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Comparative Analysis of Reinforcement Efficiency in Beams and Columns for the North Minahasa-North Sulawesi Civil Servants Flats Project

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A R T I C L E I N F O

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A B S T R A C T

This study aims to (1) compare the reinforcement from the calculation of beams and columns with the reinforcement installed in the North Minahasa Civil servantsFlats Project, (2) to analyze whether the reinforcement installed in the North Minahasa Civil servantsFlats Project is economical or not. This research was conducted in the Department of Engineering at the Manado State Polytechnic. The method used in this research is quantitative with the method of observation. The material and structural data used are the same as those in the project. The results of this study were carried out with the help of the Etabsv20 program. Based on the results of the reinforcement calculations that have been carried out, the comparison of the area of reinforcement (AS) for columns and beams between the results of ETABS and the results of the area of reinforcement installed in the project is obtained which is then converted in percentage form. In the beam, the largest percentage ratio is in the upper support area by 60% and in the plane located in the lower plane by 60%. While in the comparison column the percentage of reinforcement column (AS) from the project with the largest ETABS result is 40%

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INTRODUCTION

The construction of Civil servantsFlats is currently being intensified by the government, specifically by the Ministry of Public Works and Public Housing (PUPR) through the Directorate General of Housing Provision to increase the availability of decent housing. The limitation of land makes it difficult for Civil servantsto find suitable living spaces, and the increasing population each year drives up the cost of housing for Civil Servants. Consequently, the Civil servantsFlats were built by the Ministry of Public Works and Public Housing. In this construction process, proper planning and application methods are necessary to achieve the planned design. In Indonesia, regulations regarding Flats are governed by Law Number 11 of 2011, and for Flats Management, there are provisions in PP 13 of 2021.

Structural planning is a crucial element in constructing a building to ensure it is sturdy, safe, and economical. Overall, the structure of a building consists of two parts: 1) Upper Structure: Includes floors, beams, columns, shear walls (structural walls), and roofs, 1) Lower Structure: Comprises the foundation (Liando, 2020). The selection of a high-rise building structural system is not only based on understanding the structure in its context, but rather on functional factors, related to cultural, social, economic and technological needs. In a structural system, the structural elements have a mechanism for distributing loads from above to the ground (foundation system)(Rusalim et al., 2024).

To support user safety in buildings, structural elements must be precisely planned. Inadequate planning can lead to building failures. When constructing a building, an assessment of construction feasibility must be conducted. Building feasibility is reviewed from a security perspective, meaning that planning must create a building structure that guarantees strength while also considering cost and economic factors (Hutabarat et al., 2015). In designing multi-storey building structures, there are main principles that must be considered, namely increasing the strength of the structure against lateral forces by analyzing and designing reinforced concrete structures.(Anggraini et al., 2024)

LITERATURE REVIEW

The structure of columns and beams forms the framework of a building. Therefore, it is crucial to consider all factors that can affect their safety, including issues related to reinforcement in columns and beams (Nabilah & Zev Aljauhari, 2022). Proper and economical reinforcement must be carefully planned to prevent wastage.

METHODOLOGY

The building structure selected as the research subject is located in the North Minahasa Civil servantsFlats Development Project. The construction site of these flats is situated in Suwaan Village, Kalawat District, North Minahasa Regency, North Sulawesi. The research period was from

The research method used is a type of quantitative research method with direct observation methods from references and books. In general, to calculate a job, primary data is needed directly from the project and secondary data from related agencies such as work drawings and also project specification data.

The steps in this research can be seen as shown in the image below:

