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CHANGES IN SNI-1726 AND SNI-2847'S EFFECTS ON LOW-RISE REINFORCED CONCRETE BUILDINGS'S REINFORCING STEEL WEIGHT

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ABSTRACT

The updates of the Indonesian seismic design code (SNI 1726) and the reinforced concrete design code (SNI 2847) have been applied in practice simultaneously. Based on these new codes, seismic loads generally increase, especially for low-rise buildings, and the reinforcement design requirements become much more stringent. Therefore, the construction industry predicts that there will be a significant increase in the need for reinforcing steel. This paper would like to describe the comparison of the design reinforcing steel weight in a 4-story reinforced concrete case study building with a special moment resisting frame system, which is designed using a combination of SNI 1726:2012 and SNI 2847:2013, and which is designed using a combination of SNI 1726:2019 and SNI 2847:2019. This study was found that the increase in reinforcing steel is not proportional to the increase in seismic load and much smaller. This result can then be an illustration of how much increase in design reinforcing steel when using the new codes.

INTRODUCTION

As a country dominated by many earthquake-prone areas, Indonesia routinely updates its building codes to minimize the impact that may occur on structures due to earthquakes. In 2019, the National Standardization Agency of Indonesia (BSN) issued 2 new building codes: the seismic design code, SNI 1726:2019 (Badan Standardisasi Nasional, 2019b), replacing SNI 1726:2012 (Badan Standardisasi, 2012); and the reinforced concrete design code, SNI 2847:2019 (Badan Standardisasi Nasional, 2019a), substituting SNI 2847:2013 (Badan Standardisasi Nasional, 2013b).

According to SNI 1726:2019 (Badan Standardisasi Nasional, 2019b), earthquake loads for low-rise buildings increase significantly in most parts of Indonesia with the presence of 2017 seismic maps (Pusat Studi Gempa Nasional, 2017; Sutjipto & Sumeru, 2019). Meanwhile, according to SNI 2847:2019 (Badan Standardisasi Nasional, 2019a), the requirements for column confinement reinforcement are much more stringent, especially for columns that experience high compressive axial loads.

Many stakeholders are certainly curious to find out how far the impact of the changes in the two new codes on the construction industry. The purpose of this paper is to answer that question, especially for low-rise buildings that dominate the development of many cities in Indonesia. It is important to note that SNI 1726:2012 (Badan Standardisasi, 2012) and SNI 1726:2019 (Badan Standardisasi Nasional, 2019b) adopted ASCE 7-10 (American Society of Civil Engineers, 2010) and ASCE 7-16 (American Society of Civil Engineers, 2017), with modifications adapted to Indonesian conditions, including the development of the Indonesian seismic maps. While SNI

2847:2013 (Badan Standardisasi Nasional, 2013b) and SNI 2847:2019 (Badan Standardisasi Nasional, 2019a) adopted ACI 318M-11 (American Concrete Institute, 2011) and ACI 318M-14 (American Concrete Institute, 2014) identically.

The researchers would like to discover the changes in SNI-1726 and SNI-2847'S effects on low-rise reinforced concrete buildings's reinforcing steel weight. This study chose Jakarta as the project location for 2 reasons. First, because Jakarta is a benchmark for the Indonesian construction industry; and second, from a seismic design point of view, it is located in an area of moderate seismicity with no anomalies in its design response spectra for medium and soft soil site classes (Sutjipto & Sumeru, 2021).

METHOD

The methodology used in this study is straightforward. Using a case study building, a complete analysis and design was carried out based on a combination of SNI 1726:2012 (Badan Standardisasi, 2012) and SNI 2847:2013 (Badan Standardisasi Nasional, 2013b) as well as SNI 1726:2019 and SNI 2847:2019 following standard design procedures (Fanella, 2007, 2016, 2018). The reinforcing steel weights resulting from those designs were then compared.

In order to obtain more accurate and reliable results, the analysis and design of the case study building was performed by using ETABS for the building frame, SAFE for slabs, and CSiDetail for reinforcement detailing and bills of quantities (BOQ).

In order to represent a low-rise building, the study used a simple and regular 4-story reinforced concrete office building, located in Jakarta on a site class SE (soft soil) area, as a case study building. The building has a typical floor plan with a total area of 960 m^2, consisting of 3 by 5 bays of 8 m span each (24 m × 40 m), as shown in the framing plan in Figure. 1. The total height of the building is 14 m, with a typical floor height of 3.5 m, as shown in the frame elevation section in Figure. 2.

