Comparison of Earthquake Resistant Building Design Based on SNI 1726-2012 and SNI 2847-2013 with SNI 1726-2019 and SNI 2847-2019. Case Study of Indonesian International Islamic University (UIII) Student Apartment Building

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Abstract. The renewal of the Indonesian National Standard (SNI) on earthquake-resistant building planning has been carried out and will begin to be implemented, therefore research on new standards is needed so that a comparison between old standards and new standards can be known to be used as a reference for the latest structural design. The updated regulations are SNI on Earthquake Resistance Planning Procedures for Building and Non-Building Structures (SNI 1726:2019) and Structural Concrete Requirements for Building Buildings (SNI 2847:2019) which replace the previous standards, namely SNI 03-1726-2012 and SNI 03-2847-2013. The case study used in this study was the design of a 9-story building at the UIII Student Apartment in Depok. The analysis of the design results is to use the SAP 2000 application to help find out the inner styles on the structure and Microsoft Excel help for the calculation of the cross section of the structure. In these two standards, it is still the same using the SRPMK structural system, and the earthquake load analysis method used is spectrum response. The results showed that the building design according to SNI 2847-2013 and SNI 2847-2019 did not change much. The biggest difference is caused by the latest standard of the earthquake, namely SNI 1726-2019, where with that standard many changes in the value of the earthquake coefficient, resulting in a larger structural base shear force.

Keywords: The Previous Standard, The Latest Standard, Structural System, Sectional Dimensions, Cross-section Reinforcement..

1. Introduction

Indonesia is a country with a strategic location in terms of geography and geology. There are many advantages and disadvantages to this strategic location. From the geographical aspect,

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Indonesiais the center of the world's traffic lanes. However, from a geological perspective, Indonesia is very vulnerable to earthquakes due to shifts in the world's three plates [1]. The geological location of the confluence of the three world plates is what makes Indonesia an earthquake-prone location. This is evidenced by data from the official BMKG website, which states that in 2019 there have been 11573 earthquakes with the densest earthquake activity clusters on sumatra island [1]. This further strengthens the reason that buildings in Indonesia must be designed with earthquake-resistant buildings to minimize losses due to earthquakes. Earthquake events greatly affect the condition and strength of the soil in Indonesia. These conditions greatly affect the process of building construction in Indonesia. Building construction in Indonesia must be built in accordance with existing safety standards, especially for high-rise buildings so that when a natural disaster occurs such as an earthquake, the core building does not collapse so as to minimize casualties.

Calculation of building design can be said to be safe if it complies with the requirements of theIndonesian National Standard (SNI). Therefore, the SNI for building design and seismicity really needs to be updated regularly in accordance with the current conditions in Indonesia. SNI Concrete Building Design and SNI Earthquake have been updated from the previous in 2013 to the latest SNI 2019. Therefore, it is necessary to compare the design of earthquake-resistant buildings using the old standards and the new standards in order to know how the differences in building designs using the old standards and the new standard, whether it is significantly different or not, so that it can be used as one of the reference materials for the next building design. If there is a significant difference, it is necessary to do engineering to strengthen the existing structure, for example with concrete jacketting or additional bracing, that way the structure is still safe.

2. Literature Study

The literature study used as the basis for this design is:

1. SNI 1727-2018 concerning minimum design loads and related criteria for buildings and other structures.
2. SNI-2847-2013 regarding structural concrete requirements for buildings.
3. SNI-2847-2019regardingstructural concreterequirements forbuildings.
4. SNI-1726-2012 concerning procedures for planning earthquake resistance for building and non-building structures.
5. SNI-1726-2019 concerning procedures for planning earthquake resistance for building and non-building structures.

The building structure designed in this journal is an apartment building for students at UIII (International Islamic University of Indonesia) where the building consists of 8 floors with an additional of non-concrete roof. In this literature study, it is investigated what are the differences between the old standard and the new standard which will then be applied to building modeling using the SAP 2000 version 22 application to find out how the changes that occur in the building structure modeling.

