area Analysis

$$Vn = Vc + Vs$$
$$\frac{Vu}{ø} = Vc + Vs$$
$$200751{,}27 + Vs = \frac{267732}{0{,}9}$$
$$Vs \text{ span} = 96728{,}73 \text{ N}$$

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- Spacing Check based on SNI 2847:2019 Chapter 9.7.6.2.2 Page 202

- Support Area

  Approach 1 : $s \leq \frac{d}{2} \rightarrow s \leq \frac{508}{2} \rightarrow s \leq 254$ mm

  Approach 2 : $s \leq 600$ mm

  Maximum spacing of the shear reinforcement in the support area is 254 mm. Then the shear reinforcement spacing obtained from RSAP output is 260 mm does not meet the requirements.

- Span Area

  Approach 1 : $s \leq \frac{d}{2} \rightarrow s \leq \frac{539}{2} \rightarrow s \leq 269$ mm

  Approach 2 : $s \leq 600$ mm

  Maximum spacing of the shear reinforcement in the support area is 269 mm. Then the shear reinforcement spacing obtained from RSAP output is 270 mm does not meet the requirements.

- Shear Reinforcement Obtained from SNI Calculations (Conventional) :

  Support Area : 3D10 mm – 100 mm

  Span Area : 3D10 mm – 200 mm

- Theoretical Area Value

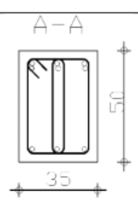
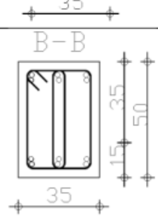
  $$\text{Av Support} = \frac{\text{Vs} \times \text{S}}{\text{Fyt} \times \text{d}} = \frac{108274{,}72 \times 270}{280 \times 508} = 205{,}53 \text{ mm}^2$$

  $$\text{Av Span} = \frac{\text{Vs} \times \text{S}}{\text{Fyt} \times \text{d}} = \frac{96728{,}73 \times 260}{280 \times 539} = 166{,}64 \text{ mm}^2$$

3.6.2 Beam Reinforcement Detail (BI2-339/Y Direction)

The following is a table of reinforcement output recapitulation obtained from RSAP which is then checked against SNI regulations 2847:2019 Chapter 10.5.1.1 Page 214 that ø Mn ≥ Mu.

Table 5 Recapitulation of flexural beam reinforcement calculations (BI2-339/Y Direction)

Area	Reinforcement (RSAP)			Mn (N.mm)	Mr (N.mm)	Mu (N.mm)	Check
	øT = 22 mm	As	A's	$(As \times fy) \times \left(d - \frac{a}{2}\right)$	ø × Mn	RSAP Output	Mr ≥ Mu
Support		6	3	339282993	305354694	302491473	*Qualify*
Span		6	3	257388408	231649557	118977333	*Qualify*

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1. Support Beam Flexural Reinforcement Checked

- Reinforcement Ratio Check

Given :

$$\mathrm{Rn} = 4{,}982\ \mathrm{Mpa} \rightarrow \rho_{\mathrm{needed}} = \frac{0{,}85\mathrm{Fc}}{\mathrm{Fy}} \times \left(1 - \sqrt{1 - \frac{2\mathrm{Rn}}{0{,}85\mathrm{Fc}}}\right)$$

$$\rho_{\mathrm{needed}} = \frac{0{,}85 \times 30}{420} \times \left(1 - \sqrt{1 - \frac{2 \times 4{,}982}{0{,}85 \times 30}}\right) = 0{,}0133$$

Minimum reinforcement ratio :

$$\rho\ \mathrm{min}\ 1 = \frac{0{,}25\sqrt{\mathrm{Fc}}}{\mathrm{Fy}} = \frac{0{,}25\sqrt{30}}{420} = 0{,}00326$$

$$\rho\ \mathrm{min}\ 2 = \frac{1{,}4}{\mathrm{Fy}} = \frac{1{,}4}{420} = 0{,}00333$$

$\rho\ \mathrm{min} = 0{,}00333\ (Determined)$

Check Reinforcement Ratio is Necessary :

$\rho\ \mathrm{needed} > \rho\ \mathrm{min} = 0{,}0133 > 0{,}00333\ (Qualify)$

- Spacing Check based on SNI 2847:2019 Chapter 24.3.2 Page 550

Given :

$$S_{\mathrm{clean}} = \frac{\mathrm{b} - (2 \times \mathrm{ts}) - (2 \times \mathrm{øs}) - (\mathrm{n} \times \mathrm{øT})}{\mathrm{n} - 1}$$

$$S_{\mathrm{clean}} = \frac{350 - (2 \times 40) - (2 \times 10) - (3 \times 22)}{3 - 1}$$

