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Behaviour Analysis of a Reinforced Concrete Building using a Special Moment Resisting Frame (SMRF) SNI - 2019

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ABSTRACT

This paper provides a template for preparing papers for electronic production of the Journal of Education Technology. A well-prepared abstract enables the reader to identify the basic content of a document quickly and accurately, to determine its relevance to their interests, and thus to decide whether to read the document in its entirety. The Abstract should be informative and completely self-explanatory, provide a clear statement of the problem, the proposed approach or solution, and point out major findings and conclusions. The Abstract should be 150 to 250 words in length. The abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited. The keyword list provides the opportunity to add keywords, used by the indexing and abstracting services, in addition to those already present in the title. Judicious use of keywords may increase the ease with which interested parties can locate our article.

Keywords:
SMRF; ETABS; Reinforce Concrete; Structure Analysis

1. INTRODUCTION

Along with the times and the increasing population, the need for infrastructure development is becoming increasingly important to support life. However, one of the main obstacles in the development process is limited land [1][2]. One solution that can be applied to overcome this problem is to erect multi- storey buildings. Therefore, in designing buildings in earthquake-prone areas, careful planning is needed so that the structure remains sturdy and does not suffer damage during an earthquake. Every building must be designed to withstand earthquake loads as well as various other loads that may occur during its use [3]. [4]. Structural analysis is a crucial aspect in planning because through this process internal forces such as bending moments, shear forces, and axial forces can be obtained. [5] [6]

The data is then used to determine the size of structural elements in order to support all loads that have been calculated, including loads due to earthquakes. Based on these considerations, the author is interested in designing the cross-sectional dimensions and reinforcement of reinforced concrete structures that are not only safe but also economical.

Based on these considerations, the author is interested in designing the cross-sectional dimensions and reinforcement of reinforced concrete structures that are not only safe but also economical. Using the data of design acceleration spectral response for short period (SDS) as well as design acceleration spectral response parameter for 1-second period (SD1), it is found that the SDS value at the construction site is 0.667 for medium soil type, while the SD1 value is 0.632 for the same soil category. Based on these data, the project site is included in seismic risk category D. Therefore, in the structural analysis, the Special Moment Support Frame System (SRPMK) method can be applied. The SRPMK method itself is required to be used in the design of buildings located in areas with risk categories D, E, and F, as stipulated in SNI 1726- 2019 [15].

Special Moment Bearing Frame System (SRPMK) is a structural system that has resistance to lateral forces through controlled inelastic deformation mechanisms in structural elements such as beams and columns [7] [8] SRPMK has special design requirements in order to behave in a ductile manner, in accordance with the provisions stipulated [9] concerning structural concrete

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requirements for buildings and other structures.
SRPMK has several key characteristics, namely:

- High Ductality: Able to undergo large deformations without sudden loss of strength capacity.
- Capacity Based Design: The structural elements are designed so that the collapse mechanism occurs in the beam element before the column (strong column-weak beam mechanism).
- Special Detailing: There are reinforcing steel detailing requirements such as channeling length, stirrup hooks, and reinforcement ratio settings to ensure controlled plastic deformation.

Beams in SRPMK must be designed to be capable of undergoing flexural mechanisms with controlled inelastic deformation [10] Key principles in beam design include:

- Flexural and shear capacity design criteria.
- Use of closed stirrups to increase ductility.
- Restriction of reinforcement ratio to avoid premature yielding mechanism.

Columns must have sufficient strength so that the failure mechanism occurs in the beam, not in the column [11]. Key principles in column design include:

- Application of the strong column-weak beam concept.
- Minimum and maximum reinforcement ratio settings.
- Use of tight transverse reinforcement to increase ductility and avoid shear collapse.

Beam-column connections in SRPMK must have sufficient capacity to withstand earthquake loads without premature failure [12] [13]. The main principles in connection design include:

- Details of reinforcement placement so that it can transmit forces properly.
- Reinforcement of plastic joint zones to improve resistance to deformation.
- Use of tight stirrups around joints.

