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The effect of concrete quality on structure period

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Abstract
The period of vibration of a structure is a very important property in structural calculations. Because the structure's vibration period will determine how much earthquake load is applied in the structure design process. The North Sulawesi region is an earthquake area with a high risk. The vibration time formula used is based on SNI 03 - 1726 – 2012 adopted from the ASCE earthquake regulations and the formula proposed by Goel and Chopra (1997). The proposed structural period formula in SNI 03 – 1726 – 2012 has the weakness of treating each earthquake zone zone for both high and low risk areas. This research study aims to formulate the structure period designed according to the SNI 03 - 1726 - 2012 Building earthquake regulations and determine the influence of concrete quality on the structure period. Research Method for Modeling 3 Dimensional Structures in Regular Buildings with a height between floors of 4m and a width of 4m, Reinforced Concrete Structure Building Category, 12 Floor Mid Rise Building. To realize this in real buildings, the Etabs Program is used in Structural Modeling. After obtaining the results of the Structure Period values, a regression analysis is made to obtain the best formula value. The results of the regression analysis showed that the 2 best formulas were based on a correlation value of 98%. From the research results, the recommended formula is T = 0.105 H0.785, T = 0.311 n0.785. The Influence of Concrete Quality on the Structure Period. The smaller the Concrete Quality, the greater the increase in the Structure Period, the impact on the structure period which is small. Concrete Quality affects the Period of the Structure.

Keywords: Structure vibration period, formula, concrete quality, earthquake load

1. Introduction

The period of vibration of a structure is a quite important parameter in the design process of a building structure. In planning earthquake-resistant building structures, initial information regarding the natural vibration time of the building structure is needed to calculate the seismic base shear forces that work. The natural vibration time of a building structure can be determined using empirical equations, or can also be determined through a dynamic analysis procedure with the help of available software. Jacobs (2008) [10] stated that determining the period of vibration of a structure can have a big impact on earthquake resistant design

The North Sulawesi region is an earthquake area with a high risk. The vibration time formula used is based on SNI 03 – 1726 – 2012 adopted from the ASCE earthquake regulations and the formula proposed by Goel and Chopra (1997) [8]. The proposed Structural Period formula in SNI 03 – 1726 – 2012 has a weakness, namely the same treatment for each earthquake area zoning for both high and low risk areas. In principle, the vibration period of a structure is the product of mass and stiffness which cannot be obtained if the structure has not been designed completely because mass and stiffness do not yet exist. But basically seismic design cannot begin without a period of structural vibration.

2. Literature Review

2.1 Earthquake Load Resisting Structural System

Moment resisting frame (moment resisting frame)

A moment-bearing frame is a space frame system in which the structural components and joints resist forces acting through shear and axial bending action. This system consists of three types, namely: ordinary moment resisting frames, intermediate moment resisting frames, and special moment resisting frames. The function and use of the three supporting frames depends on the earthquake risk in the area where the structure is located.

a. Normal Moment Resisting Frame System (SRPMB) or full elastic.
   Structures that have ductility with a ductility factor scale value of 1.0 must be planned so

that they continue to behave elastically when a strong earthquake occurs.

b. Intermediate Moment Resisting Frame System (SRPMM) or partial ductile. A building structure with a ductility factor scale value between a fully elastic building of 1.0 and a fully ductile building of 5.3.

c. Special Moment Resisting Frame System (SRPMK) or full ductile. A structural system that is capable of experiencing post-elastic deviation when it reaches the greatest collapse threshold condition, namely reaching a ductility factor value of 5.3.

2.2 Analysis of Structures Due to Earthquakes

2.2.1 Spectrum Respon

Response spectrum analysis is a method of dynamic analysis of structures where a mathematical model of the structure is applied to a planned earthquake response spectrum and based on this the response of the structure to the planned earthquake is determined through the superposition of the responses of each variety. Response Spectrum is a graph that shows the maximum response of a system with one degree of freedom. The abscissa of the spectrum is the frequency or period of the structure and the ordinate is the maximum response in the form of deviation, speed and acceleration of the structure.

