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Aspects of Structural Design of Residential Buildings in Medan City, North Sumatra Province

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Abstract: Generally, residential buildings, especially low-rise ones in North Sumatra, are not well planned and built with poor supervision. In its planning, it often overrides the calculation of structural analysis. This residential building is known to have many failures during earthquakes. The research team is interested in studying the important elements in the design and construction of residential buildings, focusing on very crucial structural aspects. By considering these aspects comprehensively, it is hoped that the end result will be a sturdy, functional, and sustainable structural design of a residential building for its occupants.

Keywords: Residential Building, Design, Regulation, North Sumatra

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1. Introduction

Building structures must be designed to withstand loads without overloading the material and have deformations that are still within the permitted limits to prevent non-structural damage and inconvenience to occupants. Planning must also pay attention to the maximum deviation due to earthquake loads to limit the possibility of building structural collapse that can cause casualties.

One of the most common building structures in Indonesia is residential buildings. Residential is a building that is used as a residence. For example, for housing, flats, condominiums (large, luxurious, high-rise buildings that are rented, or apartments) and it is possible that there is more than one function, namely residential and commercial functions. The need for residential property is one of the main basic needs for people in Indonesia. This is because the large increase in the number of Indonesia's population needs to be supported by the large availability of housing as well. It is often found that the planning and construction are not carried out with applicable technical rules/rules. In fact, the construction of residential buildings should require in-depth consideration of various aspects, ranging from the needs of residents, comfort, to most importantly the structure of the building itself.

The structure of a building is usually designed based on the earthquake-resistant structure regulations that apply at that time. Learn from the experience of earthquakes in Aceh, West Sumatra, Yogyakarta, Palu and other areas that have resulted in many residential buildings including shophouses being severely damaged by the earthquake which is mostly caused by poor building planning. Figure 1 shows a flat building damaged by an earthquake in Palu, Central Sulawesi in 2018.

North Sumatra is one of the provinces located in the area of a high-intensity earthquake. The potential danger of earthquakes in North Sumatra Province comes from the Sumatran Subduction Zones on the west coast of Sumatra and the Sumatran Great Fault.

From research by Sitompul, M, et al. (2022), it was found that there was an increase in earthquake acceleration parameters in Medan City, North Sumatra Province due to changes in seismic regulations to SNI 1726:2019 (Mizanuddin Sitompul et al., 2022). This causes the demands of the performance of residential building structures to be more considered. Low-rise residential buildings have a low natural period of structure which results in the structure receiving the maximum earthquake load. As the capital of North Sumatra Province, buildings in Medan City are dominated by residential buildings in the form of housing and shophouses which are not much different geometrically.

Figure 1. *Flat buildings damaged by the earthquake in Palu, Central Sulawesi (https://tekno.tempo.co/read/1559585/gempa-palu-2018-gedung-rusun-berbahaya-belum-juga-dibongkar)*

Based on this background, the research team is interested in studying important elements in the design and construction of residential buildings, focusing on very crucial structural aspects. By considering these aspects comprehensively, it is hoped that the end result will be a sturdy, functional, and sustainable structural design of residential buildings for its residents in the city of Medan, North Sumatra Province.

2. Loadings

2.1. Design Load for Residential Buildings

Load is a key consideration in any building design because it determines the nature and magnitude of the hazards or external forces that a building must bear to provide adequate performance (i.e., safety and usability) throughout the life of the structure. The anticipated load is influenced by the use of the building (occupancy and function), configuration (size and shape), and location (climate and site conditions). Ultimately, the type and magnitude of the design load influences critical decisions such as material selection, construction details, and architectural configuration. In order to optimize the value (i.e., performance versus economy) of the final product, therefore, the design burden must be applied realistically.

Although the building considered in this study is essentially a residential house, the principles and concepts related to the building load also apply to other similar types of construction, such as low-rise apartment buildings. In general, the recommended design loads in this study are based on the provisions applicable in the ASCE 7–16 Minimum Design Loads for Buildings and Other Structures (SNI 1726-2019 and SNI 1727-2020) standards. In general, residential structural design has not been treated as a unique engineering discipline or specialized in the development of better and more efficient design practices. Therefore, the discussion is focused on aspects of ASCE 7 and other relevant technical resources for the determination of design loads for residential structures.