$S_{\mathrm{clean}} = 92\ \mathrm{mm} > 40\ \mathrm{mm}\ (Ok)$

Reinforcement is installed in 2 layers.

$$\mathrm{Cc} = \mathrm{ts} + \mathrm{øs} = 40 + 10 = 50\ \mathrm{mm}\ /\ \mathrm{Fs} = \frac{2}{3} \times \mathrm{Fy} = \frac{2}{3} \times 420 = 280\ \mathrm{Mpa}$$

$$S = 380 \times \left(\frac{280}{\mathrm{Fs}}\right) - (2{,}5 \times \mathrm{Cc}) < 300 \times \left(\frac{280}{\mathrm{Fs}}\right)$$

$$S = 380 \times \left(\frac{280}{280}\right) - (2{,}5 \times 50) < 300 \times \left(\frac{280}{280}\right)$$

$S = 255\ \mathrm{mm} < 300\ \mathrm{mm}\ (Qualify)$

$S\ \mathrm{available} = S_{\mathrm{clean}} < S = 92\ \mathrm{mm} < 255\ \mathrm{mm}\ (Qualify)$

2. Span Beam Flexural Reinforcement Checked

- Reinforcement Ratio Check

Given :

$$\mathrm{Rn} = 3{,}112\ \mathrm{Mpa} \rightarrow \rho_{\mathrm{needed}} = \frac{0{,}85\mathrm{Fc}}{\mathrm{Fy}} \times \left(1 - \sqrt{1 - \frac{2\mathrm{Rn}}{0{,}85\mathrm{Fc}}}\right)$$

$$\rho_{\mathrm{needed}} = \frac{0{,}85 \times 30}{420} \times \left(1 - \sqrt{1 - \frac{2 \times 3{,}112}{0{,}85 \times 30}}\right) = 0{,}0079$$

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Minimum reinforcement ratio :

$$\rho \min 1 = \frac{0{,}25\sqrt{\text{Fc}}}{\text{Fy}} = \frac{0{,}25\sqrt{30}}{420} = 0{,}00326$$

$$\rho \min 2 = \frac{1{,}4}{\text{Fy}} = \frac{1{,}4}{420} = 0{,}00333$$

$$\rho \min = 0{,}00333\ (Determine)$$

Check Reinforcement Ratio is Necessary :

$$\rho\ \text{needed} > \rho \min = 0{,}0079 > 0{,}00333\ (Qualify)$$

- Spacing Check based on SNI 2847:2019 Chapter 24.3.2 Page 550

Given :

$$S_{clean} = \frac{b - (2 \times ts) - (2 \times øs) - (n \times øT)}{n - 1}$$

$$S_{clean} = \frac{350 - (2 \times 40) - (2 \times 10) - (3 \times 22)}{3 - 1}$$

$$S_{clean} = 92\ \text{mm} > 40\ \text{mm}\ (Ok)$$

Reinforcement is installed in 1 layers.

$$\text{Cc} = \text{ts} + øs = 40 + 10 = 50\ \text{mm} \ /\ \text{Fs} = \frac{2}{3} \times \text{Fy} = \frac{2}{3} \times 420 = 280\ \text{Mpa}$$

$$S = 380 \times \left(\frac{280}{\text{Fs}}\right) - (2{,}5 \times \text{Cc}) < 300 \times \left(\frac{280}{\text{Fs}}\right)$$

$$S = 380 \times \left(\frac{280}{280}\right) - (2{,}5 \times 50) < 300 \times \left(\frac{280}{280}\right)$$

$$S = 255\ \text{mm} < 300\ \text{mm}\ (Qualify)$$

$$S\ \text{available} = S_{clean} < S = 92\ \text{mm} < 255\ \text{mm}\ (Qualify)$$

3. Beam Shear Reinforcement

Based on the RSAP output, shear reinforcement is 4D22-210 mm in the plastic hinge area and 4D22-220 mm in the critical hinge area. As in the following picture :

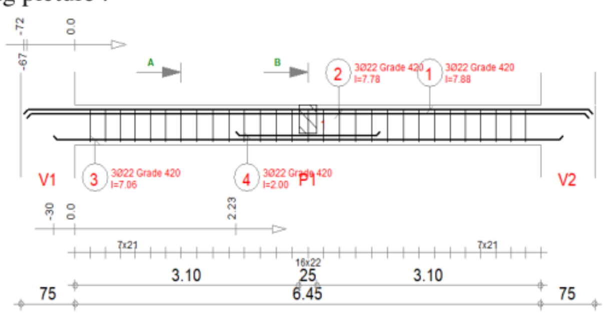

Figure 6 Shear Beam Reinforcement BI2-339

(Source : Autodesk Robot Structural Analysis Profesional, 2022)