All frames, both in the long and short directions of the building, are designed as a special moment frame system as required with a fixed base assumption (Sutjipto & Sumeru, 2022).

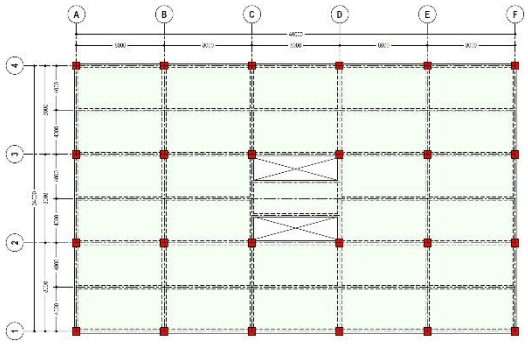


Figure 1. Typical Floor Plan of the Case Study Building.

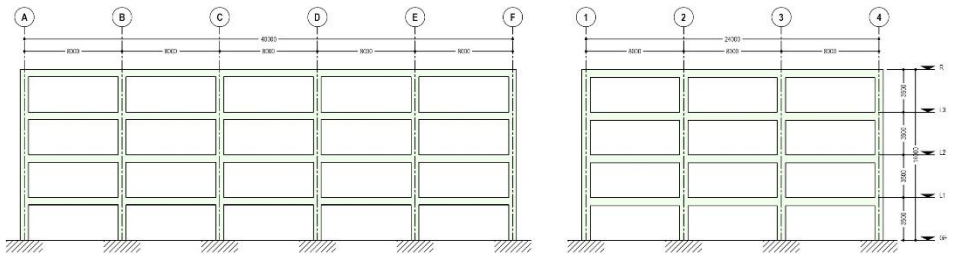


Figure 2. Typical Frame Elevation Section in the Long and Short Directions of the Case Study Building

Dimensions and specific compressive strength of concrete (f_c') of all structural elements of the case study building are as listed in Table 1. All longitudinal and transverse reinforcement are deformed bars with a specified yield stress (f_y) of 420 MPa (BjTS 420B).

Table 1. Dimensions and Concrete Specific Compressive Strength of the Structural Elements

Structural Elements			Height (mm)	Width (mm)	f_c' (MPa)
Slabs			120	-	25
Beams	Secondary		500	300	25
	Frame	Long direction	600	350	25
		Short direction	650	350	25
Columns			700	650	30

RESULT AND DISCUSSION

Gravity Loading

The gravity loads applied to the case study building are as listed in Table 2. It is important to note that the self-weights of all structural elements are taken into account automatically by the structural analysis program using a unit weight of 24 kN/m^3, thus those listed in Table 2 as dead loads are superimposed dead loads.

The live loads used in this study are in accordance with the Indonesian loading code, SNI 1727:2020 (Badan Standardisasi Nasional, 2020), whose values remain the same as the previous code, SNI 1727:2013 (Badan Standardisasi Nasional, 2013a). It should be noted that SNI 1727:2013 (Badan Standardisasi Nasional, 2013a) and SNI 1727:2020 (Badan Standardisasi Nasional, 2020) identically adopted ASCE 7-10 (American Society of Civil Engineers, 2010) and ASCE 7-16 (American Society of Civil Engineers, 2017), respectively.

Table 2. Gravity Loads on the Case Study Building

Loads			
Dead	Finishes, Ceiling & MEP	1.50	kN/m^2
	Facade	0.60	kN/m^2
Live	Roof	0.96	kN/m^2
	Office	2.40	kN/m^2

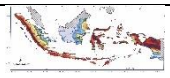
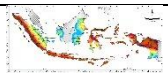
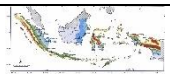
	Partitions	0.72	kN/m^2

Seismic Loading

The seismic loads determination for the case study building are given from Table 3 to Table 5 in a systematic and step-by-step manner according to SNI 1726:2012 and SNI 1726:2019 where each step can be compared.

