JURNAL MULTIDISIPLIN MADANI (MUDIMA)
Homepage: https://journal.formosapublisher.org/index.php/mudima
ISSN: 2808-5639 (Online)
Research Article

Volume 4, No 11, November (2024) | DOI: https://doi.org/10.55927/mudima.v4i11.12972 | Page: 1689-1701

The Effect of Concrete Quality on Structural Period

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ARTICLE INFO

Keywords: Structural Vibration Period, Formula, Concrete Quality, Earthquake Load

Received: 17 September
Revised : 18 October
Accepted: 28 November

ABSTRACT

An important consideration in structural calculations is a structure's vibration period, which establishes the size of the seismic stresses applied during the design phase. North Sulawesi falls within the category of high-risk earthquake region. The formula for calculating the vibration period, as outlined in SNI 03-1726-2012 is based on Goel and Chopra's (1997) approach and ASCE seismic standards. Nevertheless, SNI 03-1726-2012's formula has a notable limitation: it applies the same approach to all earthquake zones, regardless of whether the area is high-risk or low-risk. This study aims to develop a structural period formula tailored following the SNI 03-1726-2012 earthquake design guidelines and to investigate how the quality of the concrete affects the structural lifespan. Three-dimensional structural modeling of typical structures with floors is used in the study. heights of 4 meters and widths of 4 meters, specifically focusing on mid-rise reinforced concrete buildings with 12 floors. Structural modeling is conducted using the ETABS software, and regression analysis is performed on the resulting structural period values to derive the most accurate formula. The regression analysis yielded two optimal formulas, each with a correlation value of 98%: T=0.105H0.785T = 0.105 H^{0.785}T=0.105H0.785 and T=0.311n0.785T = 0.311 n^{0.785}T=0.311n0.785. The findings indicate that lower concrete quality leads to an increased structural period, albeit with a smaller overall impact. Thus, concrete quality significantly influences the structural period

INTRODUCTION

One of the most important factors in the design of building structures is the vibration period. Knowing the natural vibration period beforehand is crucial for determining the seismic base shear force operating on the structure in earthquake-resistant design.. This parameter can be determined either through empirical equations or dynamic analysis using specialized software. Jacobs (2008) highlighted that accurately determining the vibration period significantly affects earthquake-resistant design outcomes.

North Sulawesi is classified as a high earthquake risk area. The vibration period formula in SNI 03-1726-2012 originates from the ASCE earthquake standards and the model proposed by Goel and Chopra (1997). However, the Due of its equal application throughout all seismic zones, regardless of differing risk levels, the SNI 03-1726-2012 methodology has limitations. Essentially, a structure's mass and rigidity determine how long it vibrates.

—parameters that cannot be precisely defined until the structure is designed. Yet, seismic design cannot proceed without an initial estimation of the vibration period. Addressing these challenges, the author conducted a study entitled: *The Effect of Concrete Quality on Structural Period.*

METHODS

Earthquake Load Resisting Structural System

Frame that resists moments A moment-resisting frame is a three-dimensional structural system that uses bending and shearing processes to withstand forces in its connections and constituent parts. Ordinary moment-resisting frames, intermediate moment-resisting frames, and special moment-resisting frames are the three types of this system. The degree of earthquake danger in the location where the structure is located determines which of these types are used and which are chosen.

1. **Ordinary Moment-Resisting Frame System (SRPMB) or Fully Elastic**
   This structural type is designed with a ductility factor of 1.0, ensuring the frame remains elastic and undamaged even under strong earthquake forces.
2. **Intermediate Moment-Resisting Frame System (SRPMM) or Partially Ductile**
   This system has a ductility factor ranging from 1.0 (fully elastic) to 5.3 (fully ductile), offering moderate flexibility and earthquake resistance.
3. **Special Moment-Resisting Frame System (SRPMK) or Fully Ductile**
   This frame type is designed to withstand post-elastic deformations up to the ultimate collapse limit, with a ductility factor of 5.3, providing high flexibility and resilience.

