Floor Slab Analysis (Case Study: One Residence Apartment Batam Center)

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Abstract. Reinforced concrete slab are widely used in civil buildings, including as building floors, roof floors, bridge floors and dock floors. The load acting on the slab is generally calculated against gravitational loads. This study aims to analyse floor slab in One Residence Batam Center Apartment Construction Project. The moment method is used to predict the magnitude of frame and shrinkage values that refer to 2002 of SNI. Loading is carried out from dead loads and live loads with a two-way reinforcement system. Reinforcement is done using steel with a diameter of 10 mm. So that the minimum area is 313 mm square with a distance of 250 mm and is in the safe category. From the calculation results obtained the concrete elastic modulus obtained by 250 MPa with a reinforcement ratio of 0.0025. Checking the time dependency factor for dead loads is carried out within 3 months, 6 months, 12 months and more than 5 years. Long-term deflection due to frame and shrinkage is still in the safe category.

1. Introduction
In the structure of buildings generally composed of several components including roof slab, floor slab, beams and columns which are one unit of monolith in the print system in place or arranged like a precast system. The slab is a rigid planar structure made of monolith material with a small height compared to other dimensions. To plan a slab it is necessary to consider the loading, size and the requirements of the existing regulations [1]. In the construction of reinforced concrete, the thickness of the slab area is relatively very small when compared to the long span / width of the field. This concrete slab is very stiff and the direction is horizontal, so that in the building, this slab functions as a diaphragm / horizontal stiffening element which are very useful to support the rigidity of the portal beam [2]. To plan reinforced concrete slab, it is necessary to consider loading and type of placement and type of connector in the support [3]. The stiffness of the relationship between the slab and the pedestal will determine the amount of bending moment that occurs on the slab. The slab is usually supported by reinforced concrete beams that allow one-way or two-way reinforcement depending on the structural system. If the value comparison between the length and width of the slab is more than 2, then one-way slab is used but if the value of the slab comparison is not more than 2, then a two-way slab is used.

When a cold wave occurs during construction, the surface and center temperature of the face slabs continually drop with the outside air temperature. A stringer heat preservation result in smaller tensile stress and an increase in the amplitude of face slab [4]. Using the verified numerical model, the influence of slenderness ratio, axial compression ratio, steel ratio of column, cross-section moment
resistance of I-shaped steel in beam, the ultimate horizontal load decrease with the increase of column slenderness ratio, and firstly increases then decreases with the increase of axial compression ratio [5].

The linear and nonlinear responses of steel buildings with perimeter resisting frames (PMRFs) are estimated and compared to those of equivalent buildings with spatial moment resisting frames (SMRFs). The seismic performance of the steel buildings with SMRFs may be superior to that of steel buildings with PMFRs [6]. Based on the experimental results of compressive strength, prediction model were developed using regression analysis with value of the coefficient of torsional stiffness reduction for verification of the serviceability limit state (SLS) with assumption of normal probability distributed is determined [7,8].

Several models with different shapes and dimension for single piles and different properties for two soil layer with variables thickness were selected and analyzed using the finite difference method. The pile head displacement occurs due to pile’s deformation and rotation. Deformation causes internal forces in pile, though rotation induces stress in surrounding soil [4]. The CFRP plate is more effective than steel plate in increasing the load capacity of beams [9]. Beams specimens made of similar concrete mixture with the same geometry were tested under three point static loading and low velocity drop weight impact loading [10,12]. Model and time history analyses are applied regarding the code specific design, location of the first failure of columns were transmitted to the upper/less-critical stories of the frame [11].

Shrinkage is a change in the length of the test object over a period of time, where the change in length is caused not because of an external force but due to evaporation. A frame is a property where the concrete undergoes a permanent change in shape due to the fixed load acting on it [13, 14]. This happens because the intensity decreases for a certain interval of time and may end after several years. The amount of frame deformation is proportional to the magnitude of the load held and the period of loading. Shrinkage and frame cause a period change in pre stressed concrete. This change slows down and eventually stops after several years [1, 15]. Changes in these stresses result in changes in pre stressed concrete forces and can be calculated for their time effects on changes in shape such as a shortening and deflection in concrete. Following what above mentioned, this article aims at showing the analysis of floor slab based in slab reinforcement system. Checking the time dependency for loading for several times and the long term deflection due to the biggest frame and shrinkage falls into the safe category.

