Comparative study of internal force in lecture buildings in Daerah Istimewa Yogyakarta between SNI 1726-2012 and 1726-2019 with the spectrum response method (2D)

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Abstract. An earthquake is a sudden movement of the ground that comes from a wave in a place and spreads in all directions. In 2019 the Government of Indonesia has ratified a new standard on procedures for earthquake resistance planning for building and non-building structures, namely SNI 1726: 2019 as a revision of SNI 1726: 2012. The adoption of SNI 1726-2019 as a new standard has changed the scope of the procedure for calculating earthquakes to become wider so that it can follow the current developments. Earthquake loads on buildings were analyzed using dynamic response spectrum analysis. This study aims to compare the results of the calculation using the response spectrum using SNI 1726-2012 and SNI 1726-2019 in order to determine the safety of building that still use the old rules. The building structure is modeled on a lecture building with a height of 14.10 m in the Province of D.I Yogyakarta. The results of the research prove that the structure of the lecture building which still uses the old method must be rehabilitated so that it is able to withstand earthquake loads based on the new SNI 1726-2019 method. This occurs due to the discovery of new faults in Indonesia.

1. Introduction

An earthquake is a sudden movement of the ground that comes from a wave in a place and spreads from the area in all directions. Naturally, earthquakes that occur are caused by the release of energy in the earth that has been trapped long enough to create waves in all directions [4][11]. Earthquakes shake the earth which results in a sudden release of energy which creates seismic waves [5]. Earthquakes in relation to a region are related to the movement of the earth's surface and its effect on the area concerned.

Indonesia is a country that has the potential to experience an earthquake. This is because Indonesia is in the area of the Pacific earthquake route (Circum Pacific Earthquake Belt) and the Asian earthquake route (Trans Asiatic Earthquake Belt) [11]. In planning development in Indonesia, earthquake parameters must be considered. One of the earthquake parameters that directly affects the planning is the ground acceleration caused by seismic waves acting on the building period. In order to secure the building, the building must be designed as an earthquake resistant building which is planned in accordance with the applicable earthquake regulations in Indonesia. The collapse of buildings can be minimized by analyzing building modeling during an earthquake so that planners can better plan the buildings to be built [8].

In 2019 the Government of Indonesia has ratified a new standard on procedures for earthquake resistance planning for building and non-building structures, namely SNI 1726: 2019 as a revision of SNI 1726: 2012.
It is stated in the standard that the effect of an earthquake plan must be reviewed in the planning and evaluation of building and non-building structures [7]. The design seismic force can be calculated using the equivalent lateral force analysis, analysis of the variance response spectrum as well as seismic time history response analysis.

Dynamic analysis for the design of earthquake-resistant structures is carried out if a more accurate evaluation of the seismic forces acting on the structure is needed, and to determine the behavior of the structure due to the effects of the earthquake [17]. In the research [16] the results of dynamic analysis of the response spectrum using earthquake plans based on SNI 1726-2012, found that the building has a value of S1 0.30g and Ss 0.75g. Analysis of the soil compression on the basement wall per m2 is 27.361 kN / m2 or 0.2.736 t / m2 The period of vibration is 0.0926 seconds, the seismic response coefficient is 0.1800, the distribution of lateral forces is 578.489 tonnes. Every floor level so that when reviewed based on ATC-40 it is included in the Immediate Occupancy level category. It is reinforced by research [1] that comparisons using response spectrum analysis and time history analysis on a 4-story structure have the results of displacement and drift values that are not much different, with a value of 0.053919 m in the response spectrum and 0.052729 m in the time history for displacement value, while the drift value is 0.003866 m in the response spectrum and 0.003723 m in the time history. So that the building is safe against service-free \((0.03 / R) \times h\), ultimate limit \((0.02h)\), and ATC-40 (Immediate Occupancy).

With so many building plans in Indonesia that still use SNI 1726-2012 with the dynamic response spectrum analysis method. For this reason, it is necessary to conduct an evaluation of the existing building planning and then compare the capacity of the building in facing the earthquake strength defined in SNI 1726-2012 and SNI 1726-2019 by comparing the values of Mu, Pu, and Vu and minimizing the number of casualties when an earthquake occurs.

2. Loadings

In this study two types of load are used, i) gravity load which includes dead load and live load, and ii) lateral load which includes earthquake loads.

2.1 Gravity load

This loading represents all tributary dead loads and live loads. The live load and dead load based on PPIUG 1983 & PPURG 1987 refer to SNI 2847-2013. The dead load and live load work as distributed loads on buildings. Table 1 shows type of load.

| Type of Load     | Description                  | kN/m² |
|------------------|-------------------------------|-------|
| DEAD LOAD        | Dead load works on the floor  | 4.54  |
|                  | Dead load works on the beam   | 2.5   |
|                  | Dead load works on the roof   | 3.12  |
| LIVE LOAD        | Live load works on the floor  | 1.92  |
|                  | Live load works on the roof   | 1     |

2.2 Lateral load

In lateral load, there are various types of load, but the focus of this research is earthquake load using the spectrum response method between SNI 1726-2012 and SNI 1726-2019

2.2.1 Design Spectrum Responses

The design spectrum response that will be used in the analysis comparison is SNI 1726-2012 and SNI 1726-2019. The design response spectrum is required to take into account the influence of torque, moment and displacement of the center of mass from the center of rigidity. The stages of the spectrum response design according to SNI 1726-2012 and 2019 in a way that has been adjusted to the research needs [6]:

- Observe the location of the building to be evaluated
- Determine SPT value and classification of soil type
Determine the parameters of the acceleration of the maximum earthquake response with consideration of the risk targeted MCE\textsubscript{R} (Maximum Considered Earthquake, Risk Targeted) for short periods of 0.2 seconds (S\textsubscript{S}) and 1.0 seconds (S\textsubscript{I}).

Look for the amplification factor of the response parameters of the ground surface acceleration spectrum for short periods (Fa) and 1 second period (Fy).

Determine the parameters of the acceleration spectrum response (S\textsubscript{MS} and S\textsubscript{M1}),
\[
S_{MS} = F_a \times S_s \\
S_{M1} = F_y \times S_I
\]

Determine the parameters of the design acceleration spectrum response (S\textsubscript{DS} and S\textsubscript{D1}),
\[
S_{DS} = 2/3 \times S_{MS} \\
S_{D1} = 2/3 \times S_{M1}
\]

Make a graph response to images with the provisions that have been determined SNI 1726-2012

Conditions:

a. For periods smaller than T\textsubscript{0}, the design acceleration response spectrum, S\textsubscript{a}, must be taken from Equation S\textsubscript{a} = S\textsubscript{DS} (0.4 + 0.6 (T/T\textsubscript{0}))

b. For periods greater than or equal to T\textsubscript{0} and smaller than or equal to T\textsubscript{S}, the response spectrum of the design S\textsubscript{a} = S\textsubscript{DS}.

c. For periods greater than