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SP Column Analysis in Testing the Strength and Sustainability of Industrial Building Sub-Structures

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Abstract

Analysis of *sub-structures* in cigarette factory buildings with concrete construction is essential to ensure the overall stability, safety, and efficiency of the building, especially in resisting static loads as well as dynamic loads from industrial machinery operations. This study aims to quantitatively evaluate the design capacity of lower structure elements, especially *pedestals* and *foot plates* and their repeating specifications, in order to ensure the safety and efficiency limits of materials that support sustainability. Methods: The analysis was performed using SP Column software that relies on the interaction surface diagram (P-M) method to validate the cross-sectional capacity of reinforced concrete against a combination of axial forces and bending moments, combined with computational analytical mechanics for shear and ground stress. The computational results show that *the foot plate* with an effective thickness of 0.22 m has a shear strength of 519.21 kN, far exceeding the shear force that occurs (284.267 kN). The *ratio of precision measured pedestal reinforcement* at 4%. Evaluation of steel performance proves the operating voltage is safe in the elastic region (below the modulus of 200,000 MPa). In addition, the area of the reinforced slab (113 mm²) exceeds the theoretical requirements of the structural analysis (66,987 mm²), which is an effective surplus in securing the position of the main reinforcement and resisting concrete cracks due to temperature reduction. The design of the lower structure of this factory building is proven to be daktail, safe, and legally compliant with the loading regulations of SNI 1727:2013 and the structural concrete requirements of SNI 2847:2019 (as a correction to the citation of SNI 1726 in the initial data). This computational optimization of the reinforcement ratio also prevents the waste of building materials, in line with the principles of sustainable industrial engineering.

Keywords: Structure, concrete, reinforcement, pedestal, pile cap, sustainability.

INTRODUCTION

Analysis of the lower structure of a cigarette factory building with concrete construction is essential to ensure the overall stability, safety, and efficiency of the building. The lower structure includes the foundation, piles, and other elements that are underground, all of which are responsible for supporting the overall load of the building.(Cahyono, Carina, et al., 2025)

Analysis of *sub-structures* in concrete-constructed cigarette factory buildings is a crucial aspect to ensure stability, safety, and material efficiency. These industrial buildings specifically have to bear the massive gravitational loads of heavy machinery operations, raw material storage areas, as well as dynamic loads in the form of mechanical vibrations that occur continuously. Failure to design a proportional lower structure can trigger (Triarma et al., 2025) *differential settlement* that risks damaging the integrity of the upper structure as a whole.

The substantial focus of this study is to quantitatively evaluate the design capacity of the lower structure elements, especially the pedestal cross-section and *foot plate* foundation, using SP Column software. SP Column operates specifically to analyze and design reinforced concrete elements through an interaction diagram method that identifies cross-sectional capacities to various combinations of axial forces and bending moments simultaneously.

This study is aimed at validating whether the dimensions of the planned repetition elements and specifications have met the loading demands set out in the standard, as well as complying with the requirements of structural concrete detail and earthquake resistance. The main analysis parameters investigated included the adequacy of the effective thickness of *the foot plate* (0.22 m), the resistance to the shear force of the two-way pons (with a rated capacity of 519.21 kN compared to the load of 284.267 kN), and the adequacy of the plate repeating area (113 mm² available compared to the requirement of 66.987 mm²). Through this analytical computing, the research aims to prove that the design not only meets the structural safety threshold, but also optimizes the use of materials to support the cost efficiency and sustainability of industrial building construction. (Sukma et al., 2025)

LITERATURE REVIEW

SP Column is more focused on reinforced concrete column design and analysis of axial force interaction and bending moments. The following are the analysis methods used in ETABS and SP Column for concrete column design (Havino et al., 2024). SP Column is a special software designed for the analysis and design of reinforced concrete columns, using the interaction diagram method to identify column capacities based on various combinations of axial forces and bending moments. (Panji et al., 2018)

1. Column Modeling on SP Column

1. Geometry and Material Inputs: Users provide inputs such as the cross-sectional dimensions of the columns (square, rectangle, circle), reinforcement type (longitudinal and spiral reinforcement configurations or stingers), and material properties (concrete and reinforcing steel). (Jiba & B, 2010)

2. Application of Axial Load and Bending Moment: SP Column allows users to insert a combination of axial force (P) and bending moment (Mx and My) on the column. The software then calculates the column capacity against that load combination. (Andi et al., 2023)

2. Design Methods in SP Column

1. Design Based on Standards: SP Column designs columns in accordance with regulatory codes such as ACI 318, Eurocode 2, or SNI 2847. The program checks whether the column cross-section meets the strength requirements based on the interaction diagram, including flexural strength, axial strength, and interaction between the two. (Sosiawan et al., n.d.)