3. Building Structure Data and Loading

The Apartment Student Building of Universitas Islam Internasional Indonesia in Depok has the dimensions of the main structure with a height from the 1st floor to the roof floor is 35.7 meters, a length of 42.1 meters and a width of 48 meters. The structure of the building is planned with the construction of reinforced concrete buildings. The main structure uses a conventional reinforced concrete structure and the roof structure uses a concrete structure. The entire structural system is in the form of a three dimensional open frame where the vertical load-bearing system is a reinforced concrete portal. The floor slab in the analysis functions as a rigid diaphragm. Structural modeling will be carried out with the help of SAP 2000 software version 22, by dividing the structure into two models, namely the main building structure and the connecting structure. This building was designed using SNI-2847-2013 and SNI-1726-2012 with a combined design method between SRPMK (Special Moment Bearing System Frame) on the main structure of the building and the Structural Wall system Specifically on the connecting structure of the building.

The provisions of the material used in accordance with the data obtained are as follows:

- Concrete
  The requirements for Ready-mix concrete used are as follows:
  1. Beams, columns, and tie beams using 30 MPa fc' concrete.
  2. Floor slab using concrete fc'30 MPa.
  3. For practical column work and practical sloof beams use Concrete Site mix with a quality of 17.5 Mpa.
- Reinforcement Steel

The reinforcing steel used has the following specifications:

1. For reinforcing steel with a diameter of less than 13 using a plain BJTP 24 (fy 240 Mpa), and a diameter greater than 13 using a threaded BJTP 40 (fy 400 Mpa).
2. Quality steel profile BJ 37, yield stress 240 MPa.

The loads used in designing this structure are:

1. Dead Load
   Dead load on the building is determined by using the specific gravity of the building materials in accordance with the 1983 Indonesian Loading Regulations. The dead loads that are taken into account include:
   1. Reinforced Concrete 24 kN/m^3.
   2. Ceiling + hangers 0.18 kN/m^2.
   3. Mortar 21 kN/m^3.
   4. Floor finish 1.83 kN/m^3.
   5. Pair of brick 2.5 kN/m^2.

2. Live Load
   Live load is calculated as follows:
   1. Apartement 1.92 kN/m^2.
   2. Lobby 4.79 kN/m^2.

3. Earthquake Load
   Earthquake load applied to the structure is earthquake load using response spectra method. The values used to be input in the SAP 2000 program include the values of Ss, S1, T, R, , and Ic. These values are obtained from the website *puskim.co.id*, manual calculations with earthquake maps and rules on SNI-1726- 2013 and SNI-1726-2019. The earthquake load parameter values are obtained according to the type of structure. The main structure is a special moment-bearing concrete frame type. As for the connecting structure, there are only differences in the values of parameters R, , Ic , scaling factor, Ct, x, and Ta caused by the type of connecting structure, where the connecting structure includes a double wall shear structure system of special reinforced concrete. The comparison of earthquake load values on the main structure isas shownin **Table 1**.

Table 1. Key Structure Parameter Value Comparison

Parameters	Old SNI Parameter Value	New SNI Parameter Value
Site class classification	E	E
Seismic Design Categories	D	D
Ss	0.774 g	0.896
S1	0.325 g	0.419
Fa	1.17	1.183
Fv	2.7	2.361
Sms	0.91	1.060
Sm1	0.88	0.990

Sds	0.6	0.707
SD1	0.59	0.660
T0	0.194	0.187
Ts	0.968	0.934
TL	3.4	20
Scalling Factor	1.839	1.839
R (Response Modification)	8	8
Ω (Overstrength Design)	3	3
I_c (Seismic Important Factor)	1.5	1.5
Cd (Deflection Factor)	5.5	5.5
Ct	0.047	0.047
x	0.9	0.9
h^n (m)	35.7	35.7
Cu	1.4	1.4
Ta (s)	1.174	1.174

The comparison of values in **Table 1** shows that the difference occurs in the parameters of the Ss and S1 values that have increased in the New SNI, so this will greatly affect the existing structure. Furthermore, for the value of the earthquake parameter for the connecting structure, the value of the earthquake parameter does not change from the old standard and the new standard.