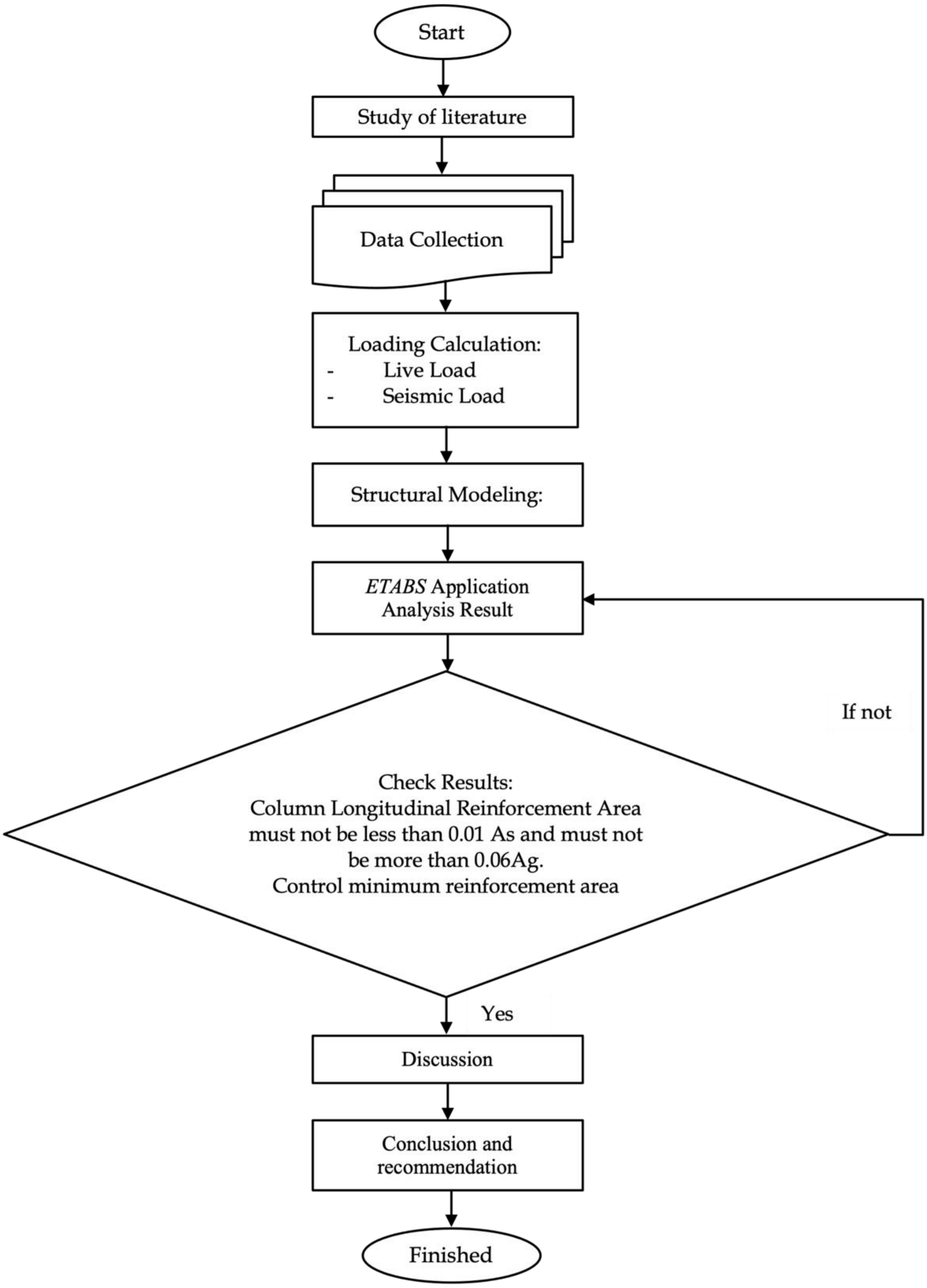

Figure 1. Research Flow Chart

Steps to Use the Etabs Program

1. Open the Etabs v20 application

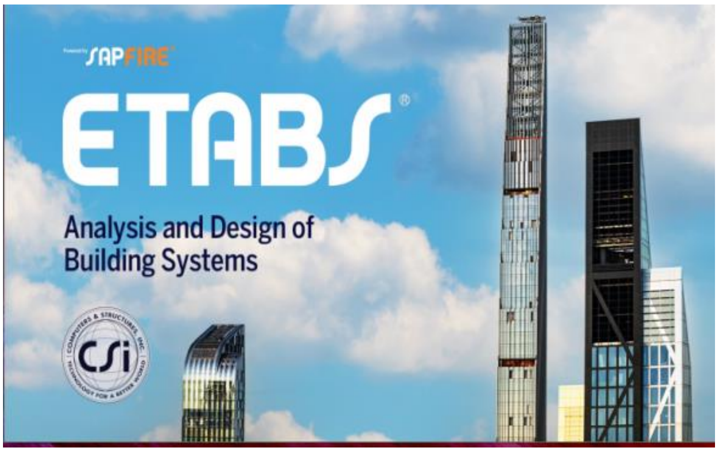

Figure 2. Initial View of Etabs v20

2. If you want to start modeling, click new model then click Use Built Settings With. And set according to below
3. Create structural modeling.
4. Editing Data Grids
5. The results of filling in the grid and story as in Figure 3.3 will be symmetrical, so to change the "Grid Data and "Story Data" according to the work drawing, the following steps are used:
   - Right click on etabs select edit grid data, then enter the building grid data that will be used.
   - Input the data grid in the x-x direction (X Grid Data) and the data grid in the y-y direction (Y Grid Data) according to the work drawing to make it easier to depict structural elements later.