Structural Analysis Due to Earthquake

Response Spectrum

1) One dynamic technique in structural analysis is response spectrum analysis, which applies an earthquake response spectrum from a design to a mathematical model of a structure. In order to assess the structural reaction to a design earthquake, this technique combines the responses of various vibrational modes.
2) A A graphical tool called a response spectrum shows the maximum responsiveness of a system with one degree of freedom when dynamic loading is applied. The graph's vertical axis displays the peak response in terms of displacement, velocity, or acceleration, while the horizontal axis depicts the structure's frequency or period.
3) For irregular building structures, it is essential to assess the impact of design earthquakes by incorporating dynamic earthquake loads. This assessment requires dynamic response analysis, which takes into account all potential vibrations that the structure might experience.

Design Response Spectrum

When this code necessitates the use of a If site-specific ground motion processes and design response spectrum are not used, the response spectrum curves need to be created based on the provided drawings and in accordance with the specified provisions.

1) For periods smaller than T_0, the design acceleration response spectrum, S_a, shall be taken from the equation
2) $S_a = S_{DS}(0{,}04 + 0{,}6\frac{T}{T_0})$
3) Period is greater than or equal to T_0 and less than or equal to T_s, the design acceleration response spectrum, S_a, is equal to the S_{DS}
4) For periods greater than T_s, the design acceleration response spectrum, S_a, is taken based on the equation:

$$S_a = \frac{S_{D1}}{T}$$

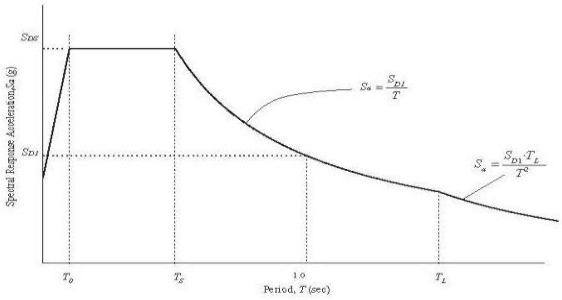
Description:

SDS: The structure's anticipated reaction to seismic acceleration during brief vibration periods is represented by the design acceleration spectral response parameter for short durations.

SD1: Design acceleration spectral response parameter that shows the structure's seismic reaction over a one-second period at a fundamental vibration period of one second.

T: Fundamental vibration period of the structure, signifying the structure's inherent oscillation period under dynamic loads.

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



Source: Planning Techniques for Earthquake Protection in Both Non-Building and Building Constructions in Accordance with SNI 1726-2012, Figure 1, Page 23

Figure 1. Design Response Spectrum

Indonesian Earthquake Area According to SNI 1726-03-2012

Planned Earthquake

Both building and non-building structures, as well as the equipment and components that go with them, must be designed and evaluated with the impacts of a projected earthquake in mind. A planned earthquake is defined by RSNI 03-1726-2012 as an occurrence that has a 2% chance of occurring within a building structure's 50-year design life. When opposed to irregular designs, structures with simple, regular, and symmetrical forms typically exhibit higher earthquake resilience (Pauly and Priestley, 1992).

In order to include all structural elements, such as floor slabs, beams, and columns, the building structure is represented in three dimensions (3D) in this study. The model's structural arrangement is regular, with floor heights of 4 meters and spans of 4 meters, as depicted in the accompanying illustration.

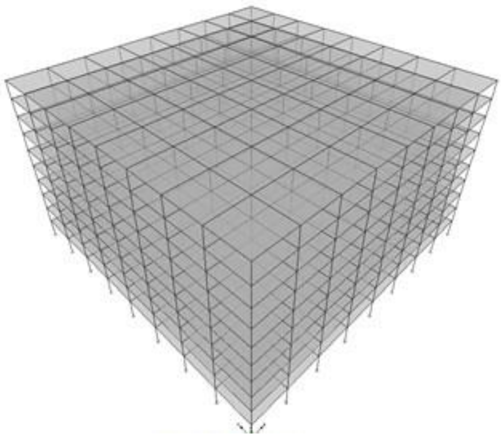


Figure 2. Regular Structure Modeling

The following technical data were used in the analysis:

- **Building Construction**: Reinforced concrete structure
- **Building Category**: Mid-rise, 12 floors
- The material specifications used in the analysis include: *(Details about material specifications should follow, such as concrete grade, steel grade, or other relevant properties.)*
- fc' Beam and Slab: 20 MPa
- fc' Column: 30 MPa
- Modulus of elasticity (Ec) of concrete beam and slab:
  $4700\sqrt{fc'}$
  $4700 = \sqrt{20} = 21019.03$ MPa
- Modulus of elasticity (Ec) of column:
  $4700\sqrt{fc'}$

$4700 = \sqrt{30} = 25742.96$ Mpa

  - Fy Steel: 400 Mpa
  - Es: 2.1 x 106 kg/cm2

1. Earthquake Load Resisting Structural System

The Moment Resisting Frame System (SRPM) is the Earthquake Load Resisting Structural System used in this investigation. Because of the significant seismic danger in North Sulawesi, the Special Moment Resisting Frame System (SRPMK) was selected for its superior ductility and ability to withstand seismic forces effectively.

The seismic design parameters are as follows:

- Earthquake Importance Factor (Ie): 1
- Response Modification Factor (R): 8
- Overstrength Factor (Ωo): 3
- Deflection Amplification Factor (Cd): 5.5

2. Load Selection

Dead loads, live loads, and seismic loads are among the loads affecting the structure. ETABS software is used to automatically compute the structure's self-weight. SNI 1727:2013, which establishes the minimal load requirements for building and other structural design, is followed for choosing loads.

Load Calculations:

1) Dead Load Calculation:
   - Slab Weight:
     0.12 m×2400 kg/m3=288 kg/m20.12 \, \text{m} \times 2400 \, \text{kg/m}^3 = 288 \, \text{kg/m}^20.12m×2400kg/m3=288kg/m2
   - Finishing Load:
     100 kg/m2100\,\text{kg/m}^2100kg/m2
   - Total Dead Load:
     288 kg/m2+100 kg/m2=388 kg/m2288 \, \text{kg/m}^2 + 100 \, \text{kg/m}^2 = 388 \, \text{kg/m}^2288kg/m2+100kg/m2=388kg/m2
2) Floor Live Load:
   - Typical Floors: 240 kg/m2240 \, \text{kg/m}^2240kg/m2
   - Roof: 100 kg/m2100 \, \text{kg/m}^2100kg/m2
3) Earthquake Load Calculation:
   - The earthquake load is determined using the Response Spectra Method, specifically for the North Sulawesi region, by referring to data available on the Ministry of Public Works website:

puskim.pu.go.id/Aplikasi/desain_spektra_indonesia_2011.

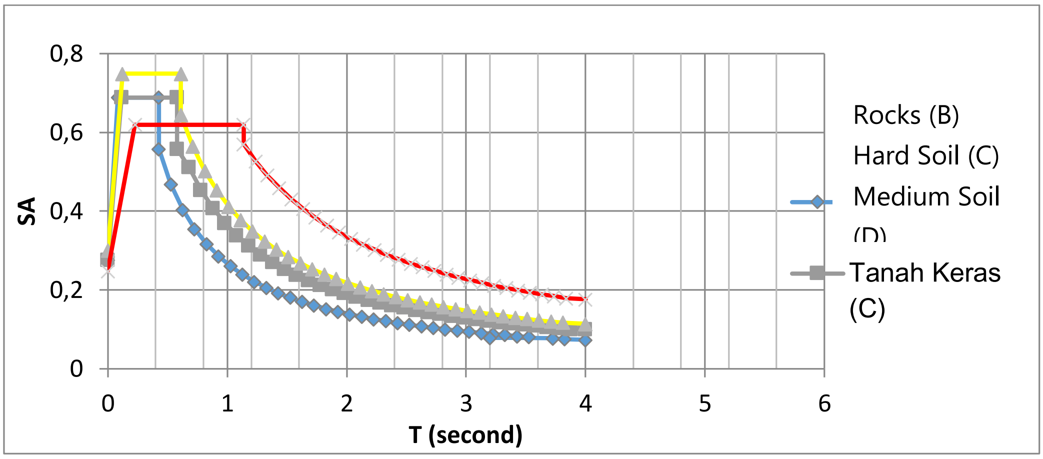
- Coordinates for the city of Manado are entered to obtain the spectral acceleration values.