2.2. Types of Loading

Buildings and structures, and parts thereof, shall be constructed to safely bear all loads, including dead loads, live loads, roof loads, flood loads, wind loads, and earthquake loads in accordance with the provisions of the code. The construction of buildings and structures in accordance with the provisions of this code must produce a system that provides a complete load path that meets the requirements to transfer the load from the point of origin of the action through the load-bearing elements to the foundation.

Especially for reinforced concrete structures, it can follow the provisions of IBC, ACI and ASCE such as:

1. ACI 318M-19 - Building Code Requirements for Structural Concrete and Commentary (SI Units).
2. ACI 332-20 - Code Requirements for Residential Concrete and Commentary (SI Units).
3. ACI PRC-314-16 (SNI 8900-2020) Guide to Simplified Design for Reinforced Concrete Buildings.
4. ACI PRC-224.5-22 - Contraction Joints in Residential Slabs-On-Ground—TechNote.
5. ASCE 7-16 (SNI 1726-2019) Procedures for earthquake resistance planning for building and non-building structures.
6. ASCE 7-16 (SNI 1727-2020) Minimum design loads and related criteria for buildings.

2.3. Earthquake Load Based on SNI 1726:2019

The design earthquake load is designated as an earthquake with the possibility of exceeding its magnitude during the life of the building structure of 50 years is 2%. To determine the spectral response of the acceleration of the MCER earthquake at ground level, a sesismic amplification factor is needed at the period of 0.2 seconds and 1 second. Amplification factors include vibration amplification factors related to acceleration in short-period vibrations (Fa) and acceleration related amplification factors representing 1-second period vibrations (Fv).

Design Response Spectrum as per Figure 2., with:

a. For periods smaller than T_0, the design acceleration response spectrum (Sa) should be taken from the equation (1)

$$S_a = S_{DS}\left(0,4 + 0,6\,\frac{T}{T_0}\right) \qquad (1)$$

b. For periods greater than or equal to To and less than or equal to Ts, the spectrum of the design acceleration response of Sa is equal to Ss

c. For periods greater than Ts, the acceleration response spectrum of the Sa design, is taken based on the equation (2)

$$S_a = \frac{S_{D1}}{T} \qquad (2)$$

With:

S_{DS} = spectral response acceleration parameters in short periods

S_{D1} = spectral response acceleration parameter at a period of 1 second

T = period of fundamental vibration of the structure

$T_0 = 0,2\,\frac{S_{D1}}{S_{DS}}$

$T_S = \frac{S_{D1}}{S_{DS}}$

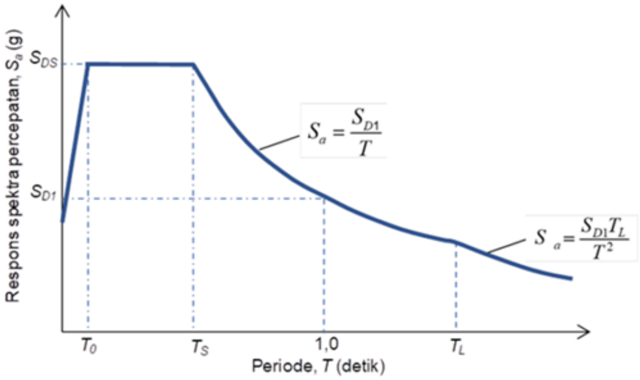

Figure 2. *SNI 1726:2019 Design Response Spectrum*

The studies that discuss the design of residential buildings that are the reference for this research can be seen in Table 1 below.