The design response spectrum parameters in Table 3 were obtained from the Indonesian Design Spectra web applications: namely Aplikasi Desain Spektra Indonesia 2010 (2010) in accordance with SNI 1726:2012 (Badan Standardisasi, 2012), and Aplikasi Respon Spektra 2021 (2021) in accordance with SNI 1726:2019 (Badan Standardisasi Nasional, 2019b), for the given location coordinates and soil site class. Figure. 3 shows the two design response spectra plotted together on one chart to illustrate how much they differ.

Table 3. Design Response Spectra of SNI 1726:2012 and SNI 1726:2019

		SNI 1726:2012	**SNI 1726:2019**
Latitude / Longitude		-6.191° / 106.786°	
Site Class		SE (soft soil)	
Seismic map for short period			
Seismic map for long period			
S_{DS}	(g)	0.607	0.670
S_{D1}	(g)	0.560	0.634
T_0	(sec.)	0.184	0.189
T_S	(sec.)	0.922	0.946

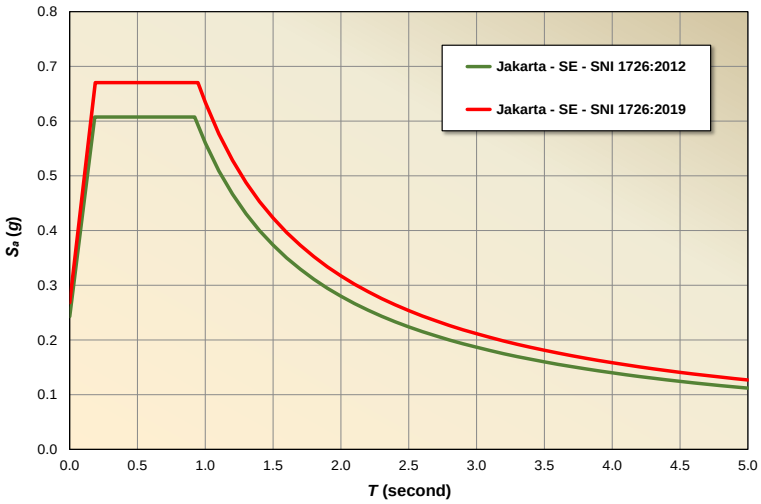
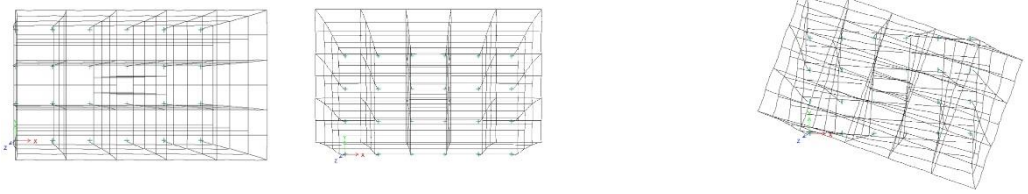


Figure 3. Design response spectra of SNI 1726:2012 and SNI 1726:2019

For the determination of seismic loads and for the design, 2 runs were carried out by applying the appropriate stiffness modifier for service level and ultimate level (MCE_R) conditions. The results of the dynamic analysis of the case study building in the form of fundamental periods and mode shapes are presented in Table 4 and Figure. 4. It can be seen that the first and second modes are translation, and the third mode is rotation, which indicates a good building behavior.

Table 4. Fundamental Period of the Case Study Building at Service and Ultimate Levels

Level	**Fundamental period (second)**		
Service	$T_1 = T_x =$ 0.642	$T_2 = T_y =$ 0.599	$T_3 = T_z = 0.542$
Ultimate (MCE_R)	$T_1 = T_x =$ 0.767	$T_2 = T_y =$ 0.726	$T_3 = T_z = 0.652$



(a) First mode - X translation

(b) Second mode - Y translation

(c) Third mode - Z rotation

Figure 4. Mode Shapes of Case Study Building

The seismic response coefficient (C_s) and the design seismic base shear (V_{Design}) calculations of case study building based on SNI 1726:2012 and SNI 1726:2019, are given in Table 5. The seismic response coefficients (C_s) of the two codes are plotted together in Figure. 5 for comparison. It shows that the fundamental periods of the case study building at service level, ultimate level and based on C_u T_a are less than T_s, thus the governing seismic response coefficient is $C_s = S_{DS}/(R/I_e)$, which is much bigger than $C_{s\ min}$. It is important to note that as shown in the last row of Table 5, the design base shear of SNI 1726:2019 is approximately 30% higher than that of SNI 1726:2012.