Seismic Considerations:

- The spectral acceleration values correspond to the Risk-Targeted Maximum Considered Earthquake (MCER), which assumes a 1% probability of collapse in 50 years for the building. Location: (Lat: 1.5049538726942067, Long: 124.85375985503197)

Table 1. Acceleration Spectral of Rock Type: Medium Soil D

Variable	Velue	T (sec)	SA (g)	T (sec)	SA (g)	T (sec)	SA (g)
PGA (g)	0.450	0	0.3	T_S + 1.2	0.24	T_S + 2.7	0.134
S_S (g)	1.034	T_0	0.749	T_S + 1.3	0.228	T_S + 2.8	0.13
S_1 (g)	0.441	T_S	0.749	T_S + 1.4	0.217	T_S + 2.9	0.127
C_{RS}	1.052	T_S + 0	0.644	T_S + 1.5	0.207	T_S + 3	0.123
C_{R1}	1.065	T_S + 0.1	0.564	T_S + 1.6	0.198	T_S + 3.1	0.12
F_{PGA}	1.050	T_S + 0.2	0.502	T_S + 1.7	0.19	T_S + 3.2	0.117
F_A	1.086	T_S + 0.3	0.453	T_S + 1.8	0.182	4	0.114
F_V	1.559	T_S + 0.4	0.412	T_S + 1.9	0.175		
PSA (g)	0.473	T_S + 0.5	0.378	T_S + 2	0.169		
S_{MS} (g)	1.123	T_S + 0.6	0.349	T_S + 2.1	0.163		
S_{M1} (g)	0.687	T_S + 0.7	0.324	T_S + 2.2	0.157		
S_{DS} (g)	0.749	T_S + 0.8	0.303	T_S + 2.3	0.152		
S_{D1} (g)	0.458	T_S + 0.9	0.284	T_S + 2.4	0.147		
T_0 (sec)	0.122	T_S + 1	0.268	T_S + 2.5	0.143		
T_S (sec)	0.612	T_S + 1.1	0.253	T_S + 2.6	0.138		



SOURCE: //PUSKIM.PU.GO.ID/APLIKASI/DESAIN_SPEKTRA_INDONESIA_2011

Figure 3. Spectral Response Spectral Response

5. Method Selection

The method used is Spectral Response, with medium soil rock type

6. Program used

In this thesis, the software used in calculating the Structural ETABS 2013 Version 13.1.1 Original is used throughout this time. To determine the correlation regression between height and the natural vibration period using the T Period data, Spss statistical program version 17

7. References to be used

The reference books utilized in this research include *Earthquake Resistance Planning Procedures for SNI 03-1726-2012, Minimum Load for Designing Buildings and Other Structures, Building and Non-Building Structures Earthquake Resistance Planning Standards for Building Structures SNI 03 - 1726 - 2002; Structural Concrete Requirements for Buildings SNI 03 - 2847 - 2013;*, and various journals related to the structural period formula.

RESULTS AND DISCUSSION

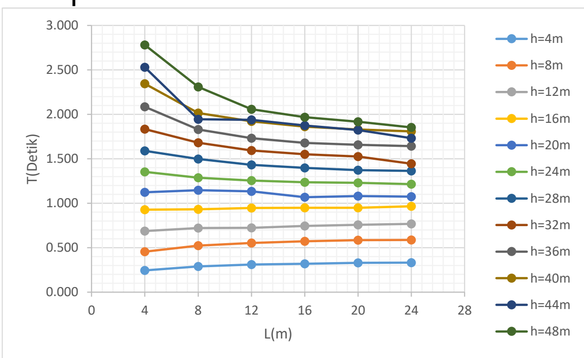
Based on the results processed using the Etabs Program, 72 values of the structure period were obtained. These values will then be used in the To determine the optimal formula, use regression analysis. Table 2 contains the values for the structural period

.

