Redesigning The Production Warehouse and Packaging House at The Agricultural Office of The Main Hall of Food Crops and Horticultural in Banten Province

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ABSTRACT

The Banten Provincial Agriculture Office aims to repurpose an existing storage warehouse into a packaging warehouse and production facility for food products. This study focuses on assessing the structural performance of the building and determining its suitability for the new functions. Utilizing the Load and Resistance Factor Design (LRFD) method, the strength of the current structure is evaluated under the anticipated loads. The analysis reveals that while most elements of the building meet the required standards, the existing columns are unable to support the intended load. Based on calculations, the nominal compressive strength value of the existing IWF column is determined to be 202.462 kN, falling short of the required strength of 255.075 kN. To address this, a recommendation is made to reinforce the columns by wrapping their steel profiles with reinforced concrete, transforming them into composite columns with a nominal compressive strength capacity of 1678.24 kN. This reinforcement approach ensures that the building can effectively accommodate the packaging and production operations for food products. The findings of this study provide essential guidance for the Banten Provincial Agriculture Office in making informed decisions on the necessary structural improvements. By implementing the proposed reinforcement measures, the building's structural integrity is enhanced, prolonging its service life and ensuring its suitability for the intended functions.

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1. INTRODUCTION

Redesign structure was intended to produce a structure which stable, strong and capable hold burden planned.Repeated happened planning due to the change in his power is in the structure that has been is only reach years the plan or because of a change a function of the building itself. Alteration of the function the office a building archive building number of the burden of dead and the burden on so as to cause failure on some element structure.It is also caused by factors tired (fatigue) of material due to the burden on the repetitious work can cause the degradation of the power of material.[1]

The Banten Provincial Agriculture Office plans to convert the storage warehouse into a Packaging and Production House warehouse as a place for production and finishing of food products. The conversion of the building's function is aimed at supporting the program to increase surrounding agricultural output.

The storage warehouse that will be allocated needs to be re-planned to find out how much influence the performance of the structure has on the conversion of the building and to review the feasibility of the previous structural planning on the life of the building.

Redesign will be carried out due to the significant addition of live loads and dead loads, so the required structural design will be taken from the evaluation results of structural calculations in the existing conditions and then a redesign is carried out for the warehouse structure.

Changes in the function of the building will have an impact on changing the load that will work on the building, it is necessary to calculate the structure in the existing conditions and plan a new structure so that the building can stand safely. changes in the function of space at Plaza Araya from the original shops to a cinema building causes a change in the imposition of floor live loads so that it is necessary to evaluate the strength of the existing structure, evaluate the performance and strength of the structure in the existing conditions to provide alternative reinforcement solutions and determine the technical specifications of the reinforcement implementation method.[2]

The research to be carried out is to analyze the Packaging and Production House warehouses by evaluating the strength of the structure in the existing conditions, the results obtained will be a reference in planning the warehouse structure with the addition of different live loads and dead loads in the existing conditions. Based on this introduction, the formulation of the research problem is how to design a gable structure using the LRFD method and what are the differences in the dimensions of the design warehouse structure to the existing structural conditions.

Amalia et al. (2020) [3] reported the design of warehouse structural elements such as trusses, curtains, beams, columns and floor slabs. The method used is the Load Resistance and Factor Design (LRFD) method referring to SNI 1729:2002 and the Indonesian Loading Regulations for Buildings (PPIUG) 1983.

Yuliafatma (2019) [4] investigated the design of the structural elements reviewed includes the upper structure to the lower structure of the building including: trusses, gording, beams, columns, base plates, floor plates, staircase construction, steel joints and foundations. The method used is the Load Resistance and Factor Design (LRFD) method which refers to SNI 1729:2015, SNI 1727:2013, SNI 1726:2013 and SNI 2847:2013.

Yaqin et al (2021) [5] reported the design of the structural elements reviewed includes trusses, beams and columns. The method used is the Load Resistance and Factor Design (LRFD) and Allowable Strength Design (ASD) methods which refer to SNI 03-1729-2002, AISC Manual of Steel Construction 2005 and PPBBI 1984.