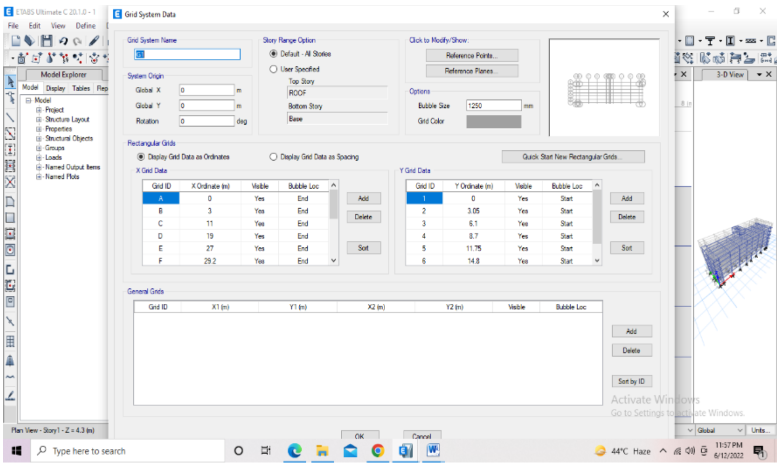
Figure 3. Data System Grid Filling

   - Sedangkan untuk mengubah st]ory data klik kanan, pilih Edit Story Data maka akan muncul boxes Story Data. Ganti ketinggian pada tiap lantai sesuai dengan gambar kerja.

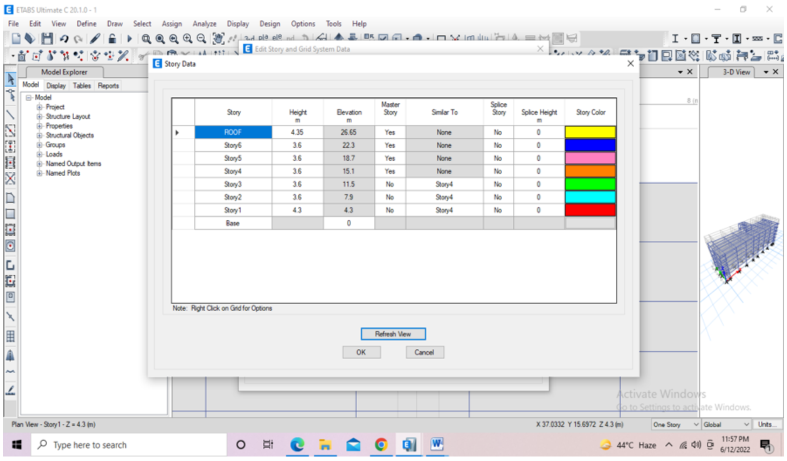

Figure 4. Input Story Data

1. Input Material Data
   a. Filling Concrete Material
      - Define > material > select add new material
      - Change the region to user and the material type to concrete then click OK
      - Material Property data > change the material name to Fc' 30 (quality of concrete used) > set the modulus of elasticity based on SNI 2847:2019 $4700*\sqrt{f'c}$ ($4700*\sqrt{30}$ = 25742.96 Mpa.
      - Click modify/show/material property design data > fill in the specified concrete compressive strength, f'c with the quality of concrete used.
   b. Filling Steel for reinforcement
      - Define > material > select code A615Gr60
      - Modify/show material> set the modulus of elasticity based on SNI 2847:2019, namely 200000 MPa.
      - Click modify/show/material property design data > input steel quality (can be seen in table 6. Mechanical Properties in SNI 2052-2017 Steel Reinforcement.
      - Make material for threaded reinforcing steel, namely BJTS 400 and BJTP 240 for plain reinforcement.
2. Make a cross-section
   a. Column Cross-section
      - Define> Section Properties> Frame Section > add new property
      - Choose rectangular concrete in the shape type because the cross-section to be made is concrete.
      - Input cross-sectional data according to size
      - Select concrete reinforcement > column (P-M2-M3 design) in design type
      - Arrange the rebar material, namely rebar 1 (BJTS 400) on the longitudinal bars and rebar 2 (BJTS 240) on the confinement bars (ties).
      - Arrange the concrete cover on the concrete cover to longitudinal rebar center
      - Set the number of reinforcement, reinforcement diameter, and reinforcement distance then select the reinforcement to be designed
      - Select modifies/show to set the moment of inertia to 0.7
      - OK

b. Making Blocks
- Define > Section Properties > Frame Section > add new property
- Choose rectangular concrete in the shape type because the cross-section to be made is concrete
- Input cross-sectional data according to the dimensions in the project
- Select concrete reinforcement > beam (M3 design only) in design type
- Arrange the rebar material, namely rebar 1 (BJTS 400) on the longitudinal bars and rebar 2 (BJTS 240) on the confinement bars (ties).
- Arrange the concrete cover on the concrete cover to longitudinal rebar center
- Select modifies/show to set the moment of inertia to 0.35 then OK

c. Making Plates
- Define > Section Properties > Slab Section > add new property
- Input cross-sectional data, select the slab type and fill in the thickness of the slab at thinness, namely 130 mm
- Select modify show to enter a moment of inertia of 0.25
- OK
- Repeat these steps to make plates with plate thicknesses of 150 mm and 200 mm.