2. Floor Slab
The floor slab is a thin structure that is given reinforcement and mortar which is designed according to plan to be able to carry the load on it. This concrete slab consists of two types, one-way slab and two-way slabs. In general the calculation of the slab is based in the following criteria:

2.1. Loading
The loads on the floor slab structure can be divided into 3 main categories, namely:

1. Dead load is a large load and the location remains the same during the working period of the structure. Usually most of the dead load consists of the weight of the structure which can be calculated with good determination of the planning configuration and dimensions. The loading in this section is the same as the beam, referring to the 1987 SKBI.

\[ W_u = 1.2 \ DL + 1.6 \ LL \] (1)

Provided that the weight of reinforced concrete is 2400 Kg/m³, the weight of the floor cover of the tile without stirring: 24 Kg/m³, the weight of the specimen mix per cm (thick): 21 Kg/m³, ceiling (including the ribs, without hangers, ceiling or stiffener) with a maximum thickness of 4 mm: 11 Kg/m³, hanging ceiling (from wood) with a maximum span of 5 m and a minimum distance of 0.8 m: 7 Kg/m³.

2. Life load are the burden of a main building which consists of the burden of human beings who fill it and move it on it. These loads work in full or in part or are totally non-existent and the
(3) Natural load mainly consists of snow load, wind pressure and pull, earthquake load, soil pressure on the part of the structure that is in the ground, loads due to the presence of a pool of water or rainwater on a flat roof and the forces that arise because of the temperature difference. Lots of information about some of the natural burdens that are often modified based on local circumstances. Suppose it depends on the climate or about the earthquake conditions that have occurred somewhere.

2.2. Slab Reinforcement System

The slab reinforcement planning system is basically divided into 2 (two), namely:

(1) One-Way Slab, namely plate planning system with one-way staple.

Characteristics of One-Way Slab: build up occurs on the side facing each other with \( L_x / L_y > 2 \), the one-way slab design is the same as reinforcement on the beam, only on the floor slab there are no shear reinforcement. The moment distribution on a one-way floor slab can be searched by means of the moment coefficient (analytical) with the requirement that minimum consists of 2 spans with side-to-side lengths and the largest spans should not be greater than 1.2 the shortest spans and loads must be evenly distributed and live loads smaller than 3 times dead load.

(2) Two-Way Slab namely plate planning systems with two-way staples.

Characteristics of Two-Way Slab: the main reinforcement is installed in 2 perpendicular ways, the side support with a comparison between the sides of the slab length and the width side is \( L_y / L_x \leq 2 \) with a slab thickness of 2 ways in accordance with SK-SNI T-15-1991-03. So that it is obtained:

\[
 h = \frac{\ln \left( \frac{0.8 + f_y}{1500} \right)}{36 + 5\beta \left( \alpha m - 0.12 \left( 1 + \frac{1}{\beta} \right) \right)} 
\]

(2)

\[
 h_{\min} = \frac{\ln \left( \frac{0.8 + f_y}{1500} \right)}{36 + 9\beta} 
\]

(3)

\[
 h_{\max} = \frac{\ln \left( \frac{0.8 + f_y}{1500} \right)}{36} \quad \text{so} \quad \beta = \frac{\ln x}{\ln y} 
\]

(4)

With criteria:

- \( \alpha_m < 2 \) minimum slab thickness is 120 mm.
- \( \alpha_m > 2 \) minimum slab thickness is 90 mm.