Aggriawan (2017) [6] reported the design of the structural elements reviewed includes curtains, beams, columns, steel joints and base plates. The method used is the Load Resistance and Factor Design (LRFD) method which refers to SNI 03-1729-2015, AISC Manual of Steel Construction 2005, AISC LRFD 1994 and PPBBI 1984.

Empung et al. (2020) [7] reported the design of the structural elements reviewed includes curtain rods, beams, columns, rafters, floor slabs, ramps, sloofs and foundations. The method used is the Load

Resistance and Factor Design (LRFD) method which refers to SNI 1729-2002, SNI 1727-2013, SNI 1726-2013 and SNI 2847-2013.

2. METHODS
2.1 THEORETICAL BASIS

Calculation analysis and planning in steel structures there are 2 methods that are usually used, these methods are the Load Factor and Resistance Design method and the Permitted Strength Design method.[8] In a comparative analysis study of the ASD and LRFD methods on gable frame structures in new market developments in Lumajang Regency, it was found that the LRFD method was more economical in its application.[9] Strength Design Based on Load and Resistance Factor Design (DFBT) or LRFD (Load and Resistance Factor Design) is a method in steel structure planning based on probability theory of load and resistance.[10]

The value of the design tensile resistance of a tensile member is determined based on the lowest value of the two types of failure conditions of the tensile member[11].

$$\varphi t.P_n = 0{,}9 \,.\, F_y \,.\, A_g \text{ (Yield Condition)} \tag{1}$$
$$\varphi t.P_n = 0{,}75 \,.\, F_u \,.\, A_e \text{ (Fraktur Condition)} \tag{2}$$

All structural components that experience compressive forces due to factored loads must comply with the equation below[11]

$$P_n = A_g \,.\, F_{cr} \tag{3}$$

The Fcr value is determined from:

1. If $\frac{L_c}{r} \leq 4{,}71 \sqrt{\frac{E}{F_y}}$

$$F_{cr} = \left(0{,}658^{\frac{F_y}{F_e}}\right) .\, F_y \tag{4}$$

2.If $\frac{L_c}{r} > 4{,}71 \sqrt{\frac{E}{F_y}}$

$$F_{cr} = 0{,}877 .\, F_e \tag{5}$$

The design resistance of a structural member that is subjected to shear forces, both stiffened and unstiffened structures in the member web, can be calculated by the following equation[11]:

$$V_n = 0{,}6\, F_y\, A_w\, C_v \tag{6}$$

Use $C_v = 1$ for plate IWF with value $h/t_w \leq 2{,}24 \sqrt{E/F_y}$ d with $\phi_v = 1$

The nominal flexural strength of an IWF beam with bending in the direction of the strength axis is determined based on the lowest value of the yield limit condition and the lateral torsional buckling condition[11].

1. Platic Condition
   In this condition all sections of the cross-section experience yielding, where this condition is achieved in short span beams (Lb ≤ Lp)

$$M_n = M_p = F_y \,.\, Z_x \tag{7}$$

2. Lateral torsion buckling inelastic condition
   This condition will occur in beams with medium span ($Lp < Lb \leq Lr$). The value of the bending moment is determined based on the equation below:

$$M_n = C_b \left[M_p - \left(M_n - 0{,}7 F_y S_x \right) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p \quad (8)$$

The design compressive strength (φc.Pn) of a concrete-encased composite member loaded axially symmetrically shall be determined for the limit state of buckling based on the member as follows:

1. If $\frac{P_{no}}{P_e} \leq 2{,}25$

$$P_n = P_{no} \left[0{,}658^{P_{no}/P_e} \right] \quad (9)$$

2. If $\frac{P_{no}}{P_e} > 2{,}25$

$$P_n = 0{,}877\, P_e \quad (10)$$

The calculation of the flexural strength of the composite column is carried out by estimating the possible height values of the neutral line (c).[12] The probability that this will occur is as follows:

A. The neutral line (c) is above the steel profile

$$ØM_n = 0{,}9 \,.\, \left\{ C_c.\, \left(d - \frac{a}{2} \right) - T_s.\, d_1 \right\} \quad (11)$$