d. Making a Shear Wall
- Define > Section Properties > Wall Section > add new property
- Input cross-sectional data, select the slab type and enter the size of the shear wall thickness at thinckness, namely 200 mm
- Select modify show to enter a moment of inertia of 0.7
- OK

3. Drawing cross-sections of structural elements

a. Column Element
- Click Crete Column in Region in the menu bar on the left of the window or you can click the column icon, then the Properties of Object box will appear, then in Property select the type of column to be used.
- Draw column elements at the designed grid points until all column elements are drawn.

b. Beam Elements
- Click Draw Line in the menu bar on the left of the window, then the Properties of Object box will appear, then in Type of Line select Frame, in Property select the type of beam to be used.
- Draw the beam elements at the grid points that are designed by clicking from joint to joint (where the beam meets the column) or according to the design length of the beam (one span cannot be drawn directly, for example from axles A to B) until all beam elements are drawn.

c. Plate Elements
- Click Draw Rectangular Area in the menu bar on the left then the Properties of Object box will appear, then in Property select PLATE, which will be drawn.
- Draw the floor plate by creating areas on the floor plate according to the plan.

d. Sliding Wall Elements (Shearwall)
- click this icon to model the shear wall

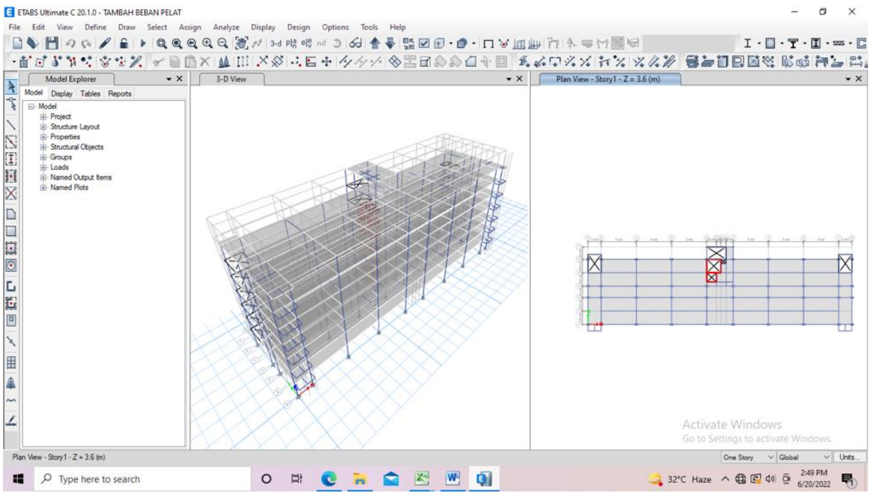

Figure 5. Modeling of Beam, Column, Plate and Shearwall Structural Elements

4. Create load patterns

Modeling of Beam, Column, Plate and Shearwall Structural Elements

5. Making Mass Source
   - Define > mass source > modify / show mass source > specified > load patterns
   - Select dead loaded pattern and multipler 1 > add
   - Select live in Load Pattern and multipler 0.25 > add
   - Uncheck the Self Element option Mass and Additional Mass
   - Checklist Specified Load Patterns
   - OK
6. Input additional dead load on slabs and beams
   - Select the plate that will be filled with the load by Select > Properties > Slab Section > select plate > Select > Close
   - Then click Assign > Shell Loads > Uniforms > Load Patterns Name , select Dead > enter load > replace existing load s > O K
   - Select the beam that will be loaded by selecting > Properties > Frame Section > select block > Select > Close
   - Then click Assign > Frames Loads > Distributed > Load Patterns Name , select Dead > enter load > replace existing load s > OK
7. Reduces live load
   - Design > Live Load Factor Reduction > select Tributare Area (Based on Design Code) > OK
8. Create load combinations
   - Define > load combinations > add new combo > enter the loading combination in Factor Scale > add > Ok
9. Make a Layout
   - Navigate to the bottom floor > the joint block that will be placed , then click assign > joints > restrains > select clamp placement > OK
10. Make Diaphragms

- Select > Properties > Slab Section > select plate
- Click Assign > shell > diaphragms > D1 > Ok

11. Check models
    - Analyze > check mode l > check the list of all existing boxes > OK
12. Running Program
    - Analyze > run analyze or you can also Fn + F5

RESULT AND DISCUSSION

Type as well as quality of the construction materials used in development building This in a way concise be included as following :

- Column = Quality F'c 35 MPa
- Beam = Quality F'c 30 MPa
- Plate = Quality F'c 30 MPa
- ShearWall = Quality F'c 35 MPa
- Steel Quality = 400 MPa
- Type land = Soft

