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Structural Analysis of one-Block Compartment Building in Sentul Indah Residence Housing

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ABSTRACT

The rapid population growth in Indonesia has also increased the need for housing, according to data from the Ministry of Home Affairs through the Directorate General of Population and Civil Registry (Dukcapil) as of June 30, 2020, 268,583,016 people. The Ministry of PUPR said that housing needs in Indonesia are still high, to fulfill them not only from the state budget, but must work together with banks, developers, and local governments. Structural analysis carried out on a one-story compartment type residential building located in one Sentul Indah Residence (SIR) housing block in the Bogor Regency area is very important to ensure that building users are in a safe condition. The research was conducted by testing the concrete quality (f'c) of existing columns, beams, and obtained concrete quality values sequentially of 30 MPa, 25 MPa, then modeling the existing structure using the ETABS application and obtained the results that the loads acting on the building and the combination of loads based on SNI were declared safe against the influence of external forces on the building by not finding structural elements that experienced over strenght (O/S). The results of the structural analysis plan based on SNI obtained the dimensions of a residential building with a size of 30 meters x 60 meters, reinforced concrete structure. The concrete material used is concrete with a quality (f'c) of 30 Mpa. Column dimensions 20x20 cm with 2D12 main reinforcement and shear reinforcement and shear reinforcement ϕ10-70, beam dimensions 15x20 cm with 2D12 main reinforcement and shear reinforcement ϕ10-100.

Keywords: structural; analysis; house; building; ETABS.

INTRODUCTION

A house is a building that functions as a livable residence, a means of family development, a reflection of the dignity of its occupants, and an asset for its owner. Housing is a collection of houses as part of settlements, both urban and rural, which are equipped with infrastructure, facilities, and public utilities as a result of efforts to fulfill livable housing... To obtain quality housing in accordance with the guidelines for building function based on Law No. 28 of 2002 concerning Building, Government Regulation No. 64 of 2016 concerning Low-Income Housing Development, PUPR Regulation No. 05/PRT/M/2016 concerning Building Permit, PUPR Regulation No. 06/PRT/M/2017 concerning Amendments to PUPR Regulation No. 05/PRT/M/2016 concerning IMB, PUPR Regulation No. 25 of 2007 concerning Certificate of Occupancy. 25 of 2007 concerning Certificate of Fitness for Function, and PUPR Regulation No. 11 of 2018 concerning Building Expert Teams, Technical Reviewers, and Building Inspectors as practical guidelines for development actors and the community in obtaining IMB and SLF, especially low-income housing, it is necessary to conduct an evaluation study of the structure of houses built., because housing is often built in the form of a row or compartment type, this research will be conducted for a one-block house consisting of 10 housing units. According to Kuswartojo (2005 in Rachman, 2010) the meaning of housing can be categorized into formal housing, namely housing built with a clear rule with a regular pattern, informal housing is an accumulation of houses built by families or individuals without following a rule so that it seems random.

The building structure evaluation study was conducted on a one-story residential building in one Sentul Indah Residence (SIR) housing block in the Bogor Regency area. The structure used in residential buildings in Sentul Indah Residence uses a reinforced concrete structure, with a double

wall type so that the structure of each house is not connected to the house next to it. The process of evaluating the structural analysis of residential buildings is guided by the requirements of SNI 2847-2019 concerning structural concrete requirements for building buildings and their explanations, SNI 1726-2019 concerning procedures for earthquake resistance planning for building and non-building structures, SNI 1727-2020 concerning minimum design loads and related criteria for buildings and other structures, and Loading Planning Guidelines for Houses and Buildings (PPURG) in 1987.

Houses are classified based on the developers and occupants, namely as follows (Law No. 1 of 2011 concerning Housing and Settlement Areas):

a. Commercial houses are houses built for profit according to the needs of the community.

b. Public houses are houses built to meet the housing needs of the Low-Income Community.

c. Self-subsistent houses are organized on the initiative and efforts of the community, either individually or in groups.

d. Special houses are organized in order to meet the needs of houses for special needs, provided by the government and / or local governments.

e. State houses are provided by the government and/or local government.

The purpose of the research is to analyze the building structure against the working load based on SNI. This research is limited by several provisions including, Existing structure in one block building of Sentul Indah Residence Housing, structural analysis covers the upper structure, does not analyze the lower structure or foundation. Structural analysis using the Extended Three-Dimensional Analysis of Building Systems (ETABS) application, manual analysis using the Ms. Excel application, and column analysis using the SPColumn application, and structural drawing design using the AutoCAD application.