Table 2. Structures' Period Values Range from one to Twelve Stories, with Six Span Variants

T		L (m)					
Level	Tall(m)	L = 4	L = 8	L = 12	L = 16	L = 20	L = 24
1	4	0,245	0,290	0,310	0,320	0,330	0,333
2	8	0,455	0,523	0,554	0,573	0,585	0,587
3	12	0,687	0,721	0,724	0,744	0,758	0,768
4	16	0,927	0,933	0,947	0,949	0,950	0,965
5	20	1,124	1,146	1,135	1,068	1,080	1,075
6	24	1,353	1,287	1,256	1,236	1,230	1,216
7	28	1,590	1,498	1,431	1,398	1,373	1,363
8	32	1,834	1,680	1,594	1,552	1,526	1,444
9	36	2,086	1,829	1,731	1,679	1,658	1,643
10	40	2,345	2,015	1,922	1,862	1,829	1,809
11	44	2,529	1,945	1,939	1,875	1,823	1,731
12	48	2,780	2,308	2,058	1,969	1,916	1,853

From Table 2, the value of the structural period of The structural period value is derived in the Etabs software and ranges from 1 to 12 floors, with variations of 6 spans of 4 to 24 meters. For more information, the structural period value is displayed as a graph that creates a pattern, as shown in Figure 4.



Source: Ms. Excel Processed Data

Figure 4. Graph of the Relationship between the Lengthening and the Duration of the Structure

Judging from the existing Pattern Graph, the relationship between Length Increase and Structural Period is Varied, from a height of 4 m The pattern tends to be flat, where the span length has no effect on the structural period, and it occurs in the Low Rise Building category. The blue line is 16 meters high, while the yellow line spans 4 to 24 meters. In contrast, a 20-meter-tall dark blue line to a 48-meter-tall green line with a 4- to 12-meter span, the Pattern that occurs the value In the

Mid Rise Building category, there is a notable shift in the pattern to the structural period value when the structural period declines. In the design process, a small structural vibration time will result in a significant base shear value. Once the structure period value has been determined, the value is utilized in the regression analysis to derive the formula; Table 3 provides a more detailed view of the structural period formula's regression analysis findings.

Formula Period Structure

Table 3. Results of Formula Period Structure Regression Analysis

No	Funtion	C	r (%)	
1	$T = C_1 H^{C2}$	C_1 = 0,105	98	T = f (H)
		C_2 = 0,785		
2	$T = C_1 n^{C2}$	C_1 = 0,311	98	T = f (n)
		C_2 = 0,785		

From the results presented in **Table 3**, using **Formula 1**, where T=f(H)T = f(H)T=f(H) is expressed as a power function, a correlation value of **98%** was achieved. Similarly, for **Formula 2**, where T=f(n)T = f(n)T=f(n) is also modeled as a power function, a correlation value of **98%** was obtained.

The comparison of structural period values derived from the HHH function is detailed in **Table 4**, allowing for a direct evaluation of the results obtained from both formulas.

Table 4. A Comparison of the H Function Structure's Values Period

H(m)	SNI 1726 – 03 - 2002	SNI 1726 – 03 - 2012	North Sulawesi Formula Proposal
4	0,170	0,160	0,312
8	0,285	0,299	0,537
12	0,387	0,431	0,738
16	0,480	0,558	0,926
20	0,567	0,682	1,103
24	0,651	0,803	1,272
28	0,730	0,923	1,436
32	0,807	1,041	1,595
36	0,882	1,157	1,749
40	0,954	1,272	1,900
44	1.025	1,386	2,048
48	1.094	1,499	2,193

The comparison of the structural period values based on the HHH function, as shown in Table 4, considers building heights ranging from 4 m to 48 m. The analysis reveals that the structural period values for Sulut are generally greater than those specified in SNI 03-1726-2002 and SNI 03-1726-2012, as derived from the HHH function.