Dimensions Beam

Table 1. Dimensions Beam

ELEMENT	DIMENSIONS	
	b (mm)	h (mm)
BIX1	350	600
BIY1	400	600
B2Y1	300	450
BAX1	300	600
BAX2	300	600
BAX3	300	600

Dimensions Column

Table 2. Column Dimensions

ELEMENT	DIMENSIONS (mm)	
	b (mm)	H (mm)
K 40.80	400	800
K1A	300	500
K1B	300	500
KC	400	800
K.D	400	800
TO	400	800

Calculation of Additional Dead Load and Live Load

1. Dead Load

   Load on beam:
   - 1st floor and roof:

     (floor height – beam height) x 57.5 kg/m² (height wall)

     (3.6 m – 0.6 m) x 57.5 kg/m²= 172.5 kg/m = 1.69 k N /m

- Floors 2-6:
  (floor height – beam height) x 57.5 kg/m² (height wall)
  (3.4 m – 0.6 m) x 57.5 kg/m2 = 161 kg/m = 1.57 k N /m

Load on the plate floor :
Tiles = 24 kg/m²
Specs = 42 kg/m²
Ceiling = 20 kg/m²
ME = 25 kg/m²
Total load dead on the plate floor is 111 kg/m² or 1.11 kN /m²
Load on roof plate:
Waterproofing = 28 kg/m²
Spec = 42 kg/m²
ME = 15 kg/m²
Total load dead on the roof plate is 85 kg/m ² or 0.85 kN /m²

2. Living Burden
   Live load on the floor based on function building that is House stacking (rusun) is 1.92 kN /m² and for roof plate taken of 1 kN /m²

Earthquake Load Calculation

1. Response Spectrum Design
   Soil data taken through RSA 2019 app with enter coordinate from location North Minahasa civil servants flats which have been obtained from *Google Earth/ Maps*. Soil data assumed land soft because it's in the field No there is land data.
   Response Program 2019 Indonesia Earthquake Map Spectra
   (C) Copyright Puskim - PusGeN - ESRC, 2019-2020
   City Name: Manado
   Longitude / Longitude: 124.9504097 Degrees
   Latitude / Latitude: 1.449992 Degrees
   Site Class: SE - Soft Soil
   PGA = 0.470513 g
   PGAm = 0.592364 g
   CRs = 0.000000
   CR 1 = 0.000000
   Ss = 1.042265 g
   S1 = 0.468769 g
   TL = 12,000000 seconds
   Fa = 1.066188
   Fv = 2.262462
   SMS = 1.111250 g
   Sm 1 = 1.060572 g
   Sds = 0.740834 g
   SD 1 = 0.707048 g
   T0 = 0.190879 seconds
   Ts = 0.954395 seconds

Based on the data above so can generated chart For response spectrum taken from puskim For land soft as following:

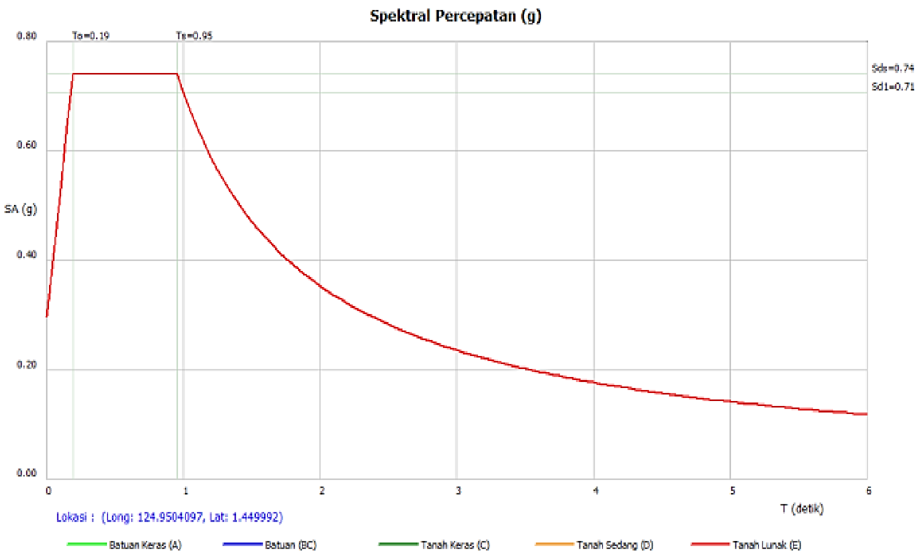

Figure 6. Design Spectrum Response

Table 3. Type structure

Type structure	Ct	x
System frame bearer moment in which the frame bear 100% of the force what seismic is required and what is not covered or connected with more components stiff and will prevent frame from deflection If charged style seismic : • Moment resisting steel frame • Moment resisting concrete frame	0.0724 0.0466	0.8 0.9
Frame steel with braces eccentric	0.0731	0.75
Frame steel with braces restrained to buckling	0.0731	0.75
All system structure other	0.0488	0.75