2. Column Capacity Check: Based on the axial load input and bending moment, the SP Column generates the column capacity value and compares it with the applied load. If the applied load is greater than the calculated capacity, the software provides recommendations for improving the design, such as increasing reinforcement or changing the cross-sectional dimensions. (Rahmat et al., 2019)

3. Non-Prismatic Design and Column with Spiral Shingles

1. Non-Prismatic Columns: SP Columns can also be used to design columns that have dimensional variations along the height of the column (non-prismatic), which are often found in high-rise buildings or buildings with load changes at various heights. (Imriyanti, 2022)

2. Column with Spiral Rebar: If the column is designed with spiral reinforcement, SP Column takes into account the additional strength provided by the spiral reinforcement in calculating the axial capacity and bending of the column. (Almufid & Santoso, 2021)

3. Analysis of the lower structure of a cigarette factory building using SP Column involves a review of various aspects which include structural analysis methods, the use of SP Column software, and its application in the design of factory buildings. (Atmaja et al., 2023)

SP Column: More focus on the detailed analysis and design of reinforced concrete column elements. SP Column provides an in-depth analysis of column capacity based on axial force interaction diagrams and bending moments. It is used for more detailed design and ensures that the columns meet the local strength requirements. (Andalas & Ricardo Husni, 2016)

4. Validate Structural Strength Through SP Columns and Interaction Diagrams

The use of SP Columns is based on its excellence in accurately representing the Interaction Surface Diagram (P-M). The study conducted by confirmed that the SP Column is dedicated to precisely identifying the behavior and capacity of vertical elements based on the combination of axial force and biaxial deflection. This is reinforced by comparative studies showing that variations in reinforcement ratios in reinforced concrete column modeling have a significant impact on the difference in axial (P_n) and momentum (M_n) nominal capacity values; The more precisely the reinforcement ratio is calibrated, the more optimal the safety margin projected by the stress-strain curve. This algorithm ensures that the calculations on the (Cahyono, Carina, et al., 2025) (Cahyono et al., 2024) *factory pedestal* produce absolute accuracy.

5. Response of Foundation Structure Dynamics to Industrial Machinery Operations

In factory facilities, foundations are required to work beyond static conditions. Various studies have shown that the lower structure is obliged to evaluate the dynamic excitation of the machinery. A study applied the (Carina et al., 2025) *Lumped Parameter System method* to analyze the dynamic load of the engine on the foundation structure of the group pile (*Foot Plate*), proving that the ground response (represented through spring stiffness and damping) drastically alters the force transmission of the upper structure. Furthermore, soil dynamics analysis of industrial pump machine foundations validated that although dynamic loads are often smaller in size than static weights, the amplitude of vertical vibration must be kept strictly below thresholds (such as 0.04 mm in certain studies) to prevent critical resonance in the soil layer supporting *the foot plate* (Cahyono, Arifin, et al., 2025) .

RESEARCH METHODS

The complexity of calculating vertical elements that withstand the combined load gives birth to the urgency of computing software that is not only fast, but has a high level of analytical precision. SP Column software is the engineering answer to that need. Developed and continuously refined by StructurePoint (whose historical roots date back to the Engineering Software Group of the Portland Cement Association / PCA), SP Column is a dedicated computational engineering solution for the evaluation of the capacity and design of reinforced concrete cross-sections that target axial and bending forces simultaneously. Unlike simple beam analysis that considers only pure bending (where the axial force is considered zero or negligible), elements such as columns and *pedestals* work within domains where the presence of compressive loads can paradoxically increase the capacity of the cross-sectional moment to a certain point (*balanced point*), before the excessive compressive load causes the cross-section to be destroyed by absolute compressive forces.

