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Research Article

Structural Analysis of the Mixed-Use Building of Al-Amin Living Lab and Industrial Park in Sampe Cita Village, Kutalimbaru District

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Abstract: A mixed-use building refers to a combination of several different functions within a single structure, such as residential, office, shopping, and recreational functions built on one site. Designing a mixed-use building requires careful planning and consideration of various factors such as functional needs, aesthetics, and energy conservation. Additionally, the design of mixed-use buildings incorporates various functions within a single area. Floor slabs and beams use plain reinforcing steel with a quality of Fy = 240 MPa (Ø8mm). The concrete cover is taken as 20 mm. From the design results, several thickness types of slabs were obtained according to the load requirements that must be accommodated above them. The following are the moments acting on the floor slabs and beams. The reinforcement calculations are performed using the capacity strength design method according to SNI 2847-2019. The capacity design concept involves controlling the formation of plastic hinges at predetermined locations. The SAP2000 program can directly calculate the feasibility of the structural dimensions and the amount of reinforcement needed from the input program results. In the SAP2000 program, the concrete code used is the American concrete code ACI-318-05/IBC 2003, which differs in some respects from the concrete code in Indonesia SNI 2847-2019. Adjustments need to be made to comply with the regulations in Indonesia. Internal forces from the SAP2000 program are selected from load combinations that generate the maximum moments at the column face. The flexural and shear reinforcement for beams can be directly read from the SAP2000 output in the form of information on the required area of reinforcement.

Keywords: Buildings, Mixed-Use Building, Living Lab.

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1. Introduction

A multifunctional building or Mixed Use building refers to the combination of several different functions within a single building, such as residential, office, shopping, and recreational functions built on one site (Sutarman & Bendatu, 2013). Designing the structure of a mixed-use building requires careful planning and consideration of various factors such as functional needs, aesthetics, and conservation.

The design of a multifunctional building at Al-Amin Living Lab and Industrial Park in Kutalimbaru District, Sampe Cita Village, aims to create a mixed-use building to generate mutual benefits by providing a space for businesspeople and other actors to take advantage of the economic growth in Sampe Cita Village, Kutalimbaru District, thereby increasing regional income. Additionally, the building design must consider the structural analysis that will be used for the building.

Structural analysis is the process of calculating and determining the effects of loads acting on a physical structure and its components, such as buildings, bridges, docks (Dewobroto, 2005), machines, and others. Structural analysis is crucial to ensure how load distribution and impact affect the structure under review. Besides loads that influence structural behavior, the materials used and the structural system also affect the structure's behavior.

Structural analysis of a mixed-use building is the process of evaluating and planning the building structure designed for multifunctional use (Farisa & Widati, 2017). The appropriate structural system for a mixed-use building can be reinforced concrete, steel, or a combination of both. The structural system of a mixed-use building must be designed to withstand loads such as building loads, wind forces, and earthquakes.

Universitas Pembangunan Panca Budi plans to develop an area located in Glugur Rimbun, specifically in Sampe Cita Village, Kutalimbaru District, which is projected to become a Mixed Use center providing various buildings that facilitate all study programs at UNPAB. The structural analysis of the mixed-use building for this development will be named the Al-Amin Mixed Use Building. One of the functions to be developed in this area is a commercial zone, including restaurants, cafés, and meeting rooms.

Kutalimbaru District is part of Deli Serdang Regency, North Sumatra Province. The natural conditions of Kutalimbaru District generally experience two seasons: the dry season and the rainy season, both influenced by sea and mountain winds. Administratively, Kutalimbaru District borders several areas: to the north, it borders Sunggal District and Pancur Batu District; to the south, it borders Sibolangit District; to the east, it borders Pancur Batu District; and to the west, it borders Langkat Regency (BPS Deli Serdang, 2021).

Figure 1. Map of Kutalimbaru District, Deli Serdang Regency

This structural analysis aims to ensure that the building complies with all applicable regulations and standards, such as earthquake resistance regulations, fire resistance, local building regulations, and that a good structural design can make building maintenance easier and more efficient. This can reduce long-term maintenance costs.

Structural analysis studies are an important activity to determine the structure to be used. This research is essential to determine whether the structure is suitable for the planned building.

2. Literature Review

2.1. Definition of Mixed-Use Building

A mixed-use building is a structure that serves multiple functions or more than one function. A mixed-use building may consist of one or several interconnected building masses with different functions.

2.1.1. Characteristics of Mixed-Use Buildings

Characteristics of mixed-use buildings (Aharonian et al., 2004):

1. Includes two or more building functions with different purposes within a related area, such as apartments, hotels, schools, hospitals, malls, and others.
2. There is physical and functional integration of the various functions within the building.
3. The buildings are connected at a relatively close distance to each other and are linked through internal building connections.
4. Pedestrian pathways play an essential role in connecting the buildings.