Structural analysis based on SNI 2847-2019, Article 4.5 states that the analysis rules aim to estimate the internal forces and deformations of the structural system and to ensure the fulfillment of strength, serviceability and stability requirements. The basic requirement in planning building structures for design strength is determined by the design strength must be greater equal to than the necessary strength. Columns are the main structural elements that bear the combined load of compressive axial and bending moments. Columns are also the main structural elements that play the most important role in carrying lateral loads (especially earthquakes) on building structures (Lesmana, 2020). Based on SNI 2847-2019, Article 10.6.1 states that the limitation of the longitudinal reinforcement ratio must be at least 0.01 but must not exceed 0.08. Beams can be defined as one of the portal structural elements with horizontal spans, while portals are the main framework of building structures, especially buildings. The loads acting on the beam are usually in the form of bending loads, shear loads and torsion (twisting moments), so reinforcing steel is needed to withstand these loads. This reinforcement is in the form of longitudinal reinforcement (which resists bending loads) and shear/seal reinforcement (which resists shear and torsion loads) (Asroni, 2010). The general requirements in SNI 2847-2019, Article 9.5.1 explain that for each combination of factored loads used, the design strength throughout the cross section must meet $\phi Sn \geq U$, including in numbers 1 to 4 below the interaction between load effects must be considered:

1. $\phi M_n \geq M_u$
2. $\phi M_n \geq M_u$
3. $\phi T_n \geq T_u$
4. $\phi P_n \geq P_u$

The description of ϕ shall be determined in accordance with SNI 2847-2019 Table 21.2.1 on Strength Reduction Factor. Sn = nominal moment (N), shear, axial, torsional or fulcrum strength; U = required strength (N), Pn = nominal axial strength of cross section (N); Pu = factored axial force, taken as positive for compressive and negative for tensile (N); Mn = nominal flexural strength of cross section (N. mm); Mu=Factored moment at cross section (N.mm); Vu=Factored shear force of

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section (N); Vn=Nominal shear strength (N); Tn=Nominal torsional moment strength (N.mm); Tu=Factored torsional moment at section (N.mm).

RESEARCH METHOD

This research was conducted on a house located in Sentul Indah Residence Housing. The research time was from September 2022 to February 2023. The research stages are data collection used in the form of primary and secondary data. Primary data includes concrete quality from the company, documentation of existing buildings and measurement of building dimensions. Secondary data includes literature on building structures such as SNI 2847-2019 (Structural Concrete Requirements for Building and its Explanation), SNI 1726-2019 (Earthquake Resistance Planning Procedures for Building and non-building Structures), SNI 1727-2020 (Minimum Design Loads and Related Criteria for Buildings and Other Structures), and Guidelines for Loading Planning for Houses and Buildings in 1987. The next stage is structural analysis to ensure the existing structure is suitable for use. Based on the comparison of seismic design categories.

Figure 1. Sentul Indah Residence Housing Source: Personal documents

The research flowchart are shown at figure 2.