Table 5. Design Base Shear of Case Study Building Based on SNI 1726:2012 and SNI 1726:2019

	SNI 1726:2012	**SNI 1726:2019**
Approximate Period	Table 15	Table 18
C_t	0.0466	
x	0.9	
h_n (m)	14	
T_a (sec.)	0.501	
Coeff. of Upper limit	Table 14	Table 17

C_u (S_{D1} > 0.4)	1.4	
C_u T_a (sec.)	0.702	
Risk Category	II	
I_e	1.0	
Seismic Design Category (SDC)	D	
Lateral Force Resisting System	Special RC Moment Frames	
R	8	
C_s = S_{DS}/(R/I_e)	0.076	0.084
$C_{s\ min}$ = 0.044 S_{DS} I_e	0.027 > 0.010	0.030 > 0.010
W (kN)	30,162	
V (kN)	2,290	2,528
Scaling provision	Section 7.9.4.1	Section 7.9.1.4.1
Scale factor	0.85	1.00
V_{Design} (kN)	1,947	2,528
Ratio of $V_{Design\ 2019}$ to $V_{Design\ 2012}$	1.298	

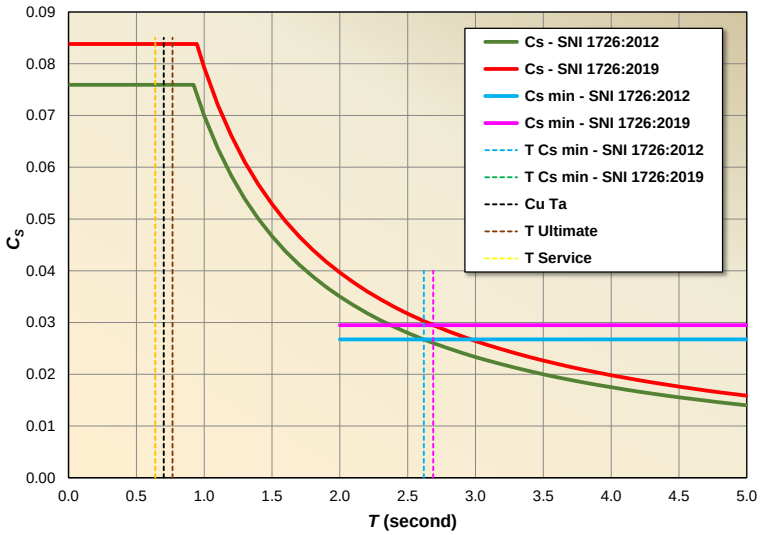
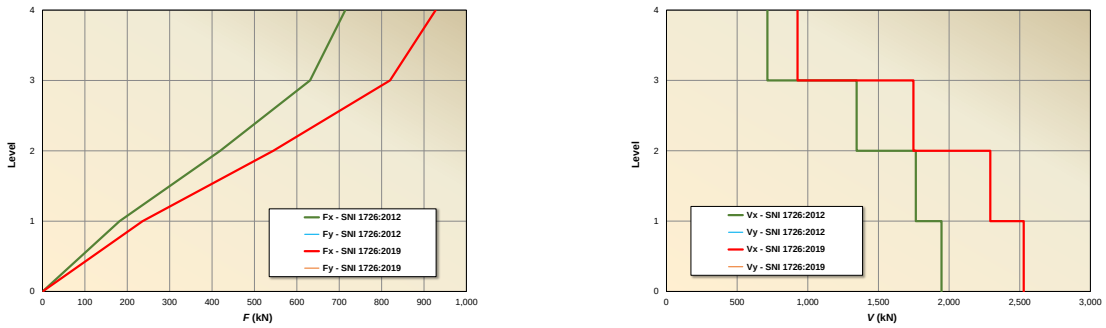


Figure 5. Seismic Response Coefficients (C_s) Based on SNI 1726:2012 and SNI 1726:2019

The seismic lateral forces and story shears according to SNI 1726:2012 (Badan Standardisasi, 2012) and 2019 (Badan Standardisasi Nasional, 2019b) respectively are shown in Figure. 6. It can be seen that the two codes differ by approximately 30%. The values in the x and y directions coincide, because their seismic base shears are scaled to the same value in both directions with respect to T_1.