2.2. Structural Analysis of Buildings

Structural analysis is the study of determining the effects of loads on a physical structure and its components. Its applications include the analysis of buildings, bridges, tools, machines, and soil (Pantow et al., 2015). Structural analysis integrates engineering mechanics, material engineering, and engineering mathematics to calculate structural deformation, internal strength, stress, pressure, support reactions, acceleration, and stability. The results of this analysis are used to verify the strength of structures that will be or have already been built.

3. Method

3.1. Research Material

The research material consists of the site location in Sampe Cita Village, Kutalimbaru District, Deli Serdang Regency, the academic community's need at Universitas Pembangunan Panca Budi for research land, and the potential for area development as a tourism facility.

3.2. Research Procedure

The research procedure is carried out as follows:
a. Field survey
b. Data compilation (field and reference)
c. Documentation
d. Data analysis
e. Discussion and deliberation
f. Conclusion and structural proposal
g. Research report

3.2.1. Observed Parameters

a. Physical conditions of the design location (contour, area, climate, architectural structural form, etc.).
b. Non-physical conditions (academic community needs at UNPAB, local culture, structural development potential, etc.).

3.2.2. Place and Time of Research

Research Location: Sampe Cita Village, Kutalimbaru District, Deli Serdang Regency. Research Duration: One (1) year.

3.2.3. Type and Scope of Research

This research is a descriptive study.

3.2.4. Data Collection Techniques

The data collection technique is a qualitative approach, and the techniques used in this research include:
• Literature Study
• Field Observation
• Data Validation
• Data Analysis

4. Results and Discussion

4.1. Structural Criteria

4.1.1. Planning Data

a. Number of floors : 2 floors + Roof
b. Floor elevation:
  - Ground floor : ± 1.00 m
  - Second floor : + 4.00 m
  - Roof : + 7.00 m
  - Stair roof : + 9.50 m
c. Building area (per floor):

- Ground floor : ± 83.15 m²
- Second floor : ± 83.15 m²
- Roof : ± 83.15 m²
- Stair roof : ± 5.7 m²

d. Concrete slab thickness:
- Floor : 12 cm
- Roof (Dag) : 10 cm

e. Column types : K1 (25x40 cm²)
K2 (20x20 cm²)

f. Beam types : B1 (20x40 cm²)
B2 (20x30 cm²)
B3 (15x30 cm²)

4.2. Material Specifications

Concrete Strength:
- Slabs, Beams & Columns : K-275 (fc'= 22.83 MPa)

Reinforcement Steel Strength:
- For Ø > 12 mm; fy = 390 MPa (BJTD 40)
- For Ø < 12 mm; fy = 235 MPa (BJTP 24)

4.3. Building Loads

a) Additional Dead Load on Floors (SDL):
- 1 cm thick sand weight = 0.16 kN/m²
- 3 cm thick mortar weight = 0.63 kN/m²
- 1 cm thick ceramic weight = 0.24 kN/m²
- Ceiling & hanger weight = 0.20 kN/m²
- MEP installation weight = 0.25 kN/m²
- Total additional dead load on floors = 1.48 kN/m²

b) Additional Dead Load on Roof Floor (SDL):
- Waterproofing weight = 0.28 kN/m²
- Ceiling & hanger weight = 0.20 kN/m²
- MEP installation weight = 0.25 kN/m²
- Total additional dead load on roof floor = 0.73 kN/m²

c) Dead Load on Beams:
- 3.2 m high wall load = 8.00 kN/m
- 1 m high parapet wall load = 2.50 kN/m

d) Live Load on Floors:
- People & equipment load = 2.5 kN/m²

e) Live Load on Roof Floor:
- People & equipment load = 1.00 kN/m²

4.4. Load Combinations

The load combinations used for analysis in SAP 2000 refer to SNI 1726:2019 and SNI 2847:2019, resulting in the following load combinations:

COMB_1	1.40	D	+	1.40	SDL									
COMB_2	1.20	D	+	1.20	SDL	+	1.60	L L						
COMB_3	1.30	D	+	1.30	SDL	+	1.00	L L	+	1.00	EQDX	+	0.30	EQDY
COMB_4	1.30	D	+	1.30	SDL	+	1.00	L L	+	1.00	EQDX	-	0.30	EQDY
COMB_5	1.30	D	+	1.30	SDL	+	1.00	L L	-	1.00	EQDX	+	0.30	EQDY
COMB_6	1.30	D	+	1.30	SDL	+	1.00	L L	-	1.00	EQDX	-	0.30	EQDY
COMB_7	1.30	D	+	1.30	SDL	+	1.00	L L	+	1.00	EQDY	+	0.30	EQDX
COMB_8	1.30	D	+	1.30	SDL	+	1.00	L L	+	1.00	EQDY	-	0.30	EQDX
COMB_9	1.30	D	+	1.30	SDL	+	1.00	L L	-	1.00	EQDY	+	0.30	EQDX
COMB_10	1.30	D	+	1.30	SDL	+	1.00	L L	-	1.00	EQDY	-	0.30	EQDX
COMB_11	0.80	D	+	0.80	SDL	+	1.00	EQDX	+	0.30	EQDY			
COMB_12	0.80	D	+	0.80	SDL	+	1.00	EQDX	-	0.30	EQDY			
COMB_13	0.80	D	+	0.80	SDL	-	1.00	EQDX	+	0.30	EQDY			
COMB_14	0.80	D	+	0.80	SDL	-	1.00	EQDX	-	0.30	EQDY			
COMB_15	0.80	D	+	0.80	SDL	+	1.00	EQDY	+	0.30	EQDX			
COMB_16	0.80	D	+	0.80	SDL	+	1.00	EQDY	-	0.30	EQDX			
COMB_17	0.80	D	+	0.80	SDL	-	1.00	EQDY	+	0.30	EQDX			
COMB_18	0.80	D	+	0.80	SDL	-	1.00	EQDY	-	0.30	EQDX			

Figure 2. Load Combinations

Load Notations:

D = Self-weight Dead Load of the Structure
SDL = Additional Dead Load on the Structure
LL = Live Load
EQDX = Dynamic Earthquake Load in the X-Direction
EQDY = Dynamic Earthquake Load in the Y-Direction

4.5. Structural Beam Modeling

The structural beam is modeled using a standard frame element with dimensions and materials as specified in the design drawings, as shown in the following illustration:

Figure 3. Beam Dimensions

4.6. Structural Column Modeling

The structural column is modeled using a standard frame element with dimensions and materials as specified in the design drawings, as shown in the following illustration:

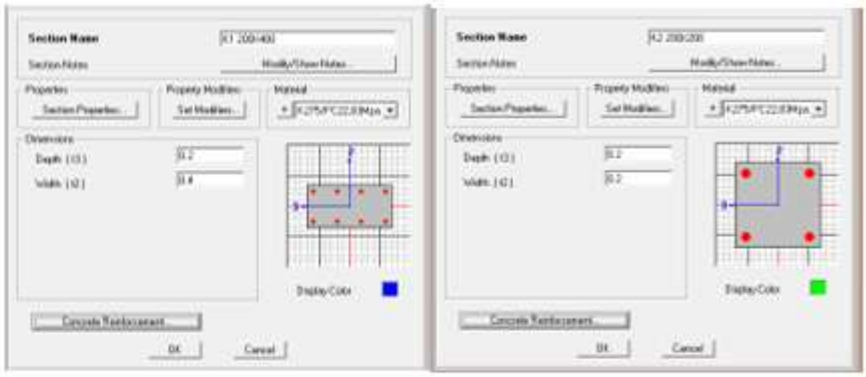

Figure 4. Beam Dimension

4.7. Support Modeling

The support is modeled as a fixed support, restricting translation and rotation along the local X, Y, and Z axes. The modeling for the fixed support is as follows:

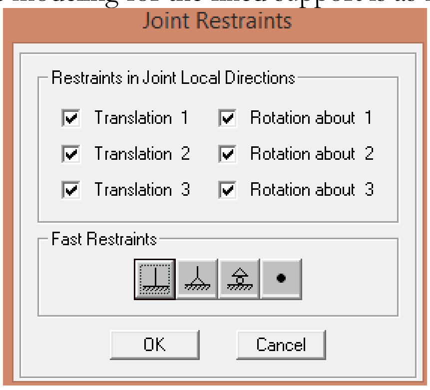

Figure 5. Fixed Support

- Building Location = Jl. Jamin Ginting Gg. Sederhana – Medan Baru
- Building Type = Boarding House
- Site Class = SC (Hard Soil, Soft Rock)
- Risk Category = II (Table 3 SNI 1726:2019)
- Importance Factor = 1.00 (Table 4 SNI 1726:2019)
- Ss = 0.6558 g (http://rsa.ciptakarya.pu.go.id/2021/)
- S1 = 0.3634 g (http://rsa.ciptakarya.pu.go.id/2021/)
- TL = 20 seconds (http://rsa.ciptakarya.pu.go.id/2021/)
- SDS = 0.4974 (SAP2000)
- SD1 = 0.3480 (SAP2000)

Based on the acceleration response parameters for short-period and 1-second periods, the seismic design category can be determined using Table 8 and Table 9 of SNI 1726:2019 as follows:

Table 1. Seismic Design Categories Based on Short Period Acceleration Response Parameters

Value *Sps*	**Risk Category**	
	I or II or III	**IV**
$Sps < 0{,}167$	A	A
$0{,}167 \leq Sps < 0{,}33$	B	C
$0{,}33 \leq Sps < 0{,}55$	C	D
$0{,}55 \leq Sps$	D	D

Source: SNI 1726:2019

Table 2. Seismic Design Categories Based on Acceleration Response Parameters at Short Periods of 1 Second

Value Sp_1	**Risk Category**	
	I or II or III	**IV**
$Sp_1 < 0{,}167$	A	A
$0{,}167 \leq Sp_1 < 0{,}33$	B	C
$0{,}33 \leq Sp_1 < 0{,}55$	C	D
$0{,}55 \leq Sp_1$	D	D

Source: SNI 1726:2019

Table 3. Seismic Design Category (KDS) and Seismic Risk

High Seismic Risk		
Low	**Medium**	**High**
KDS : A, B	KDS : C	KDS : D, E, F
SRPMB / M/ K	SRPMM /	SRPMK

Description:
SRPMB : Ordinary Moment Bearing Frame System
SRPMM : Intermediate Moment Truss System
SRPMK : Special Truss System

Based on the above data, the office building location in Royal Sumatera Housing falls into the following category:

- Seismic Design Category (KDS) = C (Table 8 & 9 SNI 1726:2019)
- Seismic Risk = Medium
- Seismic Reduction Factor (R) = 5 (Table 12 SNI 1726:2019)
- Overstrength Factor (Ω) = 3 (Table 12 SNI 1726:2019)
- Deflection Amplification Factor (Cd) = 4.5 (Table 12 SNI 1726:2019)
- Seismic Importance Factor (Ie) = 1.00 (Table 12 SNI 1726:2019)

4.8. lab & Roof Slab Reinforcement

The floor slab & roof slab use plain reinforcement steel with a strength of Fy = 240 MPa (Ø8mm). The concrete cover is 20 mm. Based on the design results, various slab thicknesses are determined according to the working loads they must accommodate. Below are the moments acting on the floor slab & roof slab.

Based on the moments acting on the floor slab and roof slab, the reinforcement diameter and spacing used can be determined, as shown in Appendix 8.

Table 4. Floor Slab & Roof Slab Reinforcement Design

Thickness of Plate	Name of Reinforcement	Area	Mu kNm	Ø mm	Distance mm	Area mm²	Concrete Quality fc'	Steel Grade fy	Effective Thickness of Plate(d)	Ø Mn kNm	a mm	Capacity Check	Installed
2ND FLOOR PLATE													
120	Bone Direction X	Support	1.75	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
		Field	2.39	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
	Bone Direction Y	Support	4.14	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
		Field	2.98	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
DAG ROOF													
120	Bone Direction X	Support	1.32	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
		Field	1.29	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
	Bone Direction Y	Support	1.22	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150
		Field	1.39	8	150	335.10	22.83	240	100	7.09	4.15	OK	P 8 - 150

4.8.1. Structural Frame Reinforcement (Beams & Columns)

Reinforcement calculations are carried out using the capacity strength design method in accordance with SNI 2847-2019. The capacity design concept refers to controlling the formation of plastic hinges at predetermined locations. SAP2000 software can directly calculate the structural dimension feasibility and the required reinforcement area based on the input process results.

In SAP2000, the concrete regulations used are based on ACI-318-05/IBC 2003, which differs in some aspects from Indonesia's SNI 2847-2019. Therefore, adjustments must be made to comply with Indonesian regulations.

The internal forces from SAP2000 are selected from load combinations that produce the maximum field moments and support moments on the column face. The flexural and shear reinforcement for beams can be directly obtained from the SAP2000 output in the form of reinforcement area information, as shown in the following figures.

5. Conclusions

Based on the discussion, the conclusions of this research are as follows:

1. Floor Slab & Roof Slab Reinforcement

   The floor slab and roof slab use plain reinforcing steel with a strength of Fy = 240 MPa (Ø8mm). The concrete cover is 20 mm. The design results determine various slab thickness types based on the working loads that must be accommodated. The following are the moments acting on the floor slab & roof slab.

2. Reinforcement Calculation

   The reinforcement calculation is performed using the capacity strength design method in accordance with SNI 2847-2019. This capacity design concept aims to control the formation of plastic hinges at predetermined locations. The SAP2000 program can directly calculate the structural dimension feasibility and the required reinforcement area from the input process results.

   In SAP2000, the concrete regulations used are based on ACI-318-05/IBC 2003, which differs in some aspects from SNI 2847-2019 in Indonesia. Therefore, adjustments must be made to comply with Indonesian regulations.

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