2.3. Slab Planning Steps

(1) One-Way Slab

- Determine the minimum slab thickness of one way and supporting beam in accordance with SK-SNI T-15-1991-03. So that the theoretical and \( hf = \text{Koefisien } f_y \times 400 \times \left( 0.4 + \frac{f_y}{700} \right) \) with the provision of \( b < 2hf \).

- Determine the loading of the floor slab with factored load method and moment coefficient \( M = \text{Koefisien } x W_u \times \ln^3 \).
- Determine slab reinforcement with \( k = \frac{M_u}{bd^2} \) to get a reinforcement ratio value (\( \rho \)).

(2) Two-Way Slab
- Determining the maximum slab thickness and maximum thickness value using equations (3) and (4).
- Specifies the value of \( \alpha_m \) from each panel with \( \alpha_m = \frac{\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4}{4} \).
- Check the value of \( h_{\text{actual}} \) from the \( \alpha_m \) value that has been obtained. The value of \( h_{\text{trial}} \) may be used if it is greater than \( h_{\text{actual}} \).
- Calculates the load that occurs and multiplied by the safety factor using equation (1).
- Calculate the reinforcement ratio in concrete \( \rho \) and estimate the magnitude of the diameter of the main reinforcement and determine the effective height of the \( x(\phi) \) way, namely \( dx = h - p - \frac{1}{2} \phi \) reinforcement direction \( x \). So that the \( k = \frac{M_u}{bd^2} \) value is obtained to get the value of the \( (\rho) \) reinforcement ratio with the criteria used \( \rho_{\text{min}} < \rho < \rho_{\text{max}} \) with the following criteria:

\[
\rho_{\text{min}} = 0.75 \left( \frac{0.85 f'c}{f_y} \right) \left( \frac{600}{600 + f_y} \right)
\]

(a) If \( \rho_{\text{analisa}} > \rho \) then use \( \rho_{\text{min}} \)
(b) If \( \rho_{\text{analisa}} < \rho \) then use \( \rho_{\text{max}} \)

3. Data and Method
The scope of project work is the construction of One Residence Batam Center Apartments with 30 floors and 1 basement with 300 rooms. Each floor consists of 12 residential units with a width of 1.8 meters corridor. The following are data obtained from PT. Recta Construction in the Construction of One Residence Apartment Batam Center. Construction of this building starts from December 2017 to December 2019. Researcher only discusses the calculation of the floor slab which starts from the calculation of loading, calculation of the moment slab due to factored load, slab reinforcement planning and control of slab deflection.

3.1. Building Dimensions

| Floor                    | Spacious (m²) | High (m) |
|-------------------------|---------------|----------|
| Semi Basement           | 1125          | 3.8      |
| 1st Floor               | 1125          | 6        |
| 2nd Floor - 28th Floor  | 691           | 3.2      |
| 29th Floor              | 691           | 3.4      |
| 30th Floor              | 691           | 4.53     |
| Floor Roof              | 691           | 3.57     |

Based on table 1 above, the dimensions of the building floor are divided into 6 categories namely Semi Basement, 1st Floor, 2nd Floor – 28th Floor, 29th Floor, 30th Floor and Floor Roof with a minimum area is 691 m² and a maximum is 1125 m². The minimum height is 3.2 m and a maximum is 6 m.

3.2. Tie Beam Size

| Table 2. Dimensions of Tie Beam. |
|----------------------------------|
| Type | Dimension |
|------|-----------|


Based on table 2 above the tie beam dimensions are grouped into 9 types with the smallest dimension of 200 x 400 and the largest 400 x 700.

### Column Size

**Table 3. Column Dimensions.**

| Type      | Dimension   |
|-----------|-------------|
| Column 1  | 500 x 1300  |
| Column 2  | 500 x 1300  |
| Column 2A | 500 x 1300  |
| Column 4  | 550 x 1200  |

Based on table 3 above the column dimensions are divided into 4 types, namely Column 1, Column 2, Column 2A and Column 4 with sizes 500 x 1300 and 550 x 1200.