1. Initial Data Preparation

Plan drawings: Collect drawings of the lower structure plan, including foundation plans and details of the pedestals and Foot Plates. Soil data: Get soil test results data such as sondir or SPT (Standard Penetration Test) to find out the soil support capacity. Load data: Determine the load that will be received by the lower structure, including dead load, live load, and earthquake load. (Paradise & Roesdiana , 2022) (Hikmawan & Firmanto , 2020)

2. Load Analysis

1. Identify the Type of Load (D. et al., 2016)

Before performing the analysis, it is important to know the different types of loads that act on the floor plate:

a. Dead Load: Includes the self-weight of the floor plate, building materials, and other fixed elements.

b. Live Load: Temporary loads such as people, furniture, and equipment placed on the floor.

c. Earthquake or Wind Load: Lateral loads that act on structures due to environmental factors.

2. Plate Structure Analysis (Ulina et al., 2019)

The floor plate is usually analyzed as an element that receives the load directly and passes it on to the beam that supports it. There are several types of plates that are commonly used:

a. One-way slab: If the length and width ratio is large enough (more than 2:1), the load is distributed to the support beams on the two shorter sides.

b. Two-way slab: If the ratio of length to width is close to 1:1, the load is distributed to the beams on all four sides.

3. Load Distribution on Beams (Emphasis & Samsurizal, 2018)

The load from the plates is passed to the supporting beams. Beams need to be analyzed based on the load distribution of the plates by simple beam analysis method or continuous beams. If the beam is continuous, then the analysis of the bending moment and the shear force at various points of the beam must be taken into account. Flexural moment formula for beams that support the load evenly:

$$Mmax = w \times L^2 / 8$$

Where:

W = Uniform load (kN/m)

L = length of beam span (m)

For continuous beams, more complex analysis is required, such as using the moment distribution method or matrix analysis.

4. Load Distribution to Columns (Havino et al., 2024)

The beams will distribute the load to the columns. Column analysis is usually done by considering the compressive strength and bending strength of the column (buckling). The columns must be able to support axial loads from gravitational loads as well as lateral forces due to wind or earthquakes. Calculation of axial force on columns:

$$P = \Sigma \, Beam\ load + floor\ load$$

5. Other Considerations (Andi et al., 2023)

a. Deflection control: In addition to force, deflection on beams and plates also needs to be controlled so that they do not exceed the clearance limit.

b. Environmental Influences: Factors such as earthquakes, winds, and temperature changes need to be taken into account in the design to ensure the structure remains safe and stable.

3. Geometry Modeling of Lower Structures

a. Pedestal: Create a pedestal model as the connecting element between the column above and the sloof or Foot Plate below. Determine the dimensions of the pedestal according to the plan drawing. (Sosiawan et al., n.d.)

b. Foot Plate: Foot Plate is the part that distributes the load from the column to the bore. Make a Foot Plate model with the appropriate dimensions to accommodate the bore. (Sociologists et al., n.d.)

4. Material Definition

Determine the material for each element, such as concrete for the pedestal and Foot Plate. Enter material parameters into the software, including modulus of elasticity, compressive strength of concrete, and specific gravity. (Emphasis & Samsurizal , 2018)

5. Determination of Profile and Cross-section

a. Pedestal and Sloof: Define a square or rectangular cross-section profile for a pedestal and sloof. (Cahyono, Arifin, et al., 2025)

b. Foot Plate: Define the dimensions of the Foot Plate according to the technical drawing. (Cahyono, Arifin, et al., 2025)

6. Load Deployment

a. Vertical Load: Apply the vertical load from the top structure load (column load, slab, etc.) to the pedestal, sloof, and Foot Plate. (Cahyono et al., 2024)

b. Lateral Load: Apply lateral loads such as earthquake or wind loads to the sloof and Foot Plate, which will be dispersed to the bore. (Cahyono et al., 2024)