For irregular building structures, the impact of the planned earthquake must be viewed as the effect of earthquake loading which behaves dynamically and the analysis is carried out based on dynamic response analysis, namely a dynamic analysis that takes into account all types of vibrations that may occur in the building structure.

2.2.2 Design response spectrum

If a design response spectrum is required by this code and site-specific ground motion procedures are not used, then a design response spectrum curve must be developed with reference to the drawings and following the provisions below:

For periods smaller than T0, the design acceleration response spectrum, S^a, should be taken from eq

$$S_a = S_{DS}\left(0{,}04 + 0{,}6\,\frac{T}{T_0}\right) \qquad (1)$$

For periods greater than or equal to T0 and less than or equal to Ts, the design acceleration response spectrum, S^a, is equal to SDS.

For periods greater than Ts, the design acceleration response spectrum, S^a, is taken based on the equation:

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

2.2.3 Information

SDS = design acceleration spectral response parameter for a short period

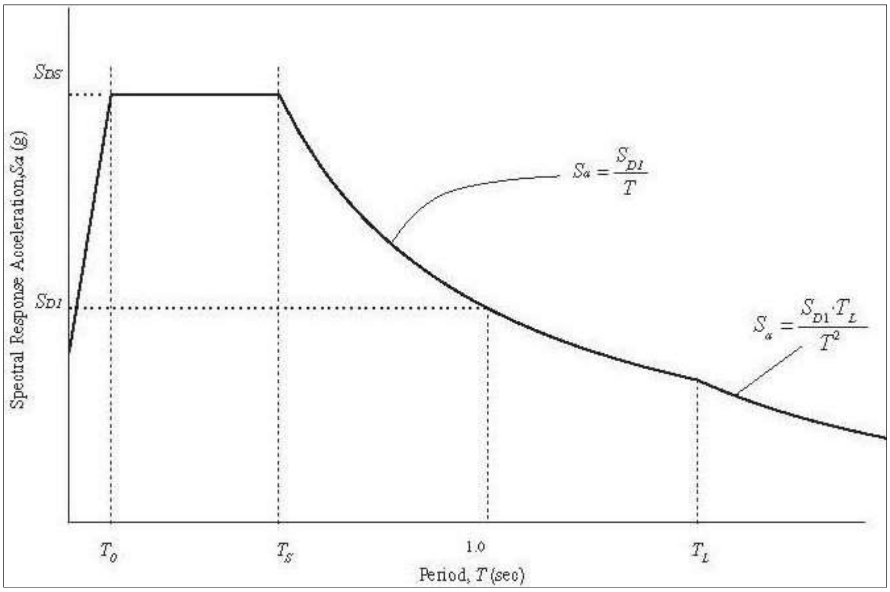
SD1 = design acceleration spectral response parameter for a period of 1 second

T = fundamental vibration period of the structure

$$T0 = 0{,}2\,\frac{S_{D1}}{S_{DS}} \qquad (3)$$

$$TS = \frac{S_{D1}}{S_{DS}} \qquad (4)$$

Image of the design response spectrum can be seen in Figure 1.



Source: Procedures for earthquake resistance planning for building and non-building structures according to (SNI 1726-2012, Figure 1, p. 23)

Fig 1: Design Response Spectrum

2.3 Indonesian Earthquake Area according to SNI 1726-03-2012

Earthquake Plan. The impact of planned earthquakes must be reviewed in the planning and evaluation of building and non-building structures, as well as various parts and equipment in general. In accordance with RSNI 03-1726-2012, a planned earthquake is defined as an earthquake with a probability of exceeding its magnitude during the 50 year life of the building structure is 2%. Buildings with regular, simple and symmetrical shapes will behave better against earthquakes than buildings that are irregular (Pauly and Priestley, 1992) [11].