4. Analysis of Design Results

4.1. Results of Running Structures with Modeling in SAP 2000

Modeling is done for 2 conditions, namely the condition of existing buildings that use old standards and structural modeling with new standards. The structure that has been modeled in the SAP 2000 application is then inputted all loads and loading combinations according to the available data. Furthermore, running against the model to produce a safe model with the criteria of all components of beams, columns, plates passed the check. After modeling the structure is safe, then an analysis of the results obtained.

4.2. Structural Analysis of Earthquake Load Factors

1. Static and Dynamic Shear Force Comparison

In SNI 1726-2012 it is regulated regarding the scale of force, that in SNI 1726-2012 requires the value of dynamic shear force must be greater than 85% static shear force, if the requirements are not met then it is necessary to give a force scale to the structure model. The changed force scale is the scalling factor resulting in a dynamic shear force value greater than the static shear force. The requirement underwent changes to SNI 1726-2019, where the dynamic shear force value must be greater than or equal to 100% static shear force. Thus, the shear force on the structure will become larger and affect the change in the dimensions of the structure. Some sample of comparison of sliding force values on UIII Student Apartment Building Structure after re-modeling can be seen in **Table 2** and **Table 3**.

Table 2. Earthquake Force control on The Main Structure based on SNI 1726-2012

Base Shear	Dynamic Base Shear (kN)	Static Base Shear (kN)	0.85 x Static Base Shear (kN)	Scale Factor 0.85 Vstatic Vdynamic	Control Vd > 85% Vs
Direction X	4775.401	5488.072	4664.861	0.977	OK
Direction Y	4588.938	5398.024	4588.320	0.9998654	OK

Table 3. Earthquake Force control on The Main Structure based on SNI 1726-2019

Base Shear	Dynamic Base Shear (kN)	Static Base Shear (kN)	1 x Static Base Shear (kN)	Scale Factor 1 Vstatic Vdynamic	Control Vd > 100% Vs
Direction X	13973.343	11656.177	11656.177	0.834172	OK
Direction Y	13508.640	11419.556	11419.556	0.8454	OK

Information:
Vd and Vs values are obtained from the results in SAP 2000 where:
Vd = dynamic shear force
Vs = static shear force

From **Table 2** and **Table 3** it can be known that the sliding force using the new standard rules results in a larger sliding force value. The factor that affects the greater the shear force is the value of the scale factor that is notiterated so that it can meet the design requirements. .

2. Inter-Floor Deviation Check

Analysis of the influence of earthquake loads can also be done by examining deviations between floors that occur due to changes in sliding forces in the structure. The greater the sliding force, the greater the deviation that occurs on each floor. Deviation calculations can be calculated according to the equation (1).

$$\delta_x = \frac{Cd \times \delta_{xi}}{I_e} \tag{1}$$

Where :

Cd = lateral deviation enlargement factor
δ_x = deviation of the center of mass at the level of x (mm)
δ_{xi} = deviation at level i
I_e = earthquake priority factor

If it is known that the Cd value is 5.5, value I_e is 1.5 and Δ_a coefficient is $0.010h_{sx}$, the value of δxi and δyi are value of join displacement from SAP200, and the hsx value is the height of the structure under the floor reviewed. Some sample of the results of the calculation of deviation control between floors are as in **Table 4** and Table **Table 5**.

Table 4. SNI Main Structure Inter-Storey Deviation Control 1726-2012

Floor	hsx (mm)	δxi (mm)	δyi (mm)	δx (mm)	δy (mm)	Δa (permit) (mm)	Information
Roof	3500	62.7741	60.6332	13.0200	7.0783	35	OK
9	3900	59.2232	58.7027	15.0597	11.5788	39	OK
8	3900	55.1160	55.5449	20.8331	17.1558	39	OK
7	3900	49.4342	50.8660	23.9509	21.5111	39	OK
6	3900	42.9021	44.9994	28.1408	25.9581	39	OK
5	3900	35.2274	37.9199	31.7255	29.8442	39	OK
4	3900	26.5750	29.7806	32.0312	32.0228	39	OK
3	3900	17.8392	21.0471	32.3371	34.4111	39	OK
2	5550	9.0200	11.6623	33.0733	42.7616	55.5	OK
1	0	0.0000	0.0000	0.0000	0.0000	0	OK