7. Load Analysis and Structural Methods

Choose the appropriate analysis method, such as static or dynamic analysis depending on the type of load. Check the load balance between the vertical load of the upper structure and the bearing capacity of the piles. Distribute the load on the sloof, Foot Plate, and bore pile evenly according to the inner force distribution. (Cahyono, Carina, et al., 2025)

8. Conduct Structural Analysis

Run the analysis to calculate the internal forces, moments, axial forces, and deflections on all elements of the lower structure (pedestal, sloof, Foot Plate, bore pile). Examine the force-force interaction between the Foot Plate and the bore pile, especially on the axial and lateral bore pile bearing capacity. (Cahyono, Carina, et al., 2025)

9. Check the Results of the Analysis

a. Pedestal: Make sure the force in the pedestal, especially the compressive force, is in accordance with the design capacity. (Cahyono, Mulyono, et al., 2025)

b. Foot Plate: Review the forces in the Foot Plate, especially the shear and moment, to make sure no failure occurs. (Cahyono, Mulyono, et al., 2025)

10. Element Design

a. Pedestal: Determine the dimensions, reinforcement, and specifications for the pedestal based on the inner force obtained. (Cahyono, Arief, et al., 2025)

b. Foot Plate: Determine the dimensions and repeating of the Foot Plate based on the load received from the column and passed to the bore pile. (Cahyono, Arief, et al., 2025)

11. Report Creation

Generate reports that include analysis results, design calculations, style diagrams, moments, and dimensions and repetition of elements. Attach details of the calculation of the bore pile capacity based on the soil data.

12. Validation and Revision

Perform design validation with manual calculations or other simulations if needed. Make revisions to the model or design if the results are not up to standard or if there are any design changes. These steps can be customized depending on the type of project, the standards used, and the field conditions. (Jiba & B, 2010)

ANALYSIS AND DISCUSSION

1. Floor Plate Analysis

Table 1. X and Y Directional Rereinforcement Control.

$$\text{As ada} = \frac{\text{As} \quad \text{b}}{\text{s}} = \frac{28{,}26 \quad 1000}{250} = 113 \quad mm^2$$

$$\text{As perlu} = 66{,}9867 \quad mm^2$$

$$\text{As ada} \geq \text{As perlu}$$

$$113{,}0 \quad mm^2 \geq 66{,}987 \quad mm^2 \quad \textbf{OK}$$

Source: Data Analysis.

1. X Directional Reinforcement

a. The control of the reinforcement space (SNI 2847 – 2019 article 8.7.2.2) is taken in accordance with the structural analysis where required.

b. The number of X Directional Reinforcement is 309.72 mm2 and in the field is installed M8 2 Layer Threaded Wiremesh whose amount of ironing is 334.9 mm2 so that the number of reinforcement axles available has been above the reinforcement axle required by the structural analysis and has met the need to bear the shear loading.

c. The amount of reinforcement of the X Direction Field is 192.00 mm and in the field is installed a 2-Layer M8 Threaded Wiremesh whose distance between reinforcements is 334.9 mm2 so that the number of available Reinforcement Axles has been above the reinforcement axles required by the structural analysis and has met the needs to bear the bending loading.

2. Y-Direction Reinforcement

a. The control of the reinforcement space (SNI 2847 – 2019 article 8.7.2.2) is taken in accordance with the structural analysis where required.

b. The amount of X-Directional Reinforcement is 310.02 mm2 and in the field is installed M8 2 Layer Threaded Wiremesh whose ironing amount is 334.9 mm2 so that the number of Reinforcement Axles available has been above the Reinforcement Axle required by the structure analysis and has met the need to bear the shear loading.

c. The number of X Direction Field Rereinforcement is 176.00 mm and in the field is installed M8 2 Thread Wiremesh whose ironing distance is 334.9 mm2 so that the number of available Rebar Axes has been above the Restrain Axle required by structural analysis and has met the need to bear bending loading.

Table 2. Recapitulation of Floor Plate Reinforcement.

Plat A	Tul. Utama Plat arah x				Tul. Utama Plat arah y			
	Tulangan			As ada	Tulangan			As ada
Tum. Kiri	ø	8	- 150	334,9 mm^2	ø	8	- 150	335 mm^2
Lapangan	ø	8	- 150	334,9 mm^2	ø	8	- 150	335 mm^2
Tum. kanan	ø	8	- 150	334,9 mm^2	ø	8	- 150	335 mm^2
Tul bagi	ø	6	- 250	113,0 mm^2	ø	6	- 250	113 mm^2

Source: Data Analysis.