3. Rresearch Method

In this research, the building structure was modeled in three dimensions (3D) including all structural elements, namely floor plates, beams and columns, a regular structure was used with a height between floors of 4 m and a width of 4 m, as shown in the following figure:

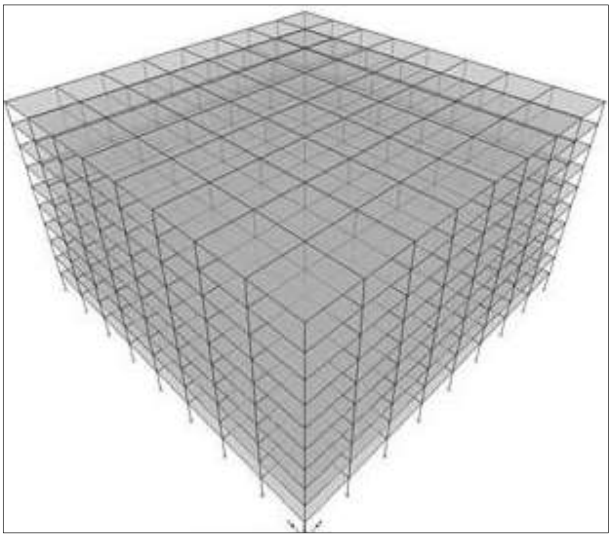


Fig 2: Regular Structure Modeling

3.1 The technical data used in the analysis are as follows

- **Building construction:** Reinforced concrete structures
- **Building Category:** Mid Rise, 12 Floors

3.2 The specifications for the materials used are as follows

- **fc' Beams and Plates:** 20 MPa
- **fc' Column:** 30 MPa
- Modulus of elasticity (Ec) of concrete beams and slabs:
- 4700 $\sqrt{fc'}$
- 4700 $\sqrt{20}$ = 21019.03 MPa
- Modulus of elasticity (Ec) of the column:
- 4700 $\sqrt{fc'}$
- 4700 $\sqrt{30}$ = 25742.96 Mpa
- **Steel Fy:** 400 Mpa
- **Es:** 2,1 x 10^6 kg/cm^2

3.3 Earthquake Load Resisting Structural Systems: The type of earthquake load-bearing structural system used is the Moment Resisting Frame System (SRPM). Because North Sulawesi is an area prone to earthquakes, a Special Moment Resisting Framing System type was chosen. The priority factors for earthquakes are taken Ie = 1, R = 8, Ωo = 3 and Cd = 5,5.

Load Selection. The loads acting on the structure are in the form of dead load, live load and earthquake load, the structure's own weight is calculated automatically using etabs. Load selection refers to the minimum load for designing buildings and other structures, SNI – 1727 – 2013