### Beam Size

**Table 4. Beam Dimensions.**

| Type      | Dimension   |
|-----------|-------------|
| Beam 1    | 250 x 500   |
| Beam 2    | 250 x 400   |
| Beam 3    | 250 x 430   |
| Beam 4    | 200 x 500   |
| Beam 5    | 150 x 180   |

Based on table 4 above, the beam dimension is categorized into 5 types, namely Beam 1 up to Beam 5 with a minimum size of 150 x 180 on Beam 5 and a maximum size of 250 x 500 on Beam 1.

![Figure 1](image)

**Figure 1.** Methods of Installing Floor Slab and Beam Formwork.

Based on figure 1, we can see the methods of installing floor slab and beam formwork by simulation design.
4. Data and Method

4.1 Regulation and Technical Data

For the design of this floor slab structure, loading refers to SNI 2847-2013, 1971 Concrete Loading Regulation which was adopted in the design of Indonesian reinforced concrete structures. The following are the variables used in the planning of the floor slab structure in the One Residence Apartment Batam Center construction project.

Table 5. Planning Variables of Floor Slab Structure.

| Variables                  | Size               |
|----------------------------|--------------------|
| Concrete Specific Gravity  | 2400 Kg/cm²        |
| Concrete Quality           | F’c = 30           |
| Floor Slab Thickness       | 15 cm              |
| Floor Slab Type            | Two-Way Slab       |
| Steel Reinforcement Quality| U-50               |
| Steel Reinforcement Diameter (D) | 10 mm           |
| Distance between Reinforcement Lx | 3.00 m     |
| Distance between Reinforcement Ly | 5.95 m    |
| Concrete Covers            | 2.5 cm             |

Based on table 5 above, the variable planning of the floor slab structure is divided into 9 variables with their respective sizes. These variables include Concrete Specific Gravity, Concrete Quality, Floor Slab Thickness, Floor Slab Type, Steel Reinforcement Quality, Steel Reinforcement Diameter (D), Distance between Reinforcement Lx, Distance between Reinforcement Ly and Concrete Covers.

4.2 Floor Slab Data

Table 6. Floor Slab Data.

| Floor Slab Dimensions | Unit  |
|-----------------------|-------|
| Lx                    | 3.00 m |
| Ly                    | 5.95 m |
| H                     | 150 mm |
| Ly/Lx                 | 1.98 mm|
| CLx                   | 62    |
| CLy                   | 35    |
| Ctx                   | 62    |
| Cty                   | 35    |

Based on table 6 above, the data obtained from One Residence Apartment Batam Center construction project based on the dimensions and units.

Figure 2. Casting The Floor Slab with a Concrete Pump.  
Figure 3. Casting The Floor Slab with Vibrator.
Based on figure 2 and figure 3, we can see the process of casting the floor slab with a concrete pump and vibrator. This work is carried out at the side of the project construction.

4.3 Loading

(1) Loading of Dead Load

| Type of Dead Load       | Unit Weight (kN/m³) | Thick (m) | Q (kN/m²) |
|------------------------|--------------------|-----------|-----------|
| Own Weight             | 24                 | 0.15      | 3.6       |
| Floor Finishing Weight | 1.1                |           | 1.1       |
| Ceiling and Frame Weight | 0.15              |           | 0.15      |
| Installation Weight (ME) | 0.19              |           | 0.19      |
| QD                     | 5.04               |           |           |

Based on table 7 above, the loading of dead loads on the One Residence Apartment Batam Center construction project is divided into 4 types, namely own weight, floor finishing weight, ceiling and frame weight and installation weight (ME) with total loading of dead load is 5.04 kN/m².

(2) Loading of Live Load
- Live Load = 250 kg/m².
- QL = 2.5 kN/m².
- Qu = (1.2*QD) + (1.6*QL) = (1.2 x 5.04) + (1.6 x 2.5) = 10.048 kN/m².