Table 3. Critical Cross-Section Inspection of X-Axis Floor Plate Steel Against the Demands of Internal Style

Structural Capacity Parameters of Floor Plates (Longitudinal Axis X)	Theoretical Needs Dimension (As−req)	Availability of Actual Field Cross-Sections (As−prov)	Verification Status
Strength Capacity of the Focus Area (Resisting Negative Moments & Latitude Shift)	309,72^2	*Double* Layer M8 Threaded Wiremesh (334,9^2)	Adequate (Capacity Surplus)
Field Area Retention Capacity (Withstanding Maximum Bending Tensile Stress)	192,00^2	*Double* Layer M8 Threaded Wiremesh (334,9^2)	Fulfilled (Safe Protected Limit)

Structural Capacity Parameters of Floor Plates (Transverse Axis Y)	Theoretical Needs Dimension (As−req)	Availability of Actual Field Cross-Sections (As−prov)	Verification Status
Strength Capacity of the Focus Area (Resisting Negative Moments & Latitude Shift)	310,02^2	*Double* Layer M8 Threaded Wiremesh (334,9^2)	Adequate (Capacity Surplus)
Field Area Retention Capacity (Withstanding Maximum Bending Tensile Stress)	176,00^2	*Double* Layer M8 Threaded Wiremesh (334,9^2)	Fulfilled (Safe Protected Limit)

Source : Data Analysis.

2. Pedestal Column Analysis

The mechanical energy and gravitational load of the upper slab floor are accumulated exponentially when they reach the steel columns supporting the roof, and then slam vertically against *the pedestal*. *Pedestals*, as short enlarged columns that creep just below ground level and above the *foot plate*, are designed to be a very massive concentrated stress redistributive bearing from the column to a much wider pressure area before hitting the thinner cross-section of the foundation plate. It is at this point that the SP Column's ability to evaluate the parameters of cross-sectional elements is manifested.

In executing computations on pedestal elements, modeling algorithms process a set of fundamental analytical input parameters. These modeling parameters include the determination of Cross-Section Geometry (such as physical dimensions of length and width), Material Properties (consisting of the compressive strength of the characteristic concrete f'_c and the melting stress of the f_y reinforcing steel), as well as the application of loads in the form of a combination of Axial Force (P_u) and Bending Moment (M_x and M_y). After these parameters are simulated through the SP Column, the main output will validate the reinforcement ratio to be in line with the performance requirements of the national standard earthquake ductility SNI 2847-2019 Article 18.7.4.1.

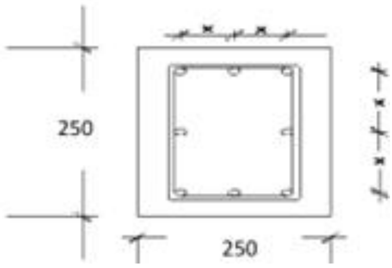
Table 4. Pedestal reinforcement distance.

$$x = \frac{\text{Jarak antar tulangan tepi}}{\text{n tulangan yg ditinjau} - 1}$$

$$= \frac{h - 2 \times d'}{\text{n tulangan yg ditinjau} - 1}$$

$$= \frac{250 - 2 \times 53}{2 - 1}$$

$$= 72 \text{ mm}$$



Luas penampang kolom (Ag)

$Ag = b \times h$

$Ag = 250 \times 250$

$Ag = 62500 \text{ mm}^2$

Luas tulangan yang diperlukan (As perlu/Ast)

$Ast = \text{n tulangan} \times 1/4 \; \Pi \; D^2$

$= 8 \times 1/4 \; 3,14 \; 100$

$= 628,000 \text{ mm}^2$

Source : Data Analysis.