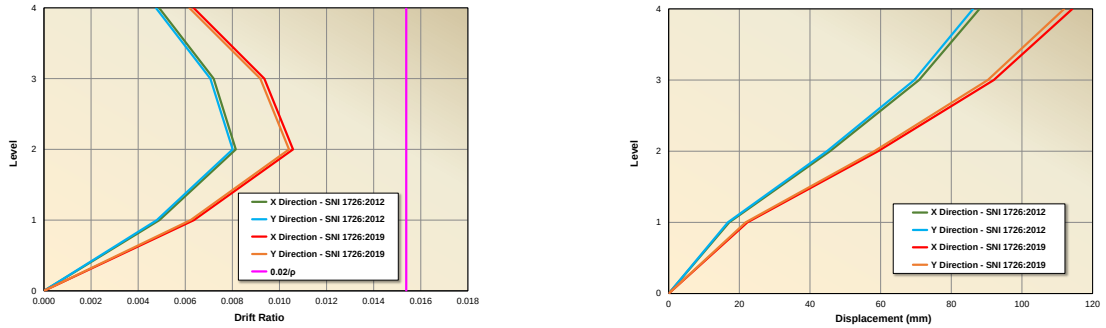


(a) (b)

Figure 6. (a) Seismic Lateral Forces; (b) Story Shears Based on SNI 1726:2012 and SNI 1726:2019

The resulting story drift ratios and story displacements from the analysis due to the corresponding seismic lateral forces, with the amplification factor C_d, are shown in Figure. 7. The story drift based on SNI 1726:2019 is approximately 30% greater than the story drift based on SNI 1726:2012, which is in line with the increase of the seismic loads. Nevertheless, the resulting story drift based on SNI 1726:2019 is still below the allowable limit.

The resulting story drift ratio and story displacement values in the x and y directions nearly coincide, this is because the lateral stiffnesses of the building in the x and y directions are almost the same, as indicated from the first and second periods of the building that are so close.



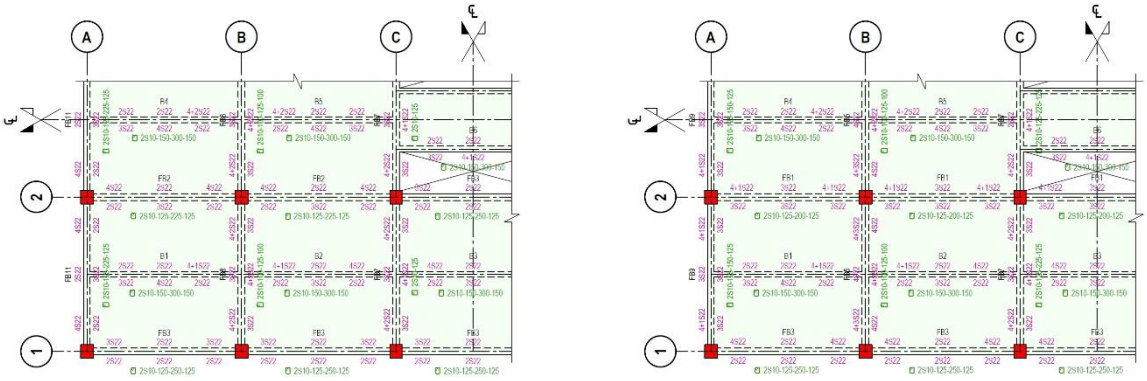
(a) (b)

Figure 7. (a) Story drift ratios; (b) displacements based on SNI 1726:2012 and SNI 1726:2019

Design Reinforcement Results

It is important to note that all slabs and secondary beams are considered to only resist gravity loads. There is a new chapter in SNI 2847:2019 (Badan Standardisasi Nasional, 2019a) (Chapter 12), regarding the function of the slab as a diaphragm that transmits seismic forces to the lateral force resisting system, however, since all frames in both directions in this case study building are assigned as lateral force resisting systems, then the chord and collector forces will be very small and can be sufficiently carried by trimmer bars and slab reinforcement. Therefore, the reinforcement of slabs and secondary beams based on SNI 2847:2013 (Badan Standardisasi Nasional, 2013b) and 2019 (Badan Standardisasi Nasional, 2019a) does not change.