Source: SNI 1726-2019 Table 18

a) Period Vibrate Structure , deep Ta unit second :

Ta = Ct x hnx

= 0.04 88 x 24.2 $^{0.75}$ = 0.532 second

b) Deviation Between Levels

Because of the building House The arrangement of CIVIL SERVANTS is building House Arrange so including category risk II, with big Ie is 1 and the Cd value is 5.5.

drift condition 1 Δ = 0.0 2 x hx

= 0.010 x 3 60 0 mm

= 72 mm

2nd floor - roof drift condition

Δ = 0.0 2 x hx

= 0.0 2 x 3 400 mm

= 68 mm

Table 4. Performance Analysis Limit Service X (Δs)

Story	hi (m)	δxe (mm)	Drift X Cd Enlargement (mm)	Drift Δs between level (mm)	Condition Δm (mm)	Note
7	3.4	52,012	286,066	31.8065	68	OKAY
6	3.4	46,229	254.2595	41.9595	68	OKAY
5	3.4	38.6	212.3	48,015	68	OKAY
4	3.4	29.87	164,285	50,699	68	OKAY
3	3.4	20,652	113,586	49,335	68	OKAY
2	3.4	11,682	64,251	41,734	68	OKAY
1	3.6	4,094	22,517	22,517	72	OKAY

Table 5. Performance Analysis Limit Service Y (Δs)

Story	hi (m)	Δs (mm)	Drift Δs between level (mm)	Drift X Cd Enlargement (mm)	Condition Δm (mm)	Note
7	3.4	48,561	5,457	30.0135	68	OKAY
6	3.4	43.104	7,275	40.0125	68	OKAY
5	3.4	35,829	7,983	43.9065	68	OKAY
4	3.4	27,846	8,247	45.3585	68	OKAY
3	3.4	19,599	7,962	43,791	68	OKAY
2	3.4	11,637	6,975	38.3625	68	OKAY
1	3.6	4,662	4,662	25,641	72	OKAY

Analysis Result

Based on results analysis carried out with help *Etabs v20 software* resulting reinforcement output For columns and beams Then compared to with reinforcement contained in the project North Minahasa civil servants flats

Can concluded comparison percentage largest in the area focus on by 60% and in the field located in the field lower by 60%. Axles installed obtained from calculation amount installed reinforcement from project and from results ETABS calculations using formula :

$$=jumlah\ tulangan \times \frac{1}{4} \times 3{,}14 \times (D^2)$$

Next, do it calculation reinforcement economical For beam from the etabs output results obtained. Based on Table 7 is known more reinforcement Economical on beams and more reinforcement economical that will be it used. For election reinforcement economical on the BIY1 beam is selected reinforcement with diameter D22, beam BAX1 children use D16, BAY1 and B2Y1 blocks use D19.

Election Reinforcement Beam Parent and Child Beam

Table 6. Comparison of the Area of Internal Column Reinforcement Form Percentage

ELEMENT	FLOOR	AS INSTALLED ETABS (mm2)	AS INSTALLED PROJECT (mm2)	PERCENTAGE
K	1	4559	5319	14%
	2	4559	5319	14%
	3	4559	5319	14%
	4	4559	5319	14%
	5	4559	5319	14%
	6	4559	5319	14%

	7	7599	5319	30%
KA	1	2267	2834	20%
	2	2267	2834	20%
	3	2267	2834	20%
	4	2267	2834	20%
	5	2267	2834	20%
	6	2267	2834	20%
	7	2267	2834	20%
KB	1	2267	2834	20%
	2	2267	2834	20%
	3	2267	2834	20%
	4	2267	2834	20%
	5	2267	2834	20%
	6	2267	2834	20%
	7	3401	2834	17%
KC	1	4559	7599	40%
	2	4559	7599	40%
	3	4559	7599	40%
	4	4559	7599	40%
	5	4559	7599	40%
	6	4559	7599	40%
	7	7599	7599	0%
TO	1	4559	7599	40%
	2	4559	7599	40%
	3	4559	7599	40%
	4	4559	7599	40%
	5	4559	7599	40%
	6	4559	7599	40%
	7	7599	7599	0%

Steps Calculation Reinforcement Economical

1. **Train Column**

   Dimensions Cross-section :
   - Width (b) : 300 mm
   - Height (h): 500 mm

   Blanket concrete : 40 mm
   Reinforcement Area (As) *Etabs* = $1500mm^2$
   Diameter of reinforcement used = 16
   Reinforcement area D16 = $200.96mm^2$
   Heavy reinforcement D16 = 1.578
   Reinforcement Price = 1,578 x Rp. 15,000
   = Rp. 23,670