Based on the extraction of computational data for the evaluation of pedestal reinforcement, the efficiency of this cross-sectional is determined by the longitudinal repetition ratio (ρ = A_st / A_g), which compares the area of the entire perpendicular main steel bar (A_st) with the gross area of its covering concrete prism (A_g). Here are the results of the data analysis:

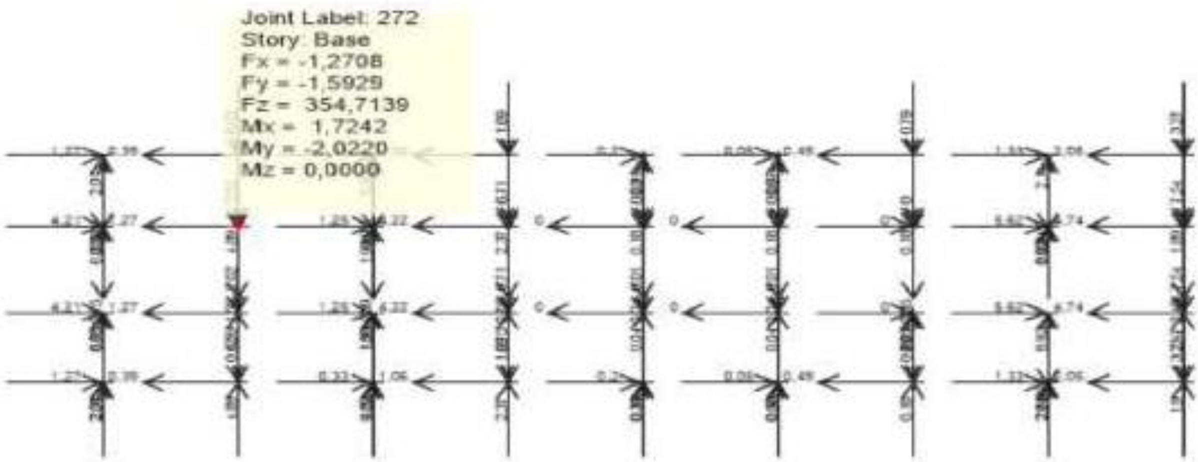


Figure 1. Styles That Work On Pedestal.
Source : Data Analysis.

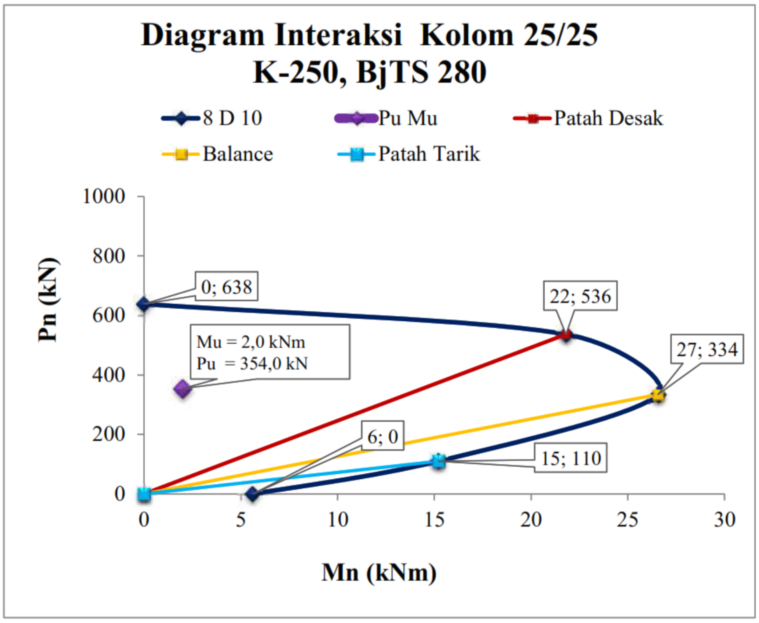


Figure 2. Reinforced Concrete Interaction Diagram on SP Column.
Source : Data Analysis.

3. Foot Plate Analysis

1. Ground Tension Control Reinforcement Area Calculation

From the results of the structural analysis, conclusions can be drawn for the strength of the foot plate against the planned load for the Ground Tension:

Base Width Foot Plate : 1.44 m2

X-Direction Moment Detention : 0.288 m3

Y-Direction Moment Detention : 0.288 m3

Ground Height Above Foot Plate : 1.1 m

Pressure Due to Heavy Foot Plate and Ground : 25.9 kN/m2

From the results of the soil tension analysis, the minimum soil tension value was obtained which was 259.310 kN / m2 so that the minimum soil tension value was greater than 0 which means that it has met the requirements for foot plate strength for soil tension control.