In the design of SRPMK, several technical standards and regulations are used, including:

- SNI 1727-2020, Minimum Design Loads and Related Criteria for Buildings and Other Structures [14].
- SNI 1726:2019 - Earthquake resistance planning procedures for building and non-building structures [15]
- SNI 2847:2019 - Requirements for structural concrete for buildings and other structures.

ACI 318-19 - Building Code Requirements for Structural [16].

2. METHOD

This research was conducted using an analytical method to determine the most economical cross- sectional dimensions. The research process is divided into several stages:

1. Data collection and processing
2. Structure Modeling
3. Structure Analysis
4. Reinforcement Design and Cross Section
5. Control of Deviation

Building data:

1. Building type : Education Facility Building
2. Building width : 42 m
3. Building length : 66 m
4. Number of floors : 10 floors
5. Floor to Floor (Typical) : 3.5 m

Loading Data:

- Self Weight

Weight of Reinforced Concrete: 23.6 kN/m^3

Dead Load of the structure is the self weight of the building (DL)

- Live Load
  Staff Room : 2.40 kN/m^2
  Teacher's Room : 2.40 kN/m^2
  Meeting Room : 4.79 kN/m^2
  Toilet : 2.87 kN/m^2
- Earthquake Load
  SS : 0.788
  S1 : 0.386

The stages carried out in this planning are as in Figure 1 below.

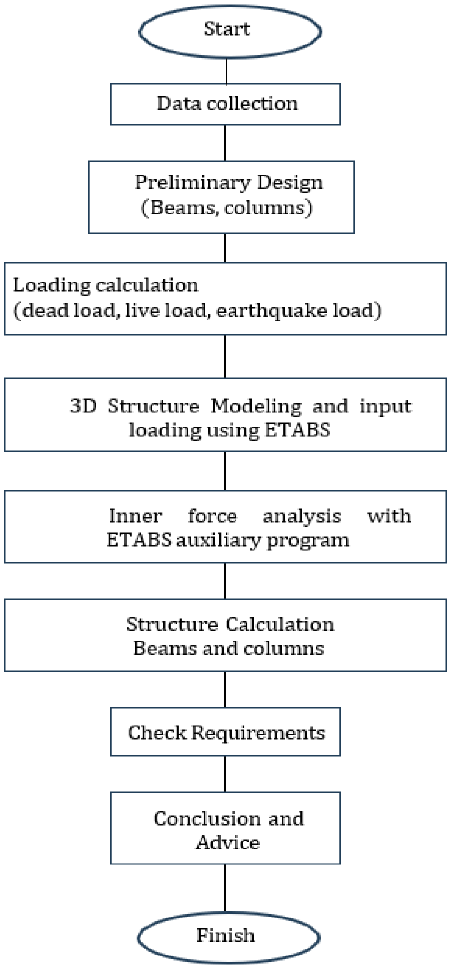


Figure 1. Flowchart Research

3. RESULT AND DISCUSSION

Result

Structure Fundamental Period Control

The fundamental period of the approach Ta is determined from the equation

$$Ta = C_t h_n^x$$

Description:

Hn = height of structure (m) above base to highest level
Ct and x are determined according to Earthquake SNI 03 - 1726 – 2019.

- Minimum Period (T_a)
  T_a = C_t x h_n^x
  = 0.0466 x $35^{0.9}$
  = 1.143 Second
- Maximum Period
  T_{max} = Cu x Ta
  = 1.4 x 1.143
  = 1.60 Second

Table 1. Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	RZ
Modal	1	1.22	0.0000	0.7690	0.0000
Modal	2	1.17	0.7092	0.0000	0.0602
Modal	3	1.06	0.0616	0.0000	0.7094
Modal	4	0.38	0.0000	0.1058	0.0000
Modal	5	0.37	0.0986	0.0000	0.0081
Modal	6	0.33	0.0078	0.0000	0.0980
Modal	7	0.20	0.0000	0.0450	0.0000
Modal	8	0.19	0.0419	0.0000	0.0026
Modal	9	0.17	0.0023	0.0000	0.0421
Modal	10	0.13	0.0000	0.0277	0.0000
Modal	11	0.12	0.0263	0.0000	0.0010
Modal	12	0.11	0.0008	0.0000	0.0265