Dead load calculation

Plate weight = 0,12m x 2400 kg/m^3 = 288 Kg/m^2

Finishing = 100 kg/m^2 +

Total = 388 Kg/m^2

Floor live loadi = 240 Kg/m^2

Floor (roof) live load = 100 Kg/m^2

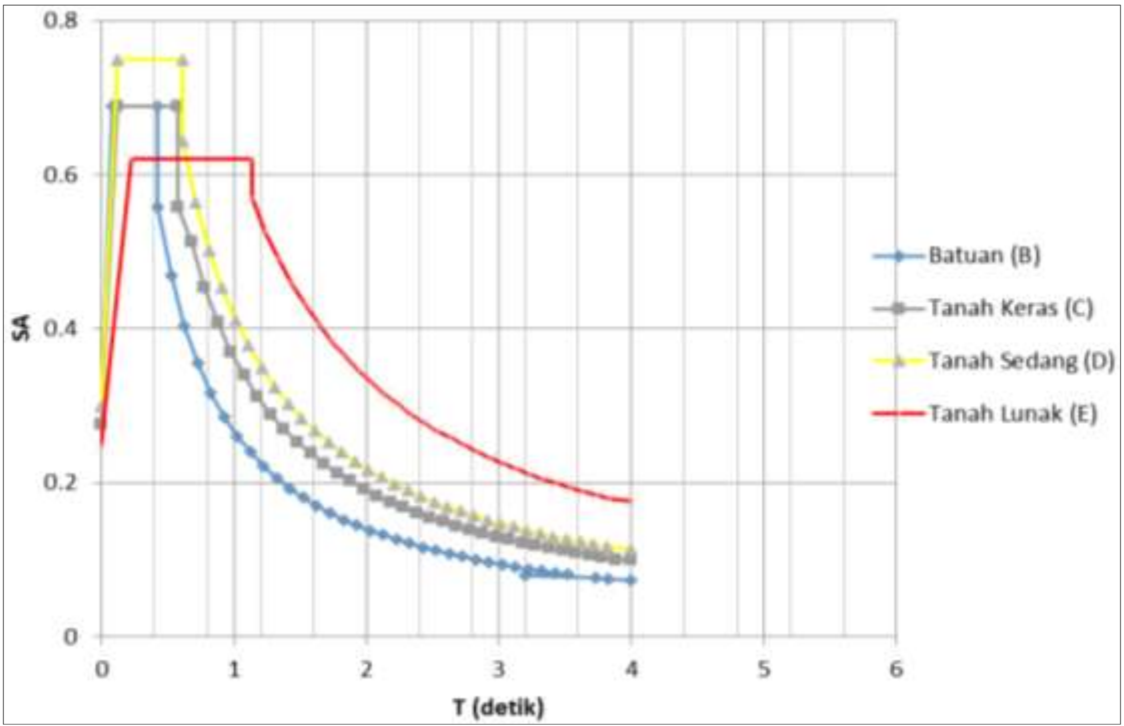
Earthquake Load using Spectra Response, especially in the North Sulawesi region by looking at the Ministry of Public Works website,

puskim.pu.go.id/Aplikasi/desain_spektra_indonesia_2011

Enter the coordinates of the city of Manado. Spectral Value of Surface Acceleration from an Earthquake Risk-Targeted Maximum Consider Earthquake With 1% Probability of Building Collapse in 50 Years. Location: (Lat: 1.5049538726942067, Long: 124.85375985503197)

Table 1: Spectral Acceleration Rock Type: Medium Soil D

Variable	Mark	T (second)	SA (g)	T (second)	SA (g)	T (second)	SA (g)
PGA (g)	0.450	0	0.3	TS + 1.2	0.24	TS + 2.7	0.134
SS (g)	1.034	T0	0.749	TS + 1.3	0.228	TS + 2.8	0.13
S1 (g)	0.441	TS	0.749	TS + 1.4	0.217	TS + 2.9	0.127
CRS	1.052	TS + 0	0.644	TS + 1.5	0.207	TS + 3	0.123
CR1	1.065	TS + 0.1	0.564	TS + 1.6	0.198	TS + 3.1	0.12
FPGA	1.050	TS + 0.2	0.502	TS + 1.7	0.19	TS + 3.2	0.117
FA	1.086	TS + 0.3	0.453	TS + 1.8	0.182	4	0.114
FV	1.559	TS + 0.4	0.412	TS + 1.9	0.175		
PSA (g)	0.473	TS + 0.5	0.378	TS + 2	0.169		
SMS (g)	1.123	TS + 0.6	0.349	TS + 2.1	0.163		
SM1 (g)	0.687	TS + 0.7	0.324	TS + 2.2	0.157		
SDS (g)	0.749	TS + 0.8	0.303	TS + 2.3	0.152		
SD1 (g)	0.458	TS + 0.9	0.284	TS + 2.4	0.147		
T0 (sec)	0.122	TS + 1	0.268	TS + 2.5	0.143		
TS (sec)	0.612	TS + 1.1	0.253	TS + 2.6	0.138		



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

Fig 3: Response Spectra

The method used is Spectra Response, with medium soil rock types, in this thesis, the software used to calculate the Structure Period uses ETABS 2013 Version 13.1.1 Original. After obtaining the T Period results, to look for the Correlation Regression between height and natural vibration period using the Spss statistics program version 17. Reference books used include: Procedures for Earthquake Resistance Planning for Building and Non-Building Structures SNI 03 – 1726 – 2012, Minimum Loads for Designing Buildings and other Structures SNI 03 – 1727 – 2013, Structural Concrete Requirements for Buildings SNI 03 – 2847 - 2013, Earthquake Resistance Planning Standards for Building Structures SNI 03 – 1726 – 2002, and journals related to structure period formulas