4.4 Slab Moment Due to Factor Load

- Field Moment Way of \( x \) (\( M_{uLx} \)) = (CLx) * (0.001) * Qu * Lx² = 5.607 kNm/m.
- Field Moment Way of \( y \) (\( M_{uLy} \)) = (CLy) * (0.001) * Qu * Lx² = 3.075 kNm/m.
- Stacking Moment Way of \( x \) (\( M_{utx} \)) = (Cx) * (0.001) * Qu * Lx² = 5.607 kNm/m.
- Stacking Moment Way of \( y \) (\( M_{uty} \)) = (Cy) * (0.001) * Qu * Lx² = 3.075 kNm/m.

![Figure 4. Moment on Floor Slab.](image)

The description of the depiction of the floor slab moment can be seen in figure 4.

4.5 Slab Reinforcement Planning

For slab reinforcement planning \( \beta_i = 0.85 \) is used in accordance with SNI 2002 because of \( F'c > 30 \text{MPa} \).

(a) Reinforcement ratio in balance \( (\beta_h) \) condition that is \( \beta_h = \beta_i * 0.85 * \left( \frac{F'c}{f_y} \right) * \left( \frac{600}{600 + f_y} \right) \)
\[ \beta_b = 0.85 \times 0.85 \left( \frac{30}{500} \right) \left( \frac{600}{600 + 500} \right) = 0.0236. \]

(b) Maximum Moment Resistance Factor, i.e:
\[ R_{\text{max}} = 0.75 \times \beta_b \times f_y \times \left( 1 - 0.5 \times 0.75 \times \beta_b \times f_y \right) \left( \frac{0.85 \times F'c}{0.85 \times F'c} \right) = 1.5357 \text{ is used } \phi = 0.8 \text{ in accordance with SNI 2002, then } ds = \frac{ts + \phi}{2} = 25 \text{ mm and } d = h - ds = 125 \text{ mm which is reviewed with a slab 1m and } b = 1000 \text{ mm.}\]

(c) Nominal Moments of the plan in accordance with SNI 2002, then \( M_n = \frac{M_u}{\phi} = 7.008 \text{ then } R_n = M_n \times 10^6 / (b \times d^2) = 0.44854. \]

(d) Reinforcement ratio required:
\[ \rho = 0.85 \times F'c / f_y \times \left( 1 - \sqrt{1 - 2 \times \left( \frac{R_n}{0.85 \times F'c} \right)} \right) = 9.44 \times 10^{-4}, \text{ so } \rho_{\text{min}} = 0.0025. \text{ Then it is used } \rho = 0.0025. \]

(e) Performed calculations \( A_s = \rho \times b \times d = 313 \text{ mm}^2. \)
So \( S = \pi / 4 \times b^2 / A_s = 251 \text{ mm and } S_{\text{max}} = 2h = 300 \text{ mm.} \text{ Then a calculation simulation is carried out with 200 Distance = 392.5 mm². Distance } A_s 225 = 348.9 \text{ mm² and distance } A_s 250 = 314 \text{ mm². Because the minimum area needed is 313 and based on the calculation results with a distance of 250 obtained 314, the reinforcement with a distance of 250 is more efficient to use, then reinforcement is used } \varnothing 10 - 250, \text{ so that the area of reinforcement is used } A_s = \pi / 4 \times \varnothing^2 / b / s = 314 \text{ mm² then } A_{s_{\text{safe}}} > A_{s_{\text{need}}}. \text{ safe.} \]

4.6 Control Slab Deflection

(a) Modulus of Concrete Elasticity \( (E_c) \) is \( E_c = 4700\sqrt{F'c} = 25.743\text{Mpa} \)
In accordance with SNI 2002, it is obtained:
- \( E_s = 200.00 \text{ Mpa} \)
- \( Q = QD + QL = 7.54 \text{ N/mm} \)
- \( L_{240} = 12.5 \text{ mm} \)
- \( I_g = \frac{1}{12} \times b \times h^3 = 281.250.000 \text{ mm}^3 \)
- \( Fr = 0.7 \times \sqrt{F'c} = 3.834 \)
- \( n = \frac{E_s}{E_c} = 7.77 \)
- \( c = n \times A_s / b = 2.441 \text{ mm} \)
- \( Icr = \frac{1}{3} \times b \times c^3 \times A_s \times (d - c)^2 = 36.666.635 \text{ mm}^4 \)
- \( Y_l = \frac{h}{2} = 75 \text{ mm} \)
- \( M_{cr} = Fr \times I_g / Y_l = 14.377.717 \text{ Nmm} \)
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- \( Ma = \frac{1}{8} Q L x^2 = 8.482.500 \) Nmm