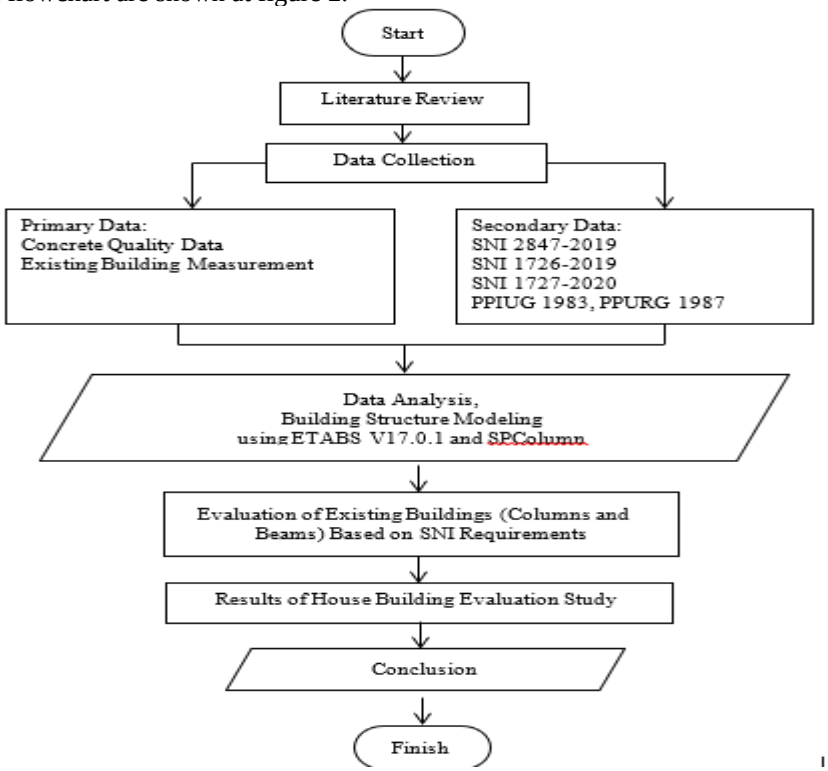

Figure 2. Research Flowchart Source: Personal documents

RESULTS AND DISCUSSION

Structure Analysis

The existing plan can be seen in Figure 3, column dimensions K20x20 cm, beam dimensions B15x20 cm with a building elevation of 6.14 m to the roof cover. Using Hammer Test Method, obtained concrete quality for column (f'c) 30 MPa and beam (f'c) 25 MPa.

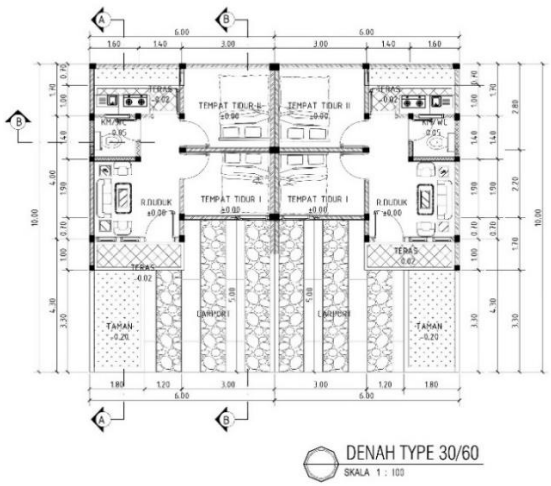

Figure 3. Type 30/60 house existing plan

Dead Load and Live Load

The analysis is carried out by entering loading data, dead loads are entered automatically in the ETABS application, but there are additional dead loads that are notated SIDL (Super Input Dead Load) and live loads acting on the building structure can be seen in Table 1.

Table 1. Dead and live loads of existing building

Dead Load *SIDL*	**Live Load**
Load on Beam (story 1)	Roof
Wall Loads = 5,25 kN/m	Human Load = 1 kN/m^2
Load on roof cover beams (story 2)	(SNI 1727-2020)
Ceiling and suspensions = 0,20 kN/m^2	
Concrete roof covering and	
Mild Steel = 0,50 kN/m^2	

Source: PPURG 1987

Seismic Loads

The lateral and vertical earthquake resisting system used is SRPMK, so the response modification coefficient (R): 8, system overpower factor (Ω): 3, deflection amplification coefficient (Cd): 5,5. The determination of the response spectrum used to analyze dynamic loads is taken from the Indonesian design response spectrum application 2021.

Table 2. Indonesian spectra design values

Grade	**T0**	**Ts**	**Sds**	**Sd1**
SD-Medium Soil	0,15	0,77	0,75	0,57
Longitude	106.84572364223132			
Latitude	-6.585181761442831			
PGA	0,4789			
ss	1,0270			
S1	0,4685			