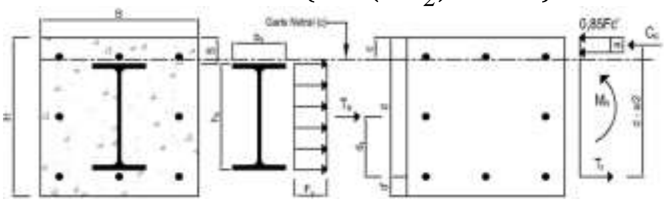

Figure 1. Possible Composite Column Neutral Line 1

B. The neutral line (c) is at the flange of the steel profile.

$$ØM_n = 0{,}9 \,.\, \left\{ C_c.\, \left(d - \frac{a}{2} \right) + C_s.\, d_2 - T_s.\, d_1 \right\} \quad (12)$$

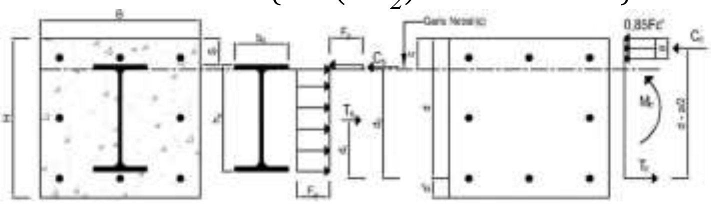

Figure 2. Possible Composite Column Neutral Line 2

C. The neutral line (c) is at the web of the steel profile.

$$ØM_n = 0{,}9 \,.\, \left\{ C_c.\, \left(d - \frac{a}{2} \right) + C_s.\, d_2 - T_s.\, d_1 \right\} \quad (13)$$

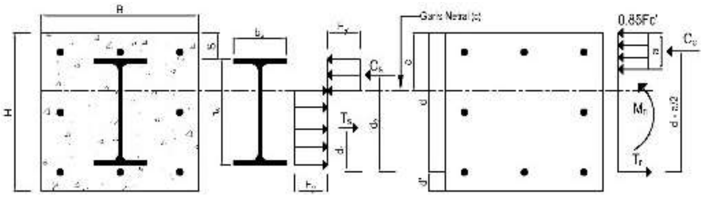

Figure 3. Possible Composite Column Neutral Line 3

The interaction of axial and bending loads in the symmetrical planes of steel components and composite structures is determined based on the following equations:

A. For $\frac{P_r}{P_c} \geq 0{,}2$

$$\frac{P_r}{P_c} + \frac{8}{9}\left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \leq 1{,}0 \quad (14)$$

B. For $\frac{P_r}{P_c} < 0{,}2$

$$\frac{P_r}{2\,P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \leq 1{,}0 \quad (15)$$

2.2 METHODOLOGY

The data needed for this research is classified into 2 types, namely primary data and secondary data. The primary data used is soil investigation data and warehouse drawings. first, land investigation using sondir and laboratory testing by PT. Geodata Mandiri for the work "Soil Investigation of Kedaireka Agrohub Untirta WP2". This is intended to obtain data on the physical properties of deep soil conditions, for the purposes of building foundation planning. Sondir testing is carried out as many as 6 (six) test points, these test points are on a predetermined building plan so that the resulting data is attached in Table 1.[13]

Table 1. Sondir Test Data

No Test Points	Depth (m)	qc (kg/cm^2)
TS1	4,20	qc > 200 kg/cm^2
TS2	3,80	qc > 200 kg/cm^2
TS3	4,00	qc > 200 kg/cm^2
TS4	4,60	qc > 200 kg/cm^2
TS5	2,00	qc > 200 kg/cm^2
TS6	3,00	qc > 200 kg/cm^2

The second primary data is testing the bulk density of the soil. Unit weight is the ratio of the weight of dry soil to a volume of soil including the pore volume of the soil, and is expressed in grams/cm^3, the results of testing the soil density in samples BH1 = 1.71 gram/cm^3 and BH2 = 1.54 gram/cm^3.