For a visual representation, the comparison of the structural period formulas based on the HHH function is illustrated in Figure 5, providing a clearer understanding of the differences and trends across the datasets.

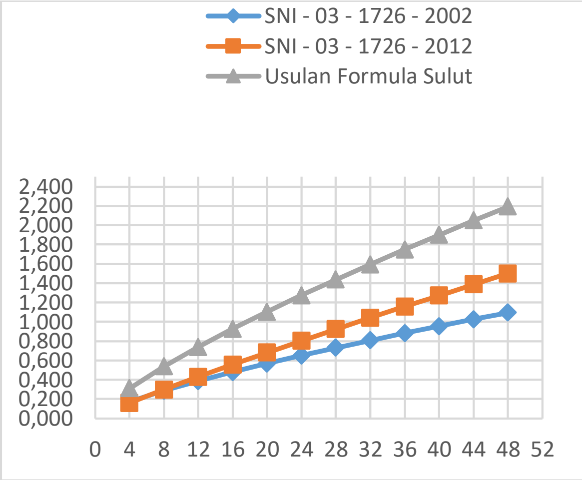


Figure 5. Comparison Graph of Formula the H Function's Period Structure

A downward-sloping graph depicting rule SNI 1726-03-2002 (the previous rule) shows that the rise in the structural period decreases with building height. However, the new rule, SNI 1726-03-2012, is situated above the previous regulation graph., suggesting that H (m) v regulation is considered more favorable. The graph of the new regulation has a steeper slope, meaning that as the building height increases, the structural period increases more significantly. This implies that taller buildings have a higher sensitivity to changes in the structural period, which indicates a higher level of risk. Therefore, the structural period needs to be carefully considered and analyzed.

The revised regulation (new regulation) improves upon the old regulation, providing more economical and better outcomes. The slope of the The slope of the proposed North Sulawesi formula and SNI 1726-03-2012 (new rule) are near and parallel, suggesting that the proposed North Sulawesi formula's behavior is consistent with the tendencies of the new regulation. This contrasts with the old regulation, whose slope shows a different trend.

For a comparison of the structural period formula based on the H-function structure and concrete quality, the graph in Figure 6 provides a visual representation.

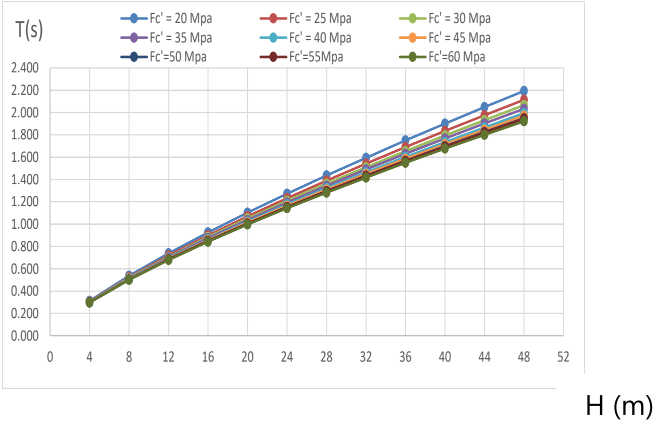


Figure 6. Comparison Chart of Formula Period Structure Function H based on Concrete Quality

The Fc' = 20 Mpa curve is above the sloped Fc' = 60 Mpa graph, which indicates that the higher the concrete quality, the less the structural period will grow. The dark Fc' = 60 Mpa and Fc' = 20 Mpa graphs indicate that the structural period increases with decreasing concrete quality, with little effect on the structural period. The structural period is impacted by the concrete's quality. Following the acquisition of the structural period formula, it is applied to an eight-story structure, comparing the SK-SNI-03-1726-2012 formula

Conclusion

- This study demonstrates that, on the assumption of medium soil type, the suggested formula for the Structural Period in North Sulawesi for the Mid Rise building category is: T = 0.105 H0.785 T = 0.311 n 0.785
- The influence on the structural period is minimal; the higher the concrete quality, the longer the structural period. The structural period is impacted by the quality of the concrete.

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