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Tl	20

Source: rsa.ciptakarya.pu.go.id

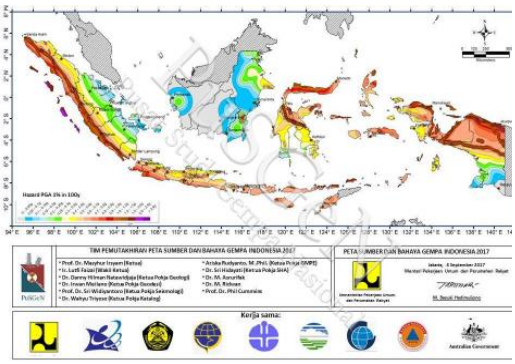

Figure 4. Seismic Zone Map
Source: rsa.ciptakarya.pu.go.id

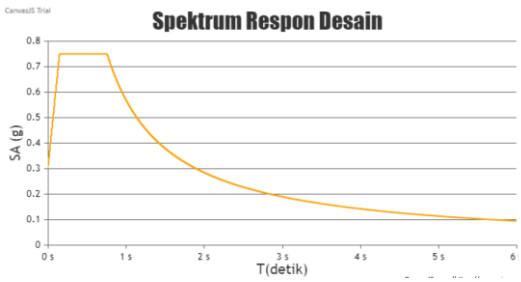

Figure 5. Design response spectrum graph
Source: rsa.ciptakarya.pu.go.id

Load Combinations

Load factors and load combinations used in the design process of reinforced concrete structures, based on SNI 2847-2019. According to SNI 2847-2019 on Load Factors and Load Combinations Article 5.3, the required strength U must be at least equal to the effect of the factorized load in Table 3 as follows:

Table 3. Load Combinations

Load Combinations	Equation	Main Load
U=1,4D	(5.3.1a)	D
U= 1,2D+1,6L+0,5(Lr or R)	(5.3.1b)	L
U=1,2D+1,6(Lr or R)+(1,0L or 0,5W)	(5.3.1c)	Lr or R
U=1,2D+1,0W+1,0L+0,5(Lr or R)	(5.3.1d)	W
U=1,2D+1,0E+1,0L	(5.3.1e)	E
U=0,9D+1,0W	(5.3.1f)	W
U=0,9D+1,0E	(5.3.1g)	E

Source: SNI 2847-2019 on Load Factors and Load Combinations Article 5.3

Captions:

U = factorized load combination, kN, kN/m' or kNm
D = Dead Load, kN, kN/m' or kNm
L = Love Load, kN, kN/m' or kNm
Lr = Roof Live Load, kN, kN/m' or kNm
R = Rain Load, kN, kN/m' or kNm
W = Wind Load, kN or kN/m'
E = Seismic Load, kN or kNm.

Results of Structure Modeling

The results of modeling the existing building structure after inputting structural element data, loads acting on the building and load combinations based on SNI are declared safe against the influence of external forces on the building by not finding structural elements that experience over strength (O/S). Over strength factor is the value of the excess strength produced by reinforced concrete structural elements due to the achievement of the ultimate strength of the cross-section compared to the strength of the cross-section when it yields / has reached the required ultimate strength (Aswin, 2019).