Table 5. Ground Tension Control.

Eksentrisitas pada fondasi :						
$e_x = M_{ux} / P_u =$	0,0048	m	<	$B_x / 6 =$	0,2000 m	(OK)
$e_y = M_{uy} / P_u =$	0,0056	m	<	$B_y / 6 =$	0,2000 m	(OK)
Tegangan tanah maksimum yang terjadi pada dasar fondasi :						
				$q_{max} = P_u / A + M_{ux} / W_x + M_{uy} / W_y + q =$	285,143	kN/m^2
	q_{max}	>	q_a	→	TIDAK AMAN ! (NG)	
Tegangan tanah minimum yang terjadi pada dasar fondasi :						
				$q_{min} = P_u / A - M_{ux} / W_x - M_{uy} / W_y + q =$	259,310	kN/m^2
	q_{min}	>	0	→	tak terjadi teg.tarik (OK)	

Source : Data Analysis.

2. Slide Review

From the results of the structural analysis, conclusions can be drawn for the strength of the foot plate against the planned load:

a. For X-Directional Shear Survey:

Distance of the Center of Reinforcement to the Outer Side of the Concrete : 0.075 m

Thick Effective Foot Plate : 0.225 m

Distance of Critical Field to Outer Side of Concrete : 0.363 m

From the results of the analysis of the shear foot plate review, it was found that the shear strength of the foot plate was 301.869 kN so that the value of the shear strength of the foot plate was greater than the ground shear force which was 11.073 kN, which means that it had met the requirements of the foot plate strength for the X-directional shear force.

b. For Y-Direction Shear Review:

Distance of the Center of Reinforcement to the Outer Side of the Concrete : 0.085 m

Thick Effective Foot Plate : 0.215 m

Distance of Critical Field to Outer Side of Concrete : 0.293 m

From the results of the analysis of the shear foot plate review, it was found that the shear strength of the foot plate is 288.453 kN so that the value of the shear strength of the foot plate is greater than the ground shear force which is 89.889 kN which means that it has met the requirements of the foot plate strength for the Y directional shear force.

Table 6. 2-Way Shear Review.

Gaya geser pons yang terjadi,	$V_{up} = (B_x * B_y - c_x * c_y) * [(q_{max} + q_{min}) / 2 - q] =$	284,267	kN
Luas bidang geser pons,	$A_p = 2 * (c_x + c_y) * d =$	0,464	m^2
Lebar bidang geser pons,	$b_p = 2 * (c_x + c_y) =$	2,160	m
Rasio sisi panjang thd. sisi pendek kolom,	$\beta_c = b_x / b_y =$	0,6250	
Tegangan geser pons, diambil nilai terkecil dari f_p yang diperoleh dari pers.sbb. :			
	$f_p = [1 + 2 / \beta_c] * \sqrt{f_c'} / 6 =$	3,130	MPa
	$f_p = [\alpha_s * d / b_p + 2] * \sqrt{f_c'} / 12 =$	1,858	MPa
	$f_p = 1 / 3 * \sqrt{f_c'} =$	1,491	MPa
Tegangan geser pons yang disyaratkan,	$f_p =$	1,491	MPa
Faktor reduksi kekuatan geser pons,	$\phi =$	0,75	
Kuat geser pons,	$\phi * V_{np} = \phi * A_p * f_p * 10^3 =$	519,21	kN

Syarat :	$\phi * V_{np}$	$\geq$	V_{up}		
	519,215	>	284,267	→	AMAN (OK)
	$\phi * V_{np}$	$\geq$	P_u		
	519,215	>	354,710	→	AMAN (OK)

Source : Data Analysis.