Given :

$$\text{Vu} = 224303\ \text{N (RSAP Output)}$$

$$\text{Vc Support} = 0{,}17\sqrt{\text{Fc}} \times \text{bd} = 0{,}17 \times \sqrt{30} \times 350 \times 408 = 132965{,}13$$

$$\text{Vc Span} = 0{,}17\sqrt{\text{Fc}} \times \text{bd} = 0{,}17 \times \sqrt{30} \times 350 \times 439 = 143067{,}87$$

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Vs Support Area Analysis

$$Vn = Vc + Vs$$

$$\frac{Vu}{ø} = Vc + Vs$$

$$132965{,}13 + Vs = \frac{224303}{0{,}9}$$

$$Vs\ support = 116260{,}43\ N$$

Vs Span Area Analysis

$$Vn = Vc + Vs$$

$$\frac{Vu}{ø} = Vc + Vs$$

$$143067{,}87 + Vs = \frac{224303}{0{,}9}$$

$$Vs\ span = 106157{,}69\ N$$

- Spacing Check based on SNI 2847:2019 Chapter 9.7.6.2.2 Page 202

- Support Area

  $\text{Approach 1}: s \le \frac{d}{2} \rightarrow s \le \frac{408}{2} \rightarrow s \le 204\ mm$

  $\text{Approach 2}: s \le 600\ mm$

  Maximum spacing of the shear reinforcement in the support area is 204 mm. Then the shear reinforcement spacing obtained from RSAP output is 210 mm does not meet the requirements.

- Span Area

  $\text{Approach 1}: s \le \frac{d}{2} \rightarrow s \le \frac{439}{2} \rightarrow s \le 219\ mm$

  $\text{Approach 2}: s \le 600\ mm$

  Maximum spacing of the shear reinforcement in the support area is 219 mm. Then the shear reinforcement spacing obtained from RSAP output is 220 mm does not meet the requirements.

- Shear Reinforcement Obtained from SNI Calculations (Conventional) :

  Support Area : 3D10 mm – 100 mm
  Span Area : 3D10 mm – 200 mm

- Theoretical Area Value

  $$Av\ Support = \frac{Vs \times S}{Fyt \times d} = \frac{116260{,}43 \times 210}{280 \times 408} = 213{,}71\ mm^2$$

  $$Av\ Span = \frac{Vs \times S}{Fyt \times d} = \frac{106157{,}69 \times 220}{280 \times 439} = 189{,}99\ mm^2$$

4. CONCLUSION

1. The optimum design of the elongated main beam / X direction using the *Robot Structural Analysis Profesional* obtains the following reinforcement results :
   - Longitudinal Reinforcement :

     Support Reinforcement : As = 6-D22 mm / A’s = 3-D22 mm
     Span Reinforcement : As = 3-D22 mm / A’s = 3-D22 mm
   - Shear Reinforcement :

     Plastic Hinge Area : 4D10 mm – 260 mm
     Critical Hinge Area : 4D10 mm – 270 mm

     Because the width of the shear reinforcement spacing result from RSAP output does not meet the requirements of SNI 2847:2019 Chapter 9.7.6.2.2, then the shear reinforcement in the design used the result from SNI calculations, namely : 3D10 mm – 100 mm in plastic hinge area and 3D10 mm – 200 mm in critical hinge area.

2. The optimum design of the elongated main beam / Y direction using the *Robot Structural Analysis Profesional* obtains the following reinforcement results :
   - Longitudinal Reinforcement :
     Support Reinforcement : As = 6-D22 mm / A's = 3-D22 mm
     Span Reinforcement : As = 6-D22 mm / A's = 3-D22 mm
   - Shear Reinforcement :
     Plastic Hinge Area : 4D10 mm – 210 mm
     Critical Hinge Area : 4D10 mm – 220 mm
     Because the width of the shear reinforcement spacing result from RSAP output does not meet the requirements of SNI 2847:2019 Chapter 9.7.6.2.2, then the shear reinforcement in the design used the result from SNI calculations, namely : 3D10 mm – 100 mm in plastic hinge area and 3D10 mm – 200 mm in critical hinge area.
3. Based on the output of the reinforcement results, designing a building based on the building information modeling (BIM) method using the *Robot Structural Analysis Professional* software can be summarized as follows :
   - *Robot Structural Analysis Professional* Software for optimal building design can be said to be more wasteful than manual check calculation results using SNI 2847:2019 (conventional). This is due to limitations in adjusting the amount of reinforcement that cannot be changed in the *Robot Structural Analysis Professional* software.
   - Reinforcement in RSAP obtains reinforcement spacing values that are greater than manual calculations. However, the spacing obtained from the RSAP results is too large so it does not meet the requirements of SNI 2847:2019.
   - Because software that supports the BIM method can be integrated at every stage or project file, the use of BIM-based software is more time efficient and easier to run than conventional software.

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