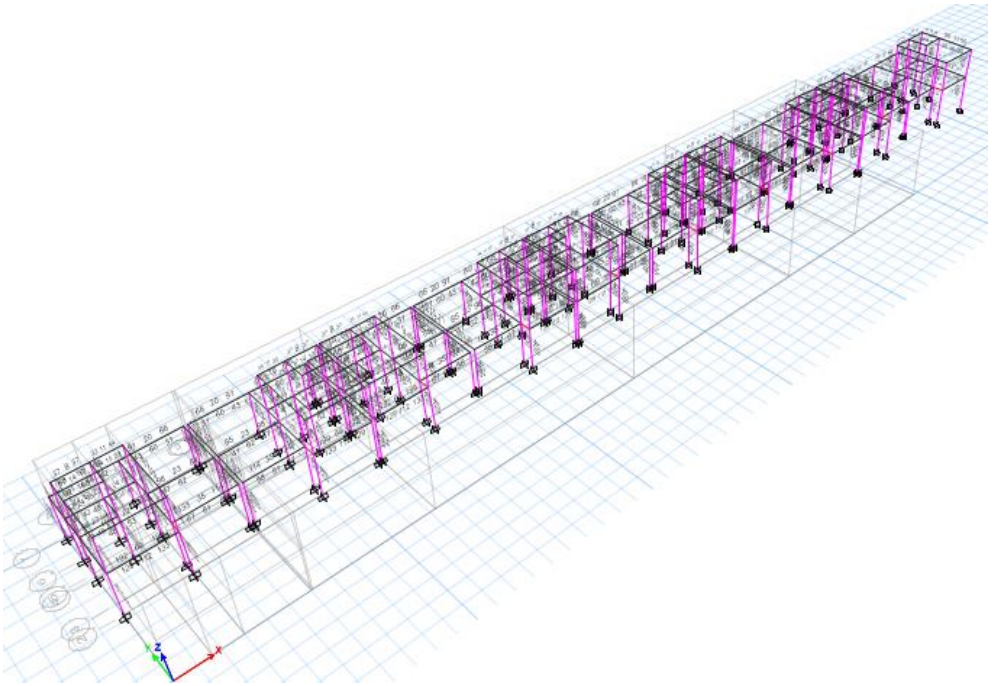

Figure 6. Structure Modeling Result Source: ETABS

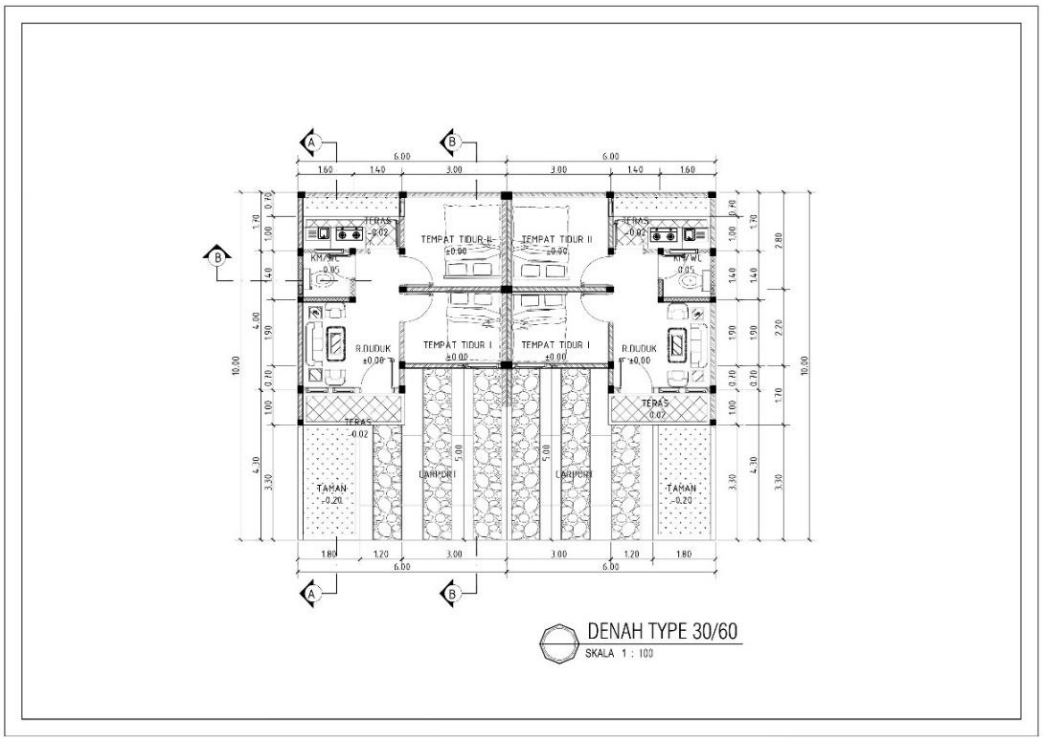

Figure 7. Type 30/60 Plan Source: Personal Documents

Super Input Dead Load (*SIDL*) and Live Load

The structural plan analysis process takes into account the additional dead load, live load and seismic load. Details of the additional dead load and live load on the building are shown in Table 4.

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Table 4. Dead load and live load

Dead Load *SIDL*	**Live Load**
Load on Beam (story 1) Wall Load 2,1 x 250 = 525 kg/m^2 = 2,25kN/m^2	
Load on Beam (story 2) Ceiling and Suspensions = 20 kg/m^2 = 0,20 kN/m^2 Concrete roof covering and mild steel = 50 kg/m^2 = 0,50 kN/m^2	Load on Beam (story 2) Mosque = 100 kg/ m^2 = 1 kN/m^2

Source: PPURG 1987

Seismic Loads

The earthquake load stages of the building plan are the same as the stages of analyzing the building structure then the load combination is also the same referring to Table 4.

Calculation of beam reinforcement for design

The calculation of reinforcement requirements on the beam elements of the design using the Ms. Excel application by entering the output results from the ETABS application to obtain the necessary moment (Mu) and the necessary load (Vu) torque load (Tu) to determine the bending and shear reinforcement. structural modeling in the form of internal forces is shown in Table 5.