- \( Ie = \left( \frac{Mcr}{Ma} \right)^3 * I_g + \left[ 1 - \left( \frac{Mcr}{Ma} \right)^3 \right] * Icr = 1.227.703.258 \) mm

In accordance with SNI 03-2847-2002, it is obtained:

- \( \delta e = 5 / 384 * Q / L x^4 / (E c * I e) = 0.252 \) mm

- \( \rho = As / (b * d) = 0.0025 \)

(b) Time dependency factor for dead load (3 Months Period), then according to SNI 2002, with

\[ \zeta = 1 \text{ so } \lambda = \frac{\zeta}{(1 + 50 * \rho)} = 0.89 \]

(c) Time dependency factor for dead load (6 Months Period), then according to SNI 2002, with

\[ \zeta = 1.2 \text{ so } \lambda = \frac{\zeta}{(1 + 50 * \rho)} = 1.07 \]

(d) Time dependency factor for dead load (12 Months Period), then according to SNI 2002, with

\[ \zeta = 1.4 \text{ so } \lambda = \frac{\zeta}{(1 + 50 * \rho)} = 1.24 \]

(e) Time dependency factor for dead load (Duration > 5 years), then according to SNI 2002, with

\[ \zeta = 2 \text{ so } \lambda = \frac{\zeta}{(1 + 50 * \rho)} = 1.7767 \]

(f) The long-term deflection due to frame and shrinkage is used the biggest, which is more than 5 years. So \( \delta_{t_e} = \lambda * 5 / 384 * Q / L x^4 / (E c * I e) = 0.447 \) mm, then \( \delta_{t_{total}} = 0.699 \) mm. Due to

\[ \delta_{t_{total}} < \frac{L}{240} \text{ then safe.} \]

4.7 Discussion

Based on calculation, slab moment due to factor load the value of field moment way for \( x \) and \( y \) is same with stacking moment of \( x \) and \( y \). Performance of the spacious cover is 313 m², so the reinforcement with a distance of 250 is more efficient to use. Modulus of Concrete Elasticity used to find the effective inertia which is equal to 1.227.703.258 mm³. Numerical analysis used for checking the time dependency factor for dead load. The duration is 3 months period, 6 months periods, 12 months periods and more than 5 years for long term. The longer period used for checking the reduction factor is also getting bigger. This means that the durability of a building in this case is that floor slab analysis is decreasing but it is still in the safe category. In planning, it is best to design a floor slab with reinforcement as needed, so that it can be avoided wasteful reinforcement during implementation. Planning should be designed to follow standard rules guidelines in building structure and before casting, it is necessary to inspect the bonding and spacing according to shop drawings and the installation of concrete decking.

5. Conclusion

For planning the floor slab in the Batam Center One Residence Apartment Development Project, reinforcement using steel with a diameter of 10 mm. The minimum area required is 313 mm² and based on the results of calculations with a distance of 250 mm it is more efficient than the maximum distance used 251 mm. So that it can be categorized as safe. Modulus of concrete elasticity was obtained at 25.743 MPa and obtained a reinforcement ratio of 0.0025. Checking the time dependency factor for dead loads is carried out for 3 months, 6 months, 12 months and more than 5 years. The
long-term deflection due to the biggest frame and shrinkage (more than 5 years) falls into the safe category because \( \delta_{\text{total}} < \frac{L}{240} \). Calculation of the floor slab used has met the SNI requirements.

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