The longitudinal and transverse reinforcement of frame beams are designed to comply all the requirements in Chapter 21 of SNI 2847:2013 (Badan Standardisasi Nasional, 2013b) and Chapter 18 of SNI 2847:2019 (Badan Standardisasi Nasional, 2019a) for special moment frame beams. Figure. 8 shows an example of a comparison of the longitudinal and transverse reinforcement of the frame beams in L3. It is clear that they increase due to the rise of seismic loads in the new code. Typically, longitudinal reinforcement is increased by 1 bar in SNI 2847:2019 (Badan Standardisasi Nasional, 2019a). Meanwhile, transverse reinforcement is relatively unchanged because it is generally controlled by confinement requirements and these requirements in SNI 2847:2019 (Badan Standardisasi Nasional, 2019a) remain the same as in SNI 2847:2013 (Badan Standardisasi Nasional, 2013b).



(a) (b)

Figure 8. Comparison of Longitudinal and Transverse Reinforcement of Secondary Beams and Frame Beams in L3 Based on (a) SNI 2847:2013; (b) SNI 2847:2019

All columns have passed the strong-column-weak-beam and joint shear requirements. Their longitudinal and transverse reinforcement are designed to meet all the requirements in Chapter 21 of SNI 2847:2013 (Badan Standardisasi Nasional, 2013b) and Chapter 18 of SNI 2847:2019 (Badan Standardisasi Nasional, 2019a) for special moment frame columns. In this case study building, not a single column has an axial compression force exceeding 0.3 A_g f_c', so the requirements of section 18.7.5.2(f) and equation (c) in table 18.7.5.4 of SNI 2847:2019 do not apply.

The column reinforcement for the case study building can be narrowed down into 2 types as shown in Figure. 9. The difference between the 2 types is only in the number of longitudinal rebars, where C1 only contains 12 S22, while C2 contains 16 S22. There is no difference of transverse reinforcement for those two types.

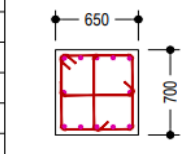
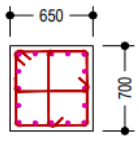
COLUMN TYPE		C1		C2	
DIMENSION		650 x 700		650 x 700	
LONGITUDINAL		12 S22		16 S22	
TRANSVERSE	AT JOINT	3 + 3 S13 - 100		3 + 3 S13 - 100	
	UPPER Lo	3 + 3 S13 - 100		3 + 3 S13 - 100	
	MIDDLE SPAN	3 + 3 S13 - 150		3 + 3 S13 - 150	
	LOWER Lo	3 + 3 S13 - 100		3 + 3 S13 - 100	
Lo		700		700	

Figure 9. Types of Column Reinforcement

For seismic loading based on SNI 1726:2012 (Badan Standardisasi, 2012), type 1 column reinforcement can be applied to all columns, starting from the base to the roof. However, for seismic loading based on SNI 1726:2019 (Badan Standardisasi Nasional, 2019b), type 2 column reinforcement needs to be applied to 4 exterior columns on grid line A and 4 exterior columns on grid line F under the L1 floor. Except for those 8 columns, type 1 column reinforcement can be applied to all other columns from the base to the roof.

This happens because basically the requirements for the seismic design of SNI 2847:2013 (Badan Standardisasi Nasional, 2013b) and SNI 2847:2019 (Badan Standardisasi Nasional, 2019a) are the same, except for the confinement requirements for columns with axial forces > 0.3 $A_g f_c'$, which does not exist in this case. In addition, the minimum column longitudinal reinforcement requirement of 1% is still able to cover the increased demand for longitudinal reinforcement due to the increase in the seismic load in SNI 1726:2019 (Badan Standardisasi Nasional, 2019b), except for the 8 columns mentioned above.

Comparison of Reinforcing Steel Weight

The bills of quantities of case study building based on SNI 1726:2012/SNI 2847:2013 and SNI 1726:2019/SNI 2847:2019 are summarized in Table 6 and Figure. 10 for comparison. As is commonly used in the Indonesian construction industry, the table also presents the ratio of the reinforcing steel weight to the concrete volume (S/C ratio) for each structural element. Note that the reinforcing steel weights in slabs, secondary beams, frame beams and columns include their standard hooks and lap splices.