Table 2. Classification of Soil Based on the Value of Fill Weight

Unit Weight (g/cm^3)	Texture Class
1,0 – 1,6	Clay, dusty clay
1,2 – 1,8	Sand, loamy sand, sandy loam

As for the secondary data used for this research include, the research location was in Drangong, Kec. Takakan, Serang City with reference to the regulations that apply among them:

A. SNI 1727:2020 (Minimum design loads and related criteria for buildings and other structures [14]
B. SNI 1726:2019 (Procedures for earthquake resistance for building and non-building structures [15]

C. SNI 1729:2020 (Specifications for structural steel buildings)[11]
D. SNI 2847:2019 (Structural concrete requirements for buildings and explanations)[16]

3.1 STRUCTURE LOADING

A. Dead Load And Live Load
   1. Confcrete Reinforcement = 24 kN/m^3
   2. Steel Structure = 78,5 kN/m^3
   3. Brick Wall = 2,5 kN/m^2
   4. Alluminium Composit Panel = 1,4 kN/m^2
   5. Stone Wall Architect = 0,26 kN/m^2

B. Live Load
   1. Warehouse = 11,97 kN/m^2
   2. Office = 2,4 kN/m^2
   3. Warehouse Roof = 0,96 kN/m^2
   4. Canopy Roof = 0,24 kN/m^2

C. Wind Load
   Some of the basic parameters required for inputting wind loads into the program include the following:
   1. Basic Wind Speed (V) =32 m/s
   2. Wind Direction Factor (Kd) = 0,85
   3. Exposure Category = Category B
   4. Topographical Factor (Kzt) = 1,00
   5. Wind Blow Factor = 0,85
   6. Elevation Factor (Ke) = 1,00

   The results obtained for the wind load value in both the x and y directions are as follows:

Table 3. wind load values

Story	Px (kN)	Py (kN)	Story	Px (kN)	Py (kN)
Story 15	-0,003	-0,004	Story 7	-0,588	-0,726
Story 11	0,000	0,000	Story 6	-0,662	-0,816
Story 10	-5,593	-6,884	Story 2	-10,951	-13,479
Story 9	-0,863	-1,063	Story 1	-10,951	-13,479
Story 8	-0,589	-0,727			

D. Earthquake Load
   1. Spectrum response input

$$T_0 = 0{,}2\ \frac{S_{D1}}{S_{DS}} = \frac{0{,}546}{0{,}678} = 0{,}161\ s$$

$$T_1 = \frac{S_{D1}}{S_{DS}} = \frac{0{,}546}{0{,}678} = 0{,}805\ s$$

$$T_L = 20\ s$$

Table 4. Input Response Spectrum

T (s)	Sa (g)	T (s)	Sa (g)	T (s)	Sa (g)	T (s)	Sa (g)
0,005	0,397	0,805	0,678	0,261	0,678	4,805	0,114
0,100	0,524	1,805	0,302	0,361	0,678	5,805	0,094
0,150	0,650	2,805	0,195	0,461	0,678	20,000	0,027
0,161	0,678	3,805	0,143	0,561	0,678	20,500	0,026

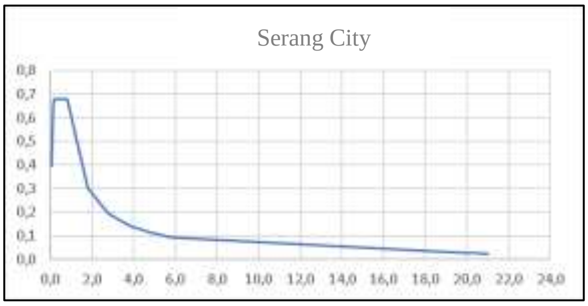

Figure 4. Spectrum Response Graph

2. Dynamic seismic force scale factor
   G = 9810 mm/s^2
   I = 1,00 (kategori risiko I)
   R = 8,00
   Faktor skala = $\frac{g.\,I}{R} = \frac{9810.\,1}{8}$
   =1226,25
3. Design seismic shear force