4. Result and Discussion

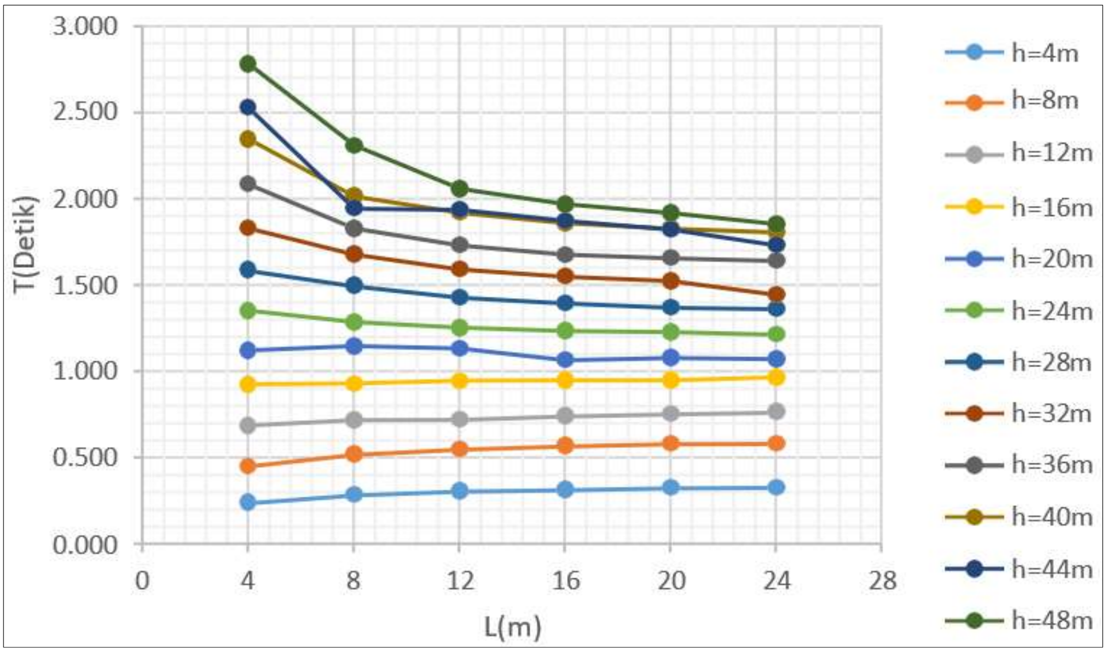
Based on the results processed in the Etabs Program, 72 Structure Period values were obtained, then these values will be used in Regression analysis, to obtain the Best formula. The structure period value can be seen from Table 2.

Table 2: Period Values for Structures 1 to 12 floors, with variations of 6 spans

T		L (m)					
Level	**Height (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

Source: 2013 ETABS Processed Data

From Table 2, the structure period values are obtained for 1 to 12 floors, with variations in 6 stretches of 4m to 24 m. The structure period values are obtained in the Etabs program. In more detail, the structure period values are expressed in graphic form and form a pattern which can be seen in Figure 4.



Source: Processed Data Ms. Excel

Fig 4: Graph of the relationship between length increase and structure period

Judging from the existing pattern graph, the relationship between the increase in length and the period of the structure varies, from a height of 4 m, the blue line to a height of 16 m, the yellow line with a span of 4 m to 24 m. The pattern that occurs tends to be flat, where the length of the span has no effect on the period. structure and it occurs in the Low Rise Building category. Meanwhile, for a height of 20 m, the dark blue line up to 48 m is a green line with a stretch of 4 m to 12 m. The pattern that occurs is that the structure period value is decreasing, there is a significant change in the pattern of the structure period value and this occurs in the Mid Rise Building category. where a small period of vibration of the structure will produce a large base shear value in the design process. After obtaining the structure period value, this value is used in regression analysis to obtain the formula. In more detail, the results of the regression analysis of the structure period formula can be seen in Table 3.