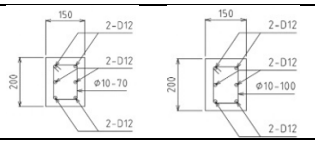
Table 5. Force output in beams

Beam	**Mu Fulcrum (-) (kNm)**	**Mu Fulcrum (+) (kNm)**	**Mu Field (-) (kNm)**	**Mu Field (+) (kNm)**	**Vu Fulcrum (kN)**	**Vu Field (kN)**	**Vg Fulcrum (kN)**	**Tu (kNm)**
B15x20	-6,8339	3,0914	-6,8339	3,0914	11,7774	11,7774	10,1129	1,0641

Source: Analysis Result

From the data, the calculation is then conducted based on SNI 2847-2019 Article 9.5.1, namely ϕSn≥U, the beam reinforcement plan is shown in Table 6.

Table 6. Reinforcement details of design beams

	B30x60	
	Fulcrum	**Field**
Figure (mm)		
Dimension	150x200	150x200
Top Rebar	2-D12	2-D12
Centre Rebar	2-D19	2-D19
Bottom Rebar	2-D12	2-D12
Shear Reinforcement	Ø10-70	Ø10-100

Source: Analysis Result

Calculation of column reinforcement for design

Calculation of column elements by checking the output results of the ETABS application in the form of internal forces using the Ms. Excel application in order to obtain the maximum load and moment shown in Table 7.

Table 7. *Output column force* K20x20

Story	Load Case/Combo	P (kN)	M2 (kNm)	M3 (kNm)
Story 1	Comb5 Y d Max	25,9769	3,4474	4,7719
Story 1	Comb5 Y d Max	28,6554	5,4519	2,7509
Story 1	Comb7 Y d Max	39,9906	2,7055	3,717

Source: Analysis Result

Based on Table 7, the data is then entered into the SPColumn application to create a column interaction diagram shown in Figure 8.

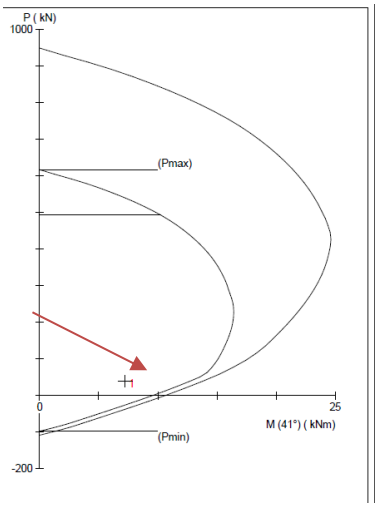
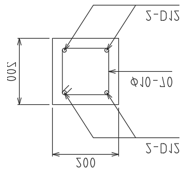
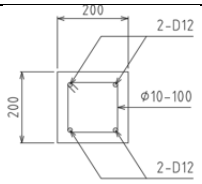


Figure 8. Column interaction diagram K20x20 Source: SPColumn Analysis Result

The results of the analysis show that the loading point is still within the interaction diagram, so the column is declared safe, indicated by the arrow in Figure 11. The results of the analysis of the K20x20 column using SPColumn are that the value of the K20x20 column ratio meets the requirements of 1.36% according to SNI 2847-2019 article 10.6.1 and the value of ϕMn/Mu>1.0 which implies that the column strength is greater than the external load. Reinforcement is shown in Table 8.

Table 8. Reinforcement details of design column

Column Type	K50 x 50	
	Fulcrum	Field
Column Detail		
Dimension, mm	200x200	200x200
Main Reinforcement	2-D12	2-D12
Shear Reinforcement	Ø10-70	Ø10-70

Source: Analysis Result

CONCLUSION

Based on the results of structural analysis and building modeling design, it is declared safe against the influence of external forces on the building by not finding structural elements that experience over strenght (O / S), so that the building structure can be used for residential housing. The results of structural analysis based on SNI obtained the dimensions of a house with a size of 30 meters x 60 meters, one floor, reinforced concrete structure. Column dimensions are 20x20 cm with 2-D12 main

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reinforcement and ϕ10-70 shear reinforcement, beam dimensions are 15x20 cm with 2-D12 main reinforcement and ϕ10-100 shear reinforcement. The building with Seismic Design Category functions as a residential house located in Sentul, Bogor Regency using static earthquake analysis (Equivalent lateral force) and dynamic earthquake analysis (Modal Response Spectrum) has met the requirements of SNI 1726-2019.

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