From the results of the structural analysis, it can be concluded that the distance between the reinforcement of the Ast value to the value of Ag is 0.04 which According to SNI 2847 – 2019 Article 18.7.4.1 the area of longitudinal reinforcement of Ast must not be less than 0.01 Ag or more than 0.06 Ag so that from the analysis of the structure it has met the requirements for the strength of the pedestal structure.

4. Summary of Analysis and Evaluation Results of the Lower Structure

To answer the research objectives that target the evaluation of the feasibility and safety of the lower structure, all SP Column computing outputs and geotechnical balance calculations are compiled into a proof matrix that summarizes the percentage and parameters of its pass to SNI.

Table 7. Summary of Lower Structure Strength Evaluation

(SP Column Analysis and Numerical Computing)

Structural Elements	Test Parameters	Standards / Minimum Requirements	Computational Results	Verification Status
Pedestal	Elongated Reinforcement Ratio	1% - 6% (SNI 2847-2019)	4%	Fulfilled (Optimal)
Pedestal	P-M Interaction Capacity	Pu, Mu inside the P-M curve	Inside the capacity envelope	Fulfilled (Secure)
Foot Plate	Ground Contact Voltage	> 0 kN/m2 (Anti uplift)	259,310 kN/m2	Fulfilled (Stable)
Foot Plate	Effective Thickness Plate	-	0.22 m	Proportional
Foot Plate	One-Way Swipe (X)	Vc > Vu (Vu = 11.073 kN)	Vc = 301.869 kN	Fulfilled
Foot Plate	One-Way Slide (Y)	Vc > Vu (Vu = 89.889 kN)	Vc = 288.453 kN	Fulfilled
Foot Plate	Bidirectional Pons Slide	Vc > Vu (Vu = 284.267 kN)	Vc = 519.210 kN	Fulfilled
Floor Plates	Recurrence Area (As)	Meet Structural Analysis	Built-in > Analysis Conditions	Fulfilled (Surplus)
Floor Plates	Steel Bending Tension	< 200,000 MPa	Well below the threshold	Fulfilled (Daktail)

Source : Data Analysis.

Through the above matrix, the validity of all supporting elements has been rationally and empirically confirmed to be far beyond critical conditions, thus confirming the high integrity of the design of this industrial building.

CONCLUSION

From the results of the structural analysis, conclusions can be drawn for the strength of the foot plate against the planned load: Effective Thickness of the Foot Plate: 0.22 m; Width of the Plane of the Pons Direction X : 0.465 m ; Width of Gsesr Pons Y Direction: 0.615 m. From the results of the analysis of the two-way review (pons), it was found that the shear strength of the pons was 519.21 kN so that the value of the shear force of the pons was greater than the shear force of the pons that occurred, which was 284.267 kN, which means that it has met the requirements for the strength of the foot plate for the review of the two-way shear (pons).

In the Floor Plate Repeat, the amount of reinforcement for the X and Y Directions is 66.987 mm2 D8 – 10 iron, the amount of ironing is 113 mm2 so that the number of reinforcement axles available has been above the reinforcement axles required by the structural analysis and has met the need to bear the load, strengthen the position of the main reinforcement and also as a reinforcement for the resistance of concrete cracks due to shrinkage and temperature differences of concrete. The charges that occurred were based on SNI 1727: 2013. One-way plate planning is adjusted to SNI 2847: 2013.

Pedestal Structure Strength with Elongated Repetition Ratio on a precision-measured *pedestal* element of 0.04 (4%). This figure fully complies with the SNI 2847-2019 standard Article 18.7.4.1 which requires the reinforcement ratio to be within the limit of 1% to 6%, thus ensuring an ideal cross-sectional capacity and daktail to bear the upper structure.

The strength of the Foot Plate with the contact voltage at the base of the foundation plate was validated to compress the ground massively with a minimum voltage recorded positive at 259.310 kN/m2. This ensures that there is no effect of foundation lifting (*uplift*), perfectly supporting the dynamic resistance of cigarette mill heavy equipment while preventing the risk of material dislocation.

From the results of the structural analysis, it can be concluded that the strength of the iron in resisting bending loading, the resulting bending load value is below the threshold of the bending strength of the reinforcement, which is 200,000 MPa so that it is in accordance with SNI 1726 – 2019 Structural Concrete Requirements for Buildings.

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