Table 3: Results of Period Structure Formula Regression Analysis

No	Fungsi Function	C	r (%)	
1	$T = C1\ H^{C2}$	C1 = 0,105	98	T = f (H)
		C2 = 0,785		
2	$T = C1\ n^{C2}$	C1 = 0,311	98	T = f (n)
		C2 = 0,785		

Source: Processed Data Ms. Excel

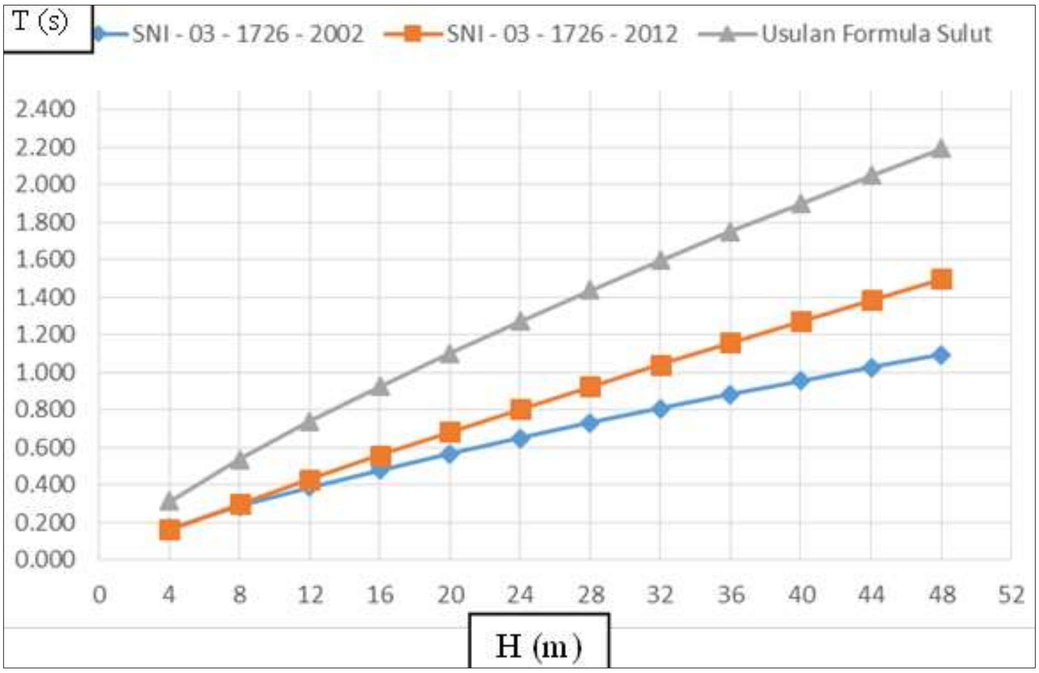
From the results in Table 3. Formula 1, T = f(H) in the form of a Power expression function, obtained a correlation value of 98%, for formula 2, T = f (n) was tried in the form of a power expression function, a correlation value was obtained. large at 98%. A comparison of the H function structure period values can be seen in Table 4.

Table 4: Comparison of Period Structure values of the H function

H (m)	SNI 1726 – 03 - 2002	SNI 1726 – 03 - 2012	Proposed North Sulawesi Formula
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