Table 5. SNI Main Structure Inter-Storey Deviation Control 1726-2019

Floor	hsx (mm)	δxi (mm)	δyi (mm)	δx (mm)	δy (mm)	Δa (permit) (mm)	Information
Roof	3500	53.2565	45.6293	11.7456	6.0330	35	OK
9	3900	50.0532	43.9839	13.5527	9.8432	39	OK
8	3900	46.3570	41.2994	18.3665	14.4965	39	OK
7	3900	41.3480	37.3458	21.6101	18.3962	39	OK
6	3900	35.4543	32.3287	25.1888	22.0835	39	OK
5	3900	28.5846	26.3059	28.0049	25.0416	39	OK
4	3900	20.9469	19.4764	27.6142	24.6778	39	OK
3	3900	13.4157	12.7461	26.4150	24.3902	39	OK
2	5550	6.2117	6.0942	22.7761	22.3454	55.5	OK
1	0	0.0000	0.0000	0.0000	0.0000	0	OK

Based on **Table 4** and **Table 5**, deviations between floors are said to be OK if the values of Δx and Δy are smaller than the value of Δa (permission). If these conditions are not met, the structure must be re-modeled by enlarging the cross-sectional dimensions of the beams and/or columns until the appropriate deviation value is obtained. From Table 6 to Table 9 it is known that deviations between floors in structures with new standards have greater value. This is influenced by the sliding force value with the latest standard greater than the value of the shear force with the old standard, so that the deviation or deflection that occurs in the structure is also getting bigger and needs to be adjusted to the dimensions of the structure..

4.3. Differences in The Design of Beam Reinforcement, Columns, and Structure Plates Using SNI 2847-2013 And SNI 2847-2019

The design of the upper structure of the building did not undergo much change between SNI 2847-2013 and SNI 2847-2019, the requirements and formulas used to calculate the reinforcement also did not change. The change in dimensions and configuration of reinforcement that occurred in this design was largely influenced by changes in the value of bedrock in the latest earthquake SNI, so that the value of the earthquake load increased and resulted in the load carried by the structure also increased. This led to the need for the addition of dimensions and reinforcement configurations to the structure of the building. Differences in dimensions and number of reinforcement can be seen in **Fig.1.** until **Fig.4.**

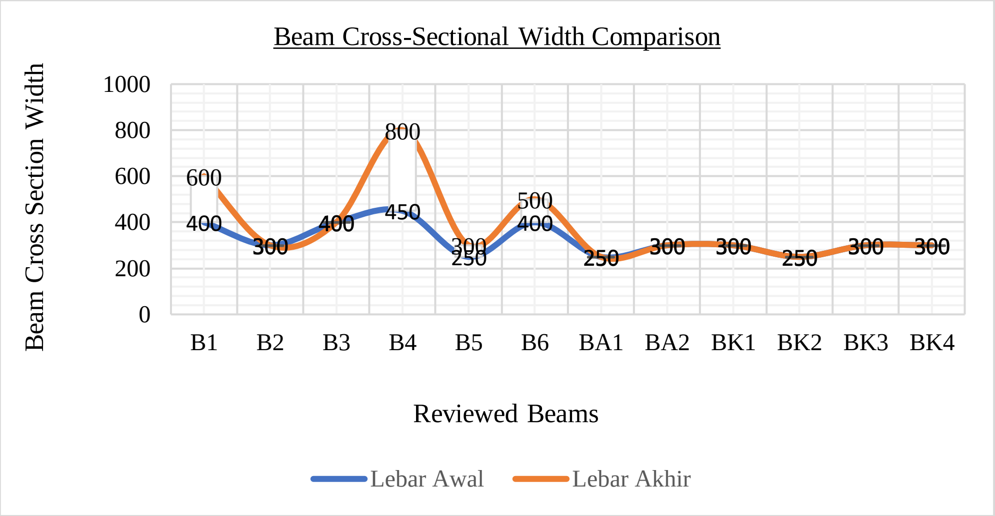

Fig.1. Comparison of Beam Cross-Sectional Width Dimensions Based on Old Standards and New Standards