Table 6. Bills of Quantities of Case Study Building Based on SNI 1726:2012/SNI 2847:2013 and SNI 1726:2019/SNI 2847:2019

Structural Elements	Concrete Volume	SNI 1726:2012/2847:2013		SNI 1726:2019/2847:2019		Ratio of 2019/2013
		Steel Weight	*S/C Ratio*	*Steel Weight*	*S/C Ratio*	
	m^3	kg	kg/m^3	kg	kg/m^3	
Slabs	461	37,979	82	37,979	82	1.0000
Secondary Beams	77	12,597	164	12,597	164	1.0000

Frame Beams	265	37,166	140	40,352	152	1.0857
Columns	153	30,240	198	30,968	203	1.0252
Lateral Force Resisting System	419	67,406	161	71,320	170	1.0559
Overall	956	117,982	124	121,896	128	1.0322

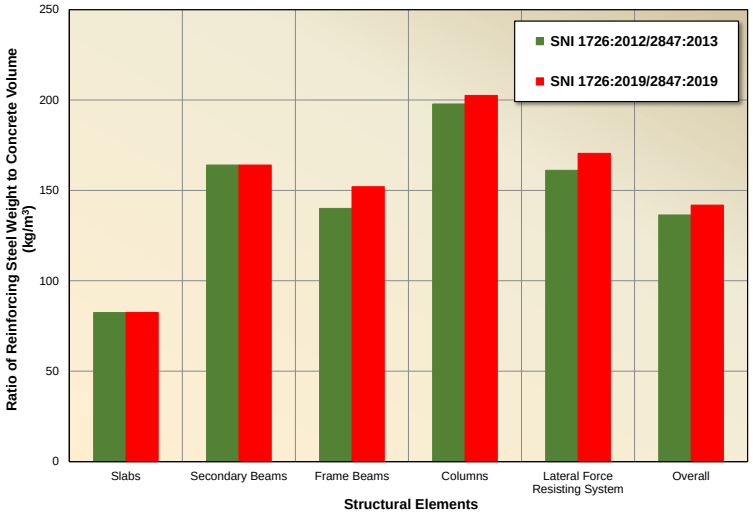


Figure 10. Comparison of S/C Ratio for Each Structural Element Based on SNI 1726:2012/SNI 2847:2013 and SNI 1726:2019/SNI 2847:2019

It can be seen that by implementing SNI 1726:2019 and SNI 2847:2019, the weight of reinforcing steel in the frame beams increases by 8.57% and in the columns increases by 2.52%. However, when taken into account for all lateral force resisting system frames the increase is 5.59% and for the overall structure, it is only 3.22%.

CONCLUSION

For low-rise buildings, which are represented by a 4-story case study building with a special moment frame structural system in this study, located in Jakarta on soft soil (SE), two important conclusions can be drawn from the results of this study. First, the design seismic load based on the new Indonesian seismic design code (SNI 1726:2019) increases by almost 30% from the previous code (SNI 1726:2012). Second, even though the design seismic load increases significantly, the reinforcing steel weight only increases by 3.22%. This is because the reinforcement detailing requirements in the new Indonesian concrete design code (SNI 2847:2019) are exactly the same as those in the previous code (SNI 2847:2013), except for columns with axial compressive forces that exceed 0.3 A_g f_c', which demands much more stringent requirements of the transverse reinforcement for concrete confinement, which are not found in this case study building. So that it can be said that the increase in the weight of the reinforcing steel is caused by an increase in the design seismic load, not caused by the new reinforcement detailing requirements.

It will be very useful for benchmarking purposes if this study were conducted for all major cities throughout Indonesia, with different levels of seismicity. Referring to Sutjipto & Sumeru (2019), besides Jakarta, there are 16 other cities that can be proposed. For the soft soil (SE) category, cities with a high level of seismicity and experiencing a significant increase in their seismic design loads are Denpasar, Kupang and Manado. Meanwhile, cities with a moderate level of seismicity and experiencing an increase in their seismic design loads are Medan, Semarang and Surabaya. A city with a low level of seismicity but experiencing a very large increase in its seismic design load is Pontianak.

The study can then be continued for other soil category, different concrete strengths, different number of stories, and other lateral force resisting structural systems, such as dual systems and bearing wall systems which are widely used in Indonesia for buildings.

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