   Calculation Amount Reinforcement :

- Reinforcement Area = ¼ x πxD^2
  = ¼ x 3.14 x16^2
  = $200.96mm^2$

Amount need KA reinforcement $= \frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$

$= \frac{1500}{200{,}96}$

= 7.46 reinforcement

≈ 8 reinforcement

Amount reinforcement column used is multiples of 4 for reinforcement distributed to each side column, then from results calculation amount need reinforcement on obtained amount the reinforcement in the KA column is 7.46 reinforcement or rounded into 8 reinforcements

- Difference = rounding – real reinforcement
  = 8 -7.46
  = 0.54

Calculation Cost = Difference Reinforcement x Reinforcement Price
= 0.54 x Rp. 23,670
= Rp. 12,782

a. Check Dimensional Limitations (SNI 2847:2019 Article 18.6.2 and Article 9.6.1.2)
   - Dimensions smallest cross section No not enough from 300 mm

     300 = 300 mm … …… OK!

b. Check the Rebar Area Requirements Longitudinal Column

And the minimum area of reinforcement in columns in accordance with the minimum area provisions in SNI 2847:2019 Article 18.7.4.1 will be calculated as follows:

$$0{,}01\ A_g \leq A_{st} \leq 0{,}06\ A_g$$

- A_g= bxh
  = 300 mm x 500 mm
  = 150,000mm^2
- 0.01 A_g= 0.01 x 150,000mm^2
  = 1500mm^2
- 0.06 A_g = 0.06 x 150,000mm^2
  = 9000mm^2
- A_{st} = ¼ x πx D^2x Number of reinforcement
  = $1/4$ x 3.14 x 16^2x 8
  = 1608 mm^2

$$\mathbf{0,01\ A_g \leq A_{st} \leq 0,06\ A_g}$$

$$\mathbf{1500\ mm^2 \leq 1608\ mm^2 \leq 9000\ mm^2 …… OK!!}$$

c. Distance Control :

❖ Minimum Reinforcement Distance

$$= \frac{\text{lebar balok}-(2 \text{ x selimut beton})-(2 \text{ x d. sengkang})-(\text{jumlah tul. satu sisi x diameter tul})}{\text{jumlah celah}}$$

$$= \frac{300-(2 \text{ x } 40)-(2 \text{ x } 10)-(3 \text{ x } 19)}{2}$$

= 76 mm OK

If conflict distance reinforcement more big than 25 mm then stated fulfil condition distance reinforcement

❖ Control Maximum Reinforcement Distance

$=\frac{\text{tinggi balok}-(2\text{ x selimut beton})-(2\text{ x d. sengkang})-(\text{jumlah tul. satu sisi x diameter tul})}{\text{jumlah celah}}$

$=\frac{500-(2\text{ x }40)-(2\text{ x }10)-(3\text{ x }19)}{2}$

= 176 mm OK

- Check Terms

= 350 mm – diameter of reinforcement main – diameter of reinforcement stirrup

= 350 mm – 16 - 10

= 324 mm

If check condition more big than control maximum distance then fulfil condition distance maximum reinforcement .

2. Beam BIX1

Dimensions Cross-section :

- Width (b) = 350 mm
- Height (h) = 600 mm

Blanket concrete : 40 mm

Diameter of reinforcement used = 22

Area of Reinforcement D22 = ¼ x $\pi x D^2$

= ¼ x 3.14 x22^2

= 379.94mm^2

Heavy reinforcement D22 = 2.984

Price of Reinforcement = 2,984 x Rp. 15,000

= Rp. 44,760

- Reinforcement main area focus :

Reinforcement area part top = 1341mm^2

Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$

$=\frac{1341}{379.94}$

= 3.5

≈ 4 reinforcement

Difference = rounding – real reinforcement

= 4 - 3.5

= 0.5

Reinforcement area part lower = 652mm^2

Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$

$=\frac{652}{379.94}$

= 1.7 reinforcement

= 2 reinforcement

Difference = rounding – real reinforcement

= 2 - 1.7

= 0.3

Reinforcement Field

Reinforcement area part top = 652 mm^2

Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$
$=\frac{652}{379.94}$
= 1.7
≈ 2 reinforcement
Difference = rounding – real reinforcement
= 2 - 1.7
= 0.3 reinforcement
Reinforcement area part lower = 652mm^2
Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$
$=\frac{652}{379.94}$
= 1.7 reinforcement
= 2 reinforcement
Difference = rounding – real reinforcement
= 2 - 1.7
= 0.3
Total Difference = 0.5 + 0.3 + 0.3 + 0.3
= 1.4 reinforcement
Calculation Cost = Total Difference x Reinforcement Price
= 1.4 x Rp. 44,760
= Rp. 62,664

a. Check terms limitation dimensions beam (SNI 2847:2019 Article 18.6.2)
   - ❖ Ln > 4d = 7200 > 4 (536) = 7200 > 2144 ….. OK!
   - ❖ Bw ≥ 0.3h and 250 mm = 300 ≥ 250 mm ….. OK!
   - ❖ B ≥ 250 mm …………………………… ….. … OK !
b. Check the Minimum Reinforcement Area Requirements for Beam (SNI 2847:2019 Article 9.6.1.2)