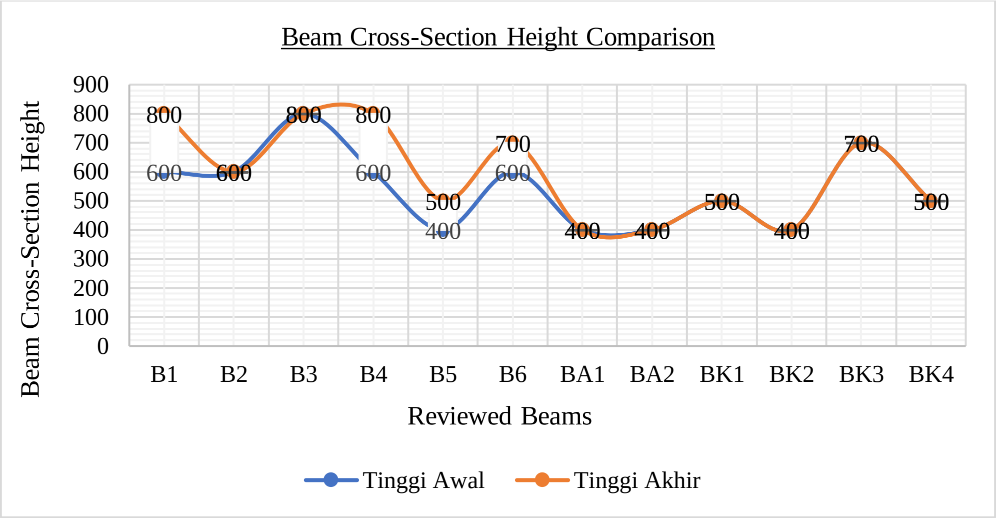

Fig.2. Comparison of Beam Cross-Section Height Dimensions Based on Old Standards and New Standards

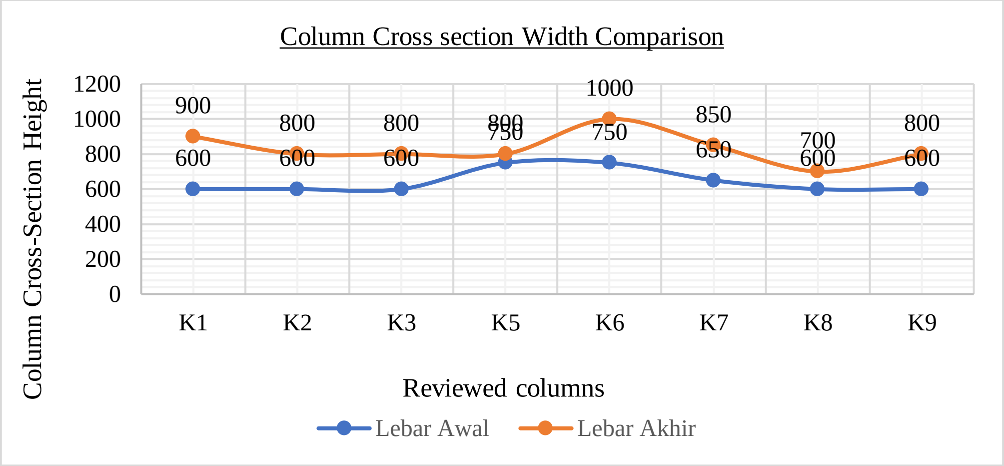

Fig.3. Column Cross-Section Width Dimension Comparison Based on Old Standards and New Standards

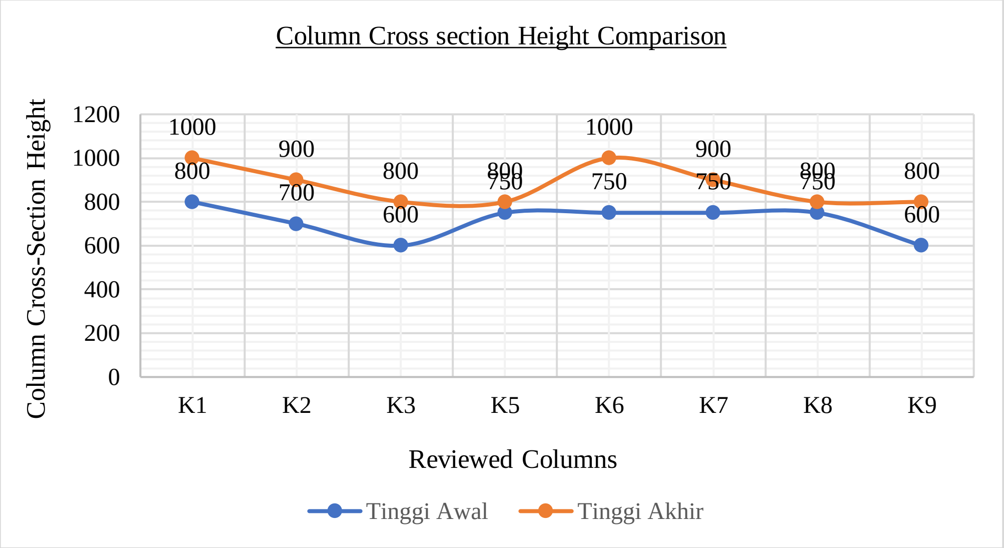

Fig.4. Comparison of Column Cross-Section Height Dimensions Based on Old Standards and New Standards

Comparison of Old Standards and New Standards

Comparison of the results of the design of The UIII Student Apartment Building using old standards and new standards will be reviewed in terms of weight and sliding force on both structures. In addition, there will also be a comparison of dimensions and reinforcement for the cross-section of beams and columns. As for the dimensions and the turning of the plate, there is no change in the dimension or the re-refining, this is because the dead load and the life load inputted in the manual calculation is the same load as the old standard. Differences in dimensions and reinforcement are strongly influenced by the shear force received by the structure, the greater the shear force, the dimensions and the number of reinforcements on some beams and / or columns must also be enlarged to be able to support the given force..

5. Conclusion

Based on the design that has been carried out, it can be concluded that analysis of differences in earthquake-resistant building structures using SNI-1726-2012 and SNI-1726-2019 is carried out by verifying the comparison of static and dynamic shear forces and checking deviations between floors. From the verification, it can be known that the static shear force on the main structure has increased by 54% for the main structure and 19% for the connecting structure. Dynamic shear forces increased by 59% for the main structure and 34% for the connecting structure. The increase in static and dynamic shear force has an impact on the value of deviations between floors that are getting bigger and bigger, so that dimensional magnification is needed to be able to withstand the sliding force that occurs due to the application of regulations to the new standard.

The cross-sectional dimensions of the structure have changed up to 78% from the initial dimension. Changes occur in the B1 beam where the cross-sectional width must be enlarged by

50% and the cross-sectional height is enlarged 33% from the initial dimension. Similarly, B4 beams with different percent width and cross-section height of beams reach 78% and 33%, and B5 beams with beam width increased by 20% and beam height increased by 25%. The B6 beam should also be enlarged in dimensions to be 25% larger at the cross-sectional width and 17% at the cross-sectional height. Changes also occur in the cross-sectional dimensions of the column where all column cross-sections experience dimensional magnification caused by the sliding force and the greater deviation. Column K1 should be enlarged by 50% for width and 25% for its cross-sectional height, K2 column should be enlarged 33% at width and 29% at column cross-sectional height, K3 column should be enlarged 33% at the width and height of its column cross section. Furthermore, in the K5 column the change that occurs is only 7% for the width and height of the cross-section, the K6 column must be added 33% of the width dimension size and 18% of the cross-sectional height of the column. The K7 column increased by 31% for the cross-sectional width and 20% for the height, the K8 column was enlarged by 17% for the width and 7% the cross-section height and the K9 column was enlarged by 33% for the width and height of its cross-section.

The new standard was designed by improving the retrofitting of the structure so that the structure is safer with significantly changed earthquake loads, therefore the dimensions and reinforcement of the structure become larger and more numerous than the previous standard.

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