Table 5. Design Shear Force

Story	Vx (kN)	Vy (kN)	Story	Vx (kN)	Vy (kN)
Story 17	0,000	0,000	Story 8	51,727	38,308
Story 16	0,000	0,000	Story 7	308,400	81,636
Story 15	3,405	2,665	Story 6	258,599	196,537
Story 14	0,000	0,000	Story 5	0,000	0,000
Story 13	0,000	0,000	Story 4	0,000	0,000
Story 12	0,000	0,000	Story 3	0,000	0,000
Story 11	0,105	0,106	Story 2	246,951	222,892
Story 10	41,886	31,431	Story 1	248,092	223,854
Story 9	85,005	18,096			

E. Load combination
1. 1,4 D
2. 1,2 D + 1,6 L + 0,5 (L_r atau R)
3. 1,2 D + 1,6 (L_r atau R) + (1,0 L atau 0,5 $W_{x/y}$)
4. 1,2 D + 1,0 $W_{x/y}$ + 1,0 L + 0,5 (L_r atau R)
5. 0,9 D + 1,0 $W_{x/y}$
6. (1,2 + 0,2SDS) D ± 1,0 $\rho E_{x/y}$ + 1,0 L
7. (0,9 – 0,2SDS) D ± 1,0 $\rho E_{x/y}$

3.2 STRUCTURAL ANALYSIS

Structural analysis was carried out using the ETABS 2017 program to produce the output of the forces on the structural elements as follows:

Table 6. Value of Internal Forces

Element	**Forces**	**Load Combination / *Load Case***	**Length (mm)**	**Value**
Gording	M_{ux}	Comb 3-1	4000	6,935 kN.m
	M_{uy}	Comb 3-1	4000	1,625 kN.m
	V_u	Comb 3-2	4000	8,891 kN
Rafter	P_u	Comb 3-3	1139,5	176,580 kN
	V_u	Comb 6-1	1139,5	13,683 kN
	M_{ux}	Comb 6-1	1139,5	9,521 kN.m
	M_{uy}	Comb 6-5	1139,5	0,143 kN.m
Beam	V_u	Comb 6-1	4800	69,876 kN
	M_{ux}	Comb 6-1	4800	23,641kN.m
Column	P_u	Comb 3-2	3450	255,075 kN
	V_u	Comb 6-1	3450	19,120 kN
	M_{ux}	Comb 6-1	3450	34,749 kN.m
	M_{uy}	Comb 6-5	3450	20,557 kN.m
Sloof	V_u	Comb 1	4800	64,800 kN
	M_u	Comb 1	4800	51,838 kN.m

Table 7. Value of the Forces in the Pedestal Column

Kondisi	Jenis Gaya	Beban Kombinasi /*Load Case*	Nilai Gaya
P_{maks}	P_u	RSX	23,261 kN
	M_{ux}		33,908 kN.m
	M_{uy}		0,144 kN.m
P_{min}	P_u	Comb 3-2	-263,940 kN
	M_{ux}		-0,757 kN.m
	M_{uy}		0,058 kN.m
$M_{y,maks}$	P_u	Comb 6-5	-91,835 kN
	M_{ux}		17,022 kN.m
	M_{uy}		52,907 kN.m
$M_{y,min}$	P_u	Comb 6-5	-181,909 kN
	M_{ux}		-18,284 kN.m
	M_{uy}		-58,137 kN.m
$M_{x,maks}$	P_u	Comb 6-1	-190,802 kN
	M_{ux}		62,520 kN.m
	M_{uy}		15,530 kN.m
$M_{x,min}$	P_u	Comb 6-1	-206,093 kN
	M_{ux}		-62,503 kN.m
	M_{uy}		-15,778 kN.m
$V_{u,Tumpuan}$	V_{ux}	Comb 6-5	34,700 kN
	V_{uy}	Comb 6-1	25,683 kN
$V_{u,Lapangan}$	V_{ux}	Comb 6-5	34,700 kN
	V_{uy}	Comb 6-1	25,683 kN

3.3 STRUCTURAL ELEMENT DESIGN

Based on the calculations that have been done, the value of the structural capacity of each steel structure element is obtained as follows:

Table 8. Value of Structure Capacity

Value of Structure Capacity		Information
Gording CNP – 100.50.5.7,5		
φVn	64,80 kN	-
φMnx	7,16 kN.m	Yield Condition
φMny	3,46 kN.m	Yield Condition
Rafter IWF – 150.75.5.7		
φPn	324,673 kN	Inelastic Bending
φVn	97,20 kN	-
φMnx	22,12 kN.m	Yield Condition
φMny	4,49 kN.m	Yield Condition
Beam IWF – 150.100.6.9		
φVn	116,64 kN	-
φMnx	33,93 kN.m	Yield Condition
φMny	10,04 kN.m	Yield Condition
φPn	202,462 kN	Elastic Bending
φVn	142,56 kN	-
φMnx	45,58 kN.m	Yield Condition
φMny	9,07 kN.m	Yield Condition
Column Composite 300x300 IWF - 200.100.5,5.8		
φPn	1678,24 kN	-
φVn	142,56 kN	-
φMnx	160,35 kN.m	Neutral Line On Steel Profile Body
φMny	114,63 kN.m	Neutral Line On Steel Profile Body

Table 9. Connection Structure Capacity Values

	Capacity Values	Vu / Tu
Connection Between *Rafter* 1		
Tensile strength, φTn	61745,36 N	576,07 N
Shear strength, φVn	37047,21 N	84,89 N
Bearing strength, φRn	139860 N	84,89 N
Combined tensile & shear, φRn	61745,36 N	576,07 N
Connection *Rafter* 2		
Shear strength, φVn	109008,96 N	9473,10 N
Connection *Rafter* 3		
Tensile strength, φTn	61745,36 N	27699,38 N
Shear strength, φVn	37047,21 N	6988 N
Bearing strength, φRn	59940 N	6988 N
Combined tensile & shear, φRn	61745,36 N	27699,38 N
Connection *Rafter* - Column		

Tensile strength, φTn	61745,36 N	2979,77 N
Shear strength, φVn	37047,21 N	556,77 N
Bearing strength, φRn	77920 N	556,77 N
Combined tensile & shear, φRn	61745,36 N	2979,77 N
Connection Column – Beam		
Tensile strength, φTn	61745,36 N	27699,38 N
Shear strength, φVn	37047,21 N	6988 N
Bearing strength, φRn	59940 N	6988 N
Combined tensile & shear, φRn	61745,36 N	27699,38 N

3.4 Comparison of results between the design warehouse and the existing warehouse

The following is a comparison between the manual calculation results and the 2017 ETABS program

Table 10. Comparison of Structure Capacity Values

	Structure Capacity	**Structure Capacity Program**
Gording CNP – 100.50.5.7,5		
φVn	64,80 kN	64,80 kN
φMnx	7,16 kN.m	7,16 kN.m
φMny	3,46 kN.m	3,07 kN.m
Rafter IWF – 150.75.5.7		
φPn	324,673 kN	326,967kN
φVn	97,20 kN	97,20 kN
φMnx	22,12 kN.m	22,12 kN.m
φMny	4,49 kN.m	4,50 kN.m
Beam IWF – 150.100.6.9		
φVn	116,64 kN	116,64 kN
φMnx	33,93 kN.m	33,94 kN.m
φMny	10,04 kN.m	10,05 kN.m
Column IWF - 200.100.5,5.8		
φPn	202,462 kN	210,42 kN
φVn	142,56 kN	142,56 kN
φMnx	45,58 kN.m	45,57 kN.m
φMny	9,07 kN.m	9,08 kN.m
Composite Column 300x300 IWF - 200.100.5,5.8		
φPn	1678,24 kN	1680,63 kN
φVn	142,56 kN	142,56 kN
φMnx	160,35 kN.m	161,90 kN.m
φMny	114,63 kN.m	116,55kN.m

4. CONCLUSION AND SUGGESTION

Based on the results of the calculation of the steel structure of the Packaging Warehouse and Production House, the following conclusions are obtained:

a. The structural strength values of all existing building elements have met the requirements except for the existing column which is unable to carry the required load.
b. The nominal compressive strength value of the existing column obtained based on the calculation is 202.462 kN. This value is far from the required compressive strength, which is 255.075 kN. Therefore, it is necessary to strengthen the column to carry the required compressive strength.
c. Alternative reinforcement with composite columns obtained a nominal compressive strength capacity value of 1678.24 kN. This value already exceeds the required compressive strength.

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