Table 1. *Table information*

Researchers	Research Title	Research Results
(Faisal & Sari, 2007)	Estimated destruction of shophouse buildings in Medan City due to the worst case scenario of the Nias subduction earthquake	The results of the non-elastic analysis using synthetic earthquake vibration force from the worst scenario of the Nias subduction earthquake found that generally shophouse buildings in Medan City experienced many cracks and some shophouses showed very low performance and could not be repaired due to a high level of destruction.
(Hadibroto et al., 2012)	Evaluation of earthquake resistance of shophouse buildings in Pematang Siantar City	The model shophouse is estimated to have suffered severe irreparable damage, and some are even thought to have collapsed.
(Pahlawan, 2012)	Evaluation of the performance of the structure of shophouse buildings in Medan City under the weight of a distant earthquake due to the influence of the change of function and shape of the building	With a change in the shape and function of a building, especially a shophouse building in Medan City, it is very dangerous for the safety of its occupants.
(Tondi Amirsyah Putra et al., 2018)	Structural deformation of shophouse buildings in Medan due to repeated earthquakes	The Ruko C model has a natural time period that exceeds the standard and deviations that exceed the maximum allowable limit.
(Alfian Wiranata Zebua, 2018)	Analysis of Earthquake Force of Residential Buildings in High Earthquake Areas	The structural model analyzed is a 4-storey regular building for residential houses. The distribution of static earthquake loads was obtained in accordance with SNI 1726:2012.
(Astarini & Utomo, 2021)	Understanding of High-Rise Residential Design Actors in Performance-Based Building Design (PBBD) in Surabaya	42.65% of design actors know the concept of PBBD, 19.12% of design actors do not know the concept, respondents who know and use it in the design process are 22.06% and 16.18% who know PBBD but have not used it in the design process.
(Sodik & Andayani, 2021)	The Effect of the Application of SNI 1726:2019 on the Design of Reinforced Concrete Frame Structure in Indonesia	There was an increase in the design base shear of 128.93% for the x direction and 131.23% for the y direction and there was a decrease in performance from the life safety level to collapse prevention if evaluated against the earthquake of the new regulation, SNI 1726:2019
(Sukrawa & Budiwati, 2022)	Seismic Risk Of Soft Story Residential Building Designed As Infilled Frames	The existence of filler walls should be considered in the analysis of multi-storey portals to avoid the collapse mechanism of the soft storey.
(Yulia & Wardi, 2022)	The Effect of the Implementation of SNI 1726:2019 on Earthquake Load and Deviations in Reinforced Concrete Structures (Case Study: Three-Story Rusunawa Building in Padang City)	There was an increase in the value of shear force and deviation between floors in the building structure which was reviewed by the analysis of dynamic earthquake loading spectral response based on SNI 1726-2019, compared to the analysis based on SNI 1726-2012

Previous studies have mostly reviewed old regulations and there has been no specific research on the technical provisions and design of residential buildings in Medan City, North Sumatra Province.

3. RESEARCH METHODS

3.1. Methodology

This research begins with a literature study and literature review first. The researcher is interested in exploring the important elements in the design and construction of residential buildings, focusing on structural aspects that are very crucial. By considering these aspects comprehensively, it is hoped that the end result will be a sturdy, functional, and sustainable structural design of a residential building for its occupants.

The location of the research is Medan City, North Sumatra Province. As the capital of North Sumatra Province, buildings in Medan City are dominated by residential buildings in the form of housing and shophouses which are not much different in geometry. Residential buildings are modeled to stand on 3 types of sites, namely hard soil (SC), medium soil (SD), and soft soil (SE).

4. Conclusion

The Seismic Force-Resisting System has been regulated in SNI 1726:2019. The selection of this structural system is influenced by the seismic design category. For the city of Medan itself, the following earthquake acceleration data was obtained.

Spectral response parameters,

$S_s = 0{,}656$ g

$S_1 = 0{,}363$ g

Table 2. Amplification Factor

Amplification Factor	SE	SD	SC
Fa	1,450	1,275	1,238
Fv	2,548	1,937	1,500

Table 3. Acceleration Response Parameters

	Site Category		
	SE	SD	SC
$S_{MS} = F_a \times S_s$	0.951	0.836	0.812
$S_{M1} = F_v \times S_1$	0.925	0.703	0.545
$S_{DS} = 2/3 \times S_{MS}$	0.634	0.558	0.541
$S_{D1} = 2/3 \times S_{M1}$	0.617	0.469	0.363
$T_S = S_{D1} / S_{DS}$	0.972	0.841	0.670
$T_0 = 0{,}2 \times T_S$	0.194	0.168	0.134

With the type of residential house utilization, Risk Category II was obtained so that the value of the Earthquake Priority Factor, Ie = 1.0 was obtained.