Source: Processed Data Ms. Excel

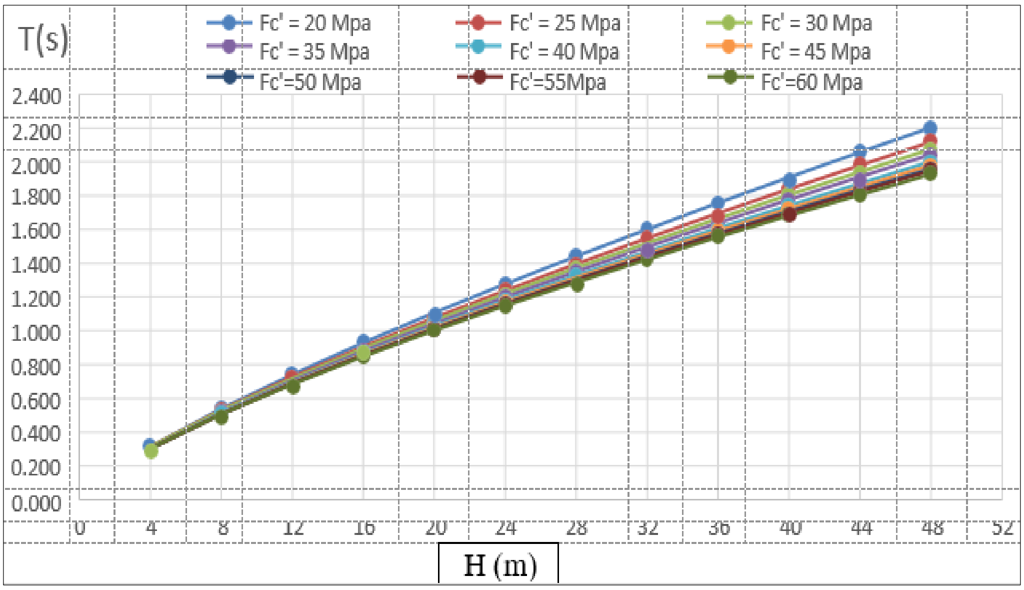
Comparison of the structure period values of the function H obtained in table 4, building height 4m to 48m, comparison of structure period values obtained. The structure period values of North Sulawesi are greater in nature than the structure period values of SNI 03 – 1726 – 2002 and SNI 03 – 1726 – 2012 based on H function. For comparison, the H function structure period formula outlined in the graph can be seen in Figure 5.



Source: Processed Data Ms. Excel

Fig 5: Comparison graph of the period formula for the structure of the function H

SNI Regulation 1726 – 03 – 2002 (Old Regulation) is below, the graph of the Old Regulation is sloping, meaning the higher the building, the smaller the period of the structure, SNI Regulation 1726 – 03 – 2012 (New Regulation) is above the Old Regulation, meaning it is considered a Regulation The new regulations are better than the old regulations, the graph of the New Regulations is gloomy, meaning that the higher the building, the greater the period of the structure, the higher the building, the higher the sensitivity of the value of the structure period, this means that the higher the building, the more sensitive the period of the structure, which means it is more risky, risky, so The period value of the structure must be studied and taken into account. the result of the revision is that the old regulations have been improved to get more economical, better results, the slope line of SNI Regulation 1726 - 03 - 2012 (New Regulation) and the slope line of the proposed formula for North Sulawesi are close, parallel, the slope is the same, different from the Old Regulations, which means The trend in the proposed North Sulawesi formula that was made is the same as the trend in the new regulations for behavior. For comparison, the H function structure period formula based on concrete quality is outlined in the graph, which can be seen in Figure 6.



Source: Processed Data Ms. Excel

Fig 6: Comparative Graph of the Period Formula for the Structure of the H function based on Concrete Quality.

The graph of Fc' = 60 Mpa is at the bottom, the graph is sloping, meaning the greater the quality of the concrete, the smaller the period of the structure, the graph of Fc' = 20 Mpa is above it. The graph of Fc' = 60 Mpa, the graph of Fc' = 20 Mpa is gloomy, meaning it is getting smaller Concrete quality increases as the period of the structure increases, the impact on the period of the structure is small. The quality of the concrete affects the period of the structure. After obtaining the structural period formula, used in 8-story buildings, compare the formula SK – SNI – 03 – 1726 – 2012.

5. Conclusion

1. This research shows that the proposed structure period formula in North Sulawesi for the Mid Rise building category, assuming medium soil type, the recommended formula is: $T = 0,105\ H^{0,785}$ $T = 0,311\ n^{0,785}$
2. The smaller the concrete quality, the greater the period of the structure, the impact on the period of the structure which is small. The quality of the concrete affects the period of the structure.

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