- Period T_c (Etabs)
  Tx = 1.169 Second
  Ty = 1.221 Second

Based on SNI 1726:2019 [2] the fundamental period of the structure used is determined as follows:

a. If Tc > Tmax then is used Tmax
b. If **< Tc < Cu ×** then is used **Tc**
c. If Tc < $T\alpha$ then is used Ta

- The fundamental period value used is:
  Tx used = 1.169 Second
  Ty used = 1.221 Second

Seismik Response Cofficient

- CS = SDS/(R/Ie)
  = 0.1251
- CSMaks direction x = SD1/(T.R/Ie)
  = 0,0971
- CSMaks direction y = SD1/(T.R/Ie)

= 0.1014

- CSMin direction x = 0.044*SDS*Ie≥0.001
  = 0.0440
- CSMin direction y = 0.044*SDS*Ie≥0.001 = 0.0363
- CS used,
  Cs direction x = 0.1014

  Cs direction y = 0.09710

Building Seismic Weight & Effective Area/Floor

Tabel 2. Effective Seismic Weight from Analysis Program by ETABS-21

Floor	Massa (kg)	Floor Area
Roof Floor	1710201,1	2116
10^{th} floor	2863395,3	1929,83
9^{th} floor	2897258,1	1929,83
8^{th} floor	2946268,5	1929,83
7^{th} floor	3020747,5	1929,83
6^{th} floor	3020747,5	1929,83
5^{th} floor	3020747,5	1929,83
4^{th} floor	2964212,4	1929,83
3^{rd} floor	2987900,4	1929,83
2^{nd} floor	3018060,6	1929,83
Total	278994,6705	kN

From Table 2. Obtainede the results the value of W = 278994.6705 kN.

Table 3. Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	RZ
Modal	1	1.221	0.0000	0.7690	0.0000
Modal	2	1.169	0.7092	0.0000	0.0602
Modal	3	1.055	0.0616	0.0000	0.7094
Modal	4	0.38	0.0000	0.1058	0.0000
Modal	5	0.366	0.0986	0.0000	0.0081
Modal	6	0.332	0.0078	0.0000	0.0980

Modal	7	0.202	0.0000	0.0450	0.0000
Modal	8	0.196	0.0419	0.0000	0.0026
Modal	9	0.179	0.0023	0.0000	0.0421
Modal	10	0.127	0.0000	0.0277	0.0000
Modal	11	0.124	0.0263	0.0000	0.0010
Modal	12	0.114	0.0008	0.0000	0.0265
	Total > 90 %		95%	95%	95%

Cs direction x = 0.1014
Cs direction y = 0.0971
W = 278994,670 kN
$V_{\text{Statik direction x}}$ = Cs.W
$V_{\text{Statik direction x}}$ = 0.1014 x 278994,670
$V_{\text{Statik direction x}}$ = 28300,79 kN (in accrodance with Etabs)
$V_{\text{Statik direction h y}}$ = Cs.W
$V_{\text{Statik direction y}}$ = 0.0971 x 278994,670
$V_{\text{Statik direction y}}$ = 27095,51 kN (in accrodance with Etabs)

Meanwhile, for V Static calculated on the Model (ETABS-2021 Program Analysis), as follows:

Tabel 4. Base Reactions

Output Case	Case Type	Step Type	Step Number	FX	FY	FZ
				kN	kN	kN
Spec Dinamic-X	Lin Resp Spec	Max		21452,5073	33,6491	0
Spec Dinamic Y	Lin Resp Spec	Max		33,6487	21142,2625	0
Static Ex	Lin Static	Step By Step	1	28300,7892	0	0
Static Ex	Lin Static	Step By Step	2	-28300,7892	0	0
Static Ex	Lin Static	Step By Step	3	-28300,7892	0	0
Static Ey	Lin Static	Step By Step	1	0	27095,514	0
Static Ey	LinStatic	Step By Step	2	-8,40E-07	-27095,514	0
Static Ey	LinStatic	Step By Step	3	8,17E-07	-27095,514	0

VxDinamik = 21452,5073 kN
VyDinamik = 21142,2625 kN

Deviation Limit Control Between Floors

This control is used to determine the extent of the deviation between floors based on the deformation of the permit [17] [15] , it is stated that the deflection of the center of mass at the x-level (δx) (mm) is determined follow the question:

$$\Delta_x = \frac{(\delta 2 - \delta 1)\ x\ Cd}{I} < \Delta a = \Delta a = 0.025\ hx$$

Keterangan:
Δx =Deviation between floors
δ = Deflection that occurs
I = Earthqueke primacy factor
hx = height of level below level x
Cd = Deflection manifaction factor

Table 5. Deviation Between Floors X-Direction

Floor	Hsx (mm)	δxe (mm)	δx = Cd.δxe/Ie	Δ (mm)	Δa=0.01hsx	Δ < Δa
Roof floor	3500	55.802	204.61	7.29	35	Ok
10th floor	3500	53.813	197.31	12.41	35	Ok
9th floor	3500	50.428	184.90	17.30	35	Ok
8th floor	3500	45.71	167.60	20.93	35	Ok
7th floor	3500	40.002	146.67	24.89	35	Ok
6th floor	3500	33.214	121.78	27.86	35	Ok
5th floor	3500	25.615	93.92	29.52	35	Ok
4th floor	3500	17.563	64.40	28.69	35	Ok
3rd floor	3500	9.738	35.71	24.17	35	Ok
2nd floor	3500	3.147	11.54	11.54	35	Ok

TABLE 6. Deviation Between Floors Y- Direction

Floor	Hsx (mm)	δye (mm)	δx = Cd. δ xe/Ie	Δ (mm)	Δa=0.01hsx	Δ < Δa
Roof Floor	3500	60.825	223.03	7.54	35	Ok
10th floor	3500	58.77	215.49	12.85	35	Ok
9th floor	3500	55.265	202.64	18.93	35	Ok
8th floor	3500	50.103	183.71	23.32	35	Ok
7th floor	3500	43.743	160.39	27.38	35	Ok
6th floor	3500	36.277	133.02	30.67	35	Ok
5th floor	3500	27.913	102.35	32.49	35	Ok
4th floor	3500	19.051	69.85	31.37	35	Ok
3rd floor	3500	10.495	38.48	26.16	35	Ok
2nd floor	3500	3.361	12.32	12.32	35	Ok

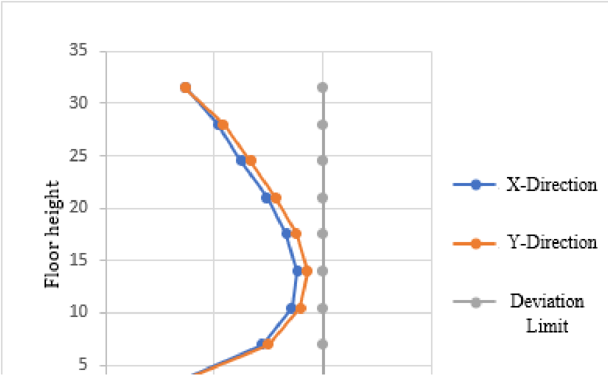


Figure 2. Inter-floor Deviation

Reinforcement of main beam

Main Beam data:
(f'c) = 35 MPa
Flexural Reinforcement (fy): BJTS 420 MPa
Shear Reinforcement (fy): BJTS 420 MPa
Beam Dimensions:
width (b) : 650 mm
lenght (h) : 950 mm
height (Lu) : 8000 mm

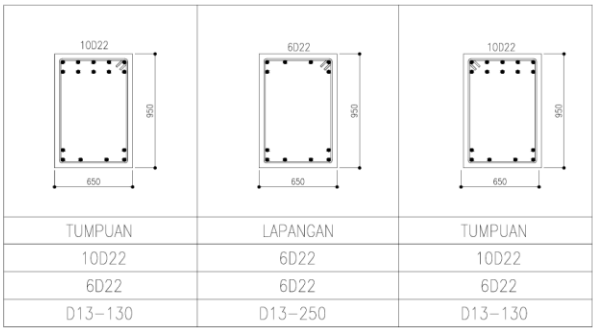


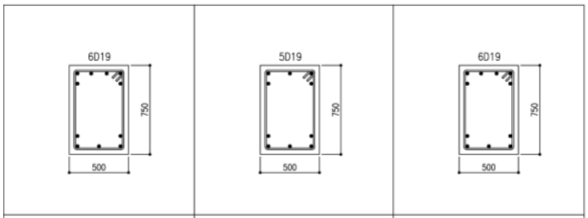
Figure 3. Detailing of main reinforcement beam

Secondary Beam Reinforcement

Secondary beam data:

f'c = 35 MPa

Flexural Reinforcement: BJTS 420 MPa
Shear Reinforcement: BJTS 420 MPa
Width (b) : 500 mm
Height (h) : 700 mm
Beam Length (Lu) : 8000 mm



TUMPUAN	LAPANGAN	TUMPUAN
6D19	5D22	6D19
5D19	5D22	5D19
D13−115	D13−200	D13−115

Figure 4. Detailing of Secondary Beam Reinforcement

Column Reinforcement

Column data
Concrete compressive strength (f'c): 25 Mpa
Yield Point and Diameter of Reinforcement used Flexural Reinforcement :480 MPa
Diameter : D-16
Shear Reinforcement :280MPa
Diameter : D-13
Column Dimensions
Width (b) : 120 cm
Length (h) : 120 cm
Height (t) : 350 cm

Moments and Shear Forces on the beam based on the results of the Structural Analysis in the Etabs program are taken the largest value at each moment as follows:
Momen (Mu) : 37407081,66 kgm
Axial Gains (p) : 14462930,25 kg Attempted to use 5 D 22 Reinforcement

Total area of reinforcement $= 15 * 0{,}25 * \pi * 22^2$

$= 15 * 0{,}25 * 3.14 * 22^2$

= 5699,1 mm2

Condition: Required ≤ Used

$3364.46\ mm^2 \leq 5699.1\ mm^2 \rightarrow$ (OK)

Calculation of stirrup reinforcement Reinforcement Sengkang used = Ø 13 Calculation of spacing between

S1 = 48 * Diameter of stirrup
= 48 * 13
= 624 mm

S2 = 16 * rebar diameter
= 16 * 22
= 352 mm

Then the stirrup distance used is the smallest distance, namely

S2 = 352 mm → 250 mm, then D13-250 is used for stirrup reinforcement.

Discussion

From the results of the internal force analysis with the help of the ETABS program, the value of the fundamental period is obtained where, Tx = 1.169 seconds and Ty = 1.221 seconds while the value of Cs in the x direction = 0.1014 and the value of Cs in the y direction = 0.09710. The final value control of the response spectrum obtained Vx Dynamic = 21452.5073 kN

Vy Dynamic = 21142.2625 kN, then obtained the control limit of deviation between floors, where the largest deviation is on the roof floor of 55.802 mm, this control is used to determine the extent of deviation between floors. [15] the deviation meets the permit deformation.

4. CONCLUSION

The conclusions of this research are as follows: Based on the structural deviation control, it is concluded that the deviation between structural levels that occurs does not exceed the allowable deviation where the largest deviation is on the roof floor of 55.802 mm, still below the maximum value of 90 mm.

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