From the data and results of the acceleration parameters above, it was found that the Seismic Design Category for the City of Medan with the type of residential housing utilization included Category D with S_{DS} values of > 0.5 and S_{D1} > 0.2, both for soft soil (SE), medium soil (SD), and hard soil (SC) conditions.

Table 4. Residential Building Structure System Options

Seismic Force-Resisting System	Structural System Limitations Including Structural Height (m)
A. Bearing wall systems	
1. Special reinforced concrete shear walls	48
2. Intermediate precast shear walls	12
3. Special reinforced masonry shear walls	48
4. Light-frame (wood) walls sheathed with wood structural panels rated for shear resistance	20
5. Light-frame (cold-formed steel) walls sheathed with wood structural panels rated for shear resistance or steel sheets	20
6. Light-frame walls with shear panels of all other materials	10
7. Light-frame (cold-formed steel) wall systems using flat strap bracing	20
B. Moment-Resisting Frame Systems	
1. Steel special moment frames	-
2. Steel special truss moment frames	48
3. Steel intermediate moment frames	10
4. Special reinforced concrete moment frames	-
5. Steel and concrete composite special moment frames	-
6. Steel and concrete composite partially restrained moment frames	30
7. Cold-formed steel—special bolted moment frame	10
C. Dual Systems With Special Moment Frames Capable Of Resisting At Least 25% Of Prescribed Seismic Forces	
1. Steel eccentrically braced frames	-
2. Steel special concentrically braced frames	-
3. Special reinforced concrete shear	

	walls	-
4.	Steel and concrete composite eccentrically braced frames	-
5.	Steel and concrete composite special concentrically braced frames	-
6.	Steel and concrete composite plate shear walls	-
7.	Steel and concrete composite special shear walls	-
8.	Special reinforced masonry shear walls	-
9.	Steel buckling-restrained braced frames	-
10.	Steel special plate shear walls	-
D.	Dual Systems With Intermediate Moment Frames Capable Of Resisting At Least 25% Of Prescribed Seismic Forces	
1.	Steel special concentrically braced frames	10
2.	Special reinforced concrete shear walls	48
3.	Steel and concrete composite special concentrically braced frames	48

For special moment-bearing frame structures and special wall structures, concrete compressive strength is required to be a minimum of 21 Mpa. Nonprestressed bars and wires shall be deformed, except plain bars or wires are permitted for use in spirals.

Maximum nominal coarse aggregate size should not be larger than (a), (b), or (c).

1. One-fifth (1/5) of the narrowest dimension between sides of forms
2. One-third (1/3) of the depth of slabs
3. Three-fourths (3/4) of the minimum clear spacing between parallel reinforcing bars.

A maximum nominal size of 19 mm is recommended for columns, girders, beams, and joists. Except for structural slabs, a larger size can be used if it meets the limits given in (a) through (c).

Maximum value of Fy permitted for design calculation (Mpa) on special seismic system for nonprestressed deformed reinforcement is determined by its usage as follows:

a. Flexure, axial force, and shrinkage and temperature, max. 420.
b. Lateral support of longitudinal bars or concrete confinement, max. 700.
c. Shear, max 420.

The dimensions of the beam must meet (a) to (c):

a. Net span, ln, must be at least 4d
b. Width of cross-section, must be at least 0.3h and 250 mm
c. The projected beam width that exceeds the width of the stacker column must not exceed the smallest values of c2 and 0.75c1 on each side of the column

The dimensions of the column must meet (a) to (b):

a. The dimensions of the smallest cross-section, measured on a straight line passing through the center of the geometry, not less than 300 mm
b. The ratio of the smallest cross-sectional dimension to its perpendicular dimension is not less than 0.4.

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