ρ min $=\frac{1.4}{\text{fy}}$
$=\frac{1.4}{400}$
= 0.0035
Used ρ min = <u>0.0035</u>
As min= ρ min xbxd
As min = 0.0035 x 350 x 536 = 656.6mm^2
Control As min terms :

a. $\frac{0.25\sqrt{f'c}}{fy}bwd$ = $\frac{0.25\sqrt{30}}{400}$ 350×536 = 642 OK!
b. $\frac{1{,}4}{\text{fy}}bwd$ = $\frac{1{,}4}{400}$ 350×536 = 656 .6 OK!

If As min is more big or The same with control condition As min points a and b then the result is OK
3. BAY1 Beam
Dimensions Cross-section :
- Width (b) = 250 mm
- Height (h) = 400 mm

Blanket concrete : 40 mm
Diameter of reinforcement used = 16
Area of Reinforcement D16 = ¼ x $\pi x D^2$
= ¼ x 3.14 x16^2
= 200.96mm^2
Heavy reinforcement D16 = 1.578 (see Table 2.2)
Price of Reinforcement = 1,578 x Rp. 15,000
= Rp. 23,670 (see Table 2.3)

Reinforcement main area focus :

Reinforcement area part top = 293mm^2
Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$
$=\frac{293}{200{,}96}$
= 1.5
≈ 2 reinforcement
Difference = rounding – real reinforcement
= 2 - 1.5
= 0.5
Reinforcement area part lower = 293mm^2
Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$
$=\frac{293}{200{,}96}$
= 1.5 reinforcement
= 0.5 reinforcement
Difference = rounding – real reinforcement
= 2 - 1.5
= 0.5

Reinforcement Field

Reinforcement area part top = 293mm^2
Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$
$=\frac{293}{200{,}96}$
= 1.5
≈ 2 reinforcement
Difference = rounding – real reinforcement
= 2 - 1.5
= 0.5
Reinforcement area part lower = 293mm^2
Amount need reinforcement beam $=\frac{\text{luas tulangan (AS)Etabs}}{\text{luas tulangan}}$
$=\frac{293}{200{,}96}$
= 1.5
≈ 2 reinforcement
Difference = rounding – real reinforcement
= 2 - 1.5
= 0.5
Total Difference = 0.5 + 0 .5 + 0.5 + 0.5

= 2 reinforcement

Calculation Cost = Total Difference x Reinforcement Price
= 2 x Rp. 23,670
= Rp. 47,340

c. Check terms limitation dimensions beam (SNI 2847:2019 Article 18.6.2)
   - Ln > 4d = 2250 > 4 (342) = 2250 > 1368 ….. OK!
   - Bw ≥ 0.3h and 250 mm = 250 ≥ 250 mm ….. OK!
   - B ≥ 250 mm …………………………… ….. … OK !

d. Check the Minimum Reinforcement Area Requirements for Beam (SNI 2847:2019 Article 9.6.1.2)

$$\rho \text{ min } = \frac{1.4}{\text{fy}}$$

$$= \frac{1.4}{400}$$

$$= 0.0035$$

Used ρ min = <u>0.0035</u>

As min= ρ min xbxd

As min = 0.0035 x 250 x 342 = 299.25mm^2

Control As min terms :

a. $\frac{0.25\sqrt{f'c}}{fy}bwd$ = $\frac{0.25\sqrt{30}}{400}$ $250\ x\ 342$ = 292 .68 OK!

b. $\frac{1,4}{\text{fy}}bwd$ = $\frac{1,4}{400}$ $250\ x\ 342$ = 299 .25 OK!

If As min is more big or The same with control condition As min points a and b then the result is OK

CONCLUSION AND RECOMENDATION

1. Based on results calculation existing reinforcement done obtained comparison wide reinforcement (AS) of columns and beams between ETABS results with results wide reinforcement installed in later projects converted in form percentage. On the beam comparison percentage largest in the area focus on by 60% and in the field located in the field lower by 60%. Meanwhile in column comparison percentage wide reinforcement (AS) column from project with results ETABS biggest namely 40%.
2. Based on from results calculations that have been made done For calculation reinforcement economical so obtained that calculated reinforcement from ETABS the result more economical compared to with from project.

FURTHER STUDY

This research still has related limitations, so further research needs to be carried out on the topic Comparative Analysis of Reinforcement Efficiency in Beams and Columns in order to perfect this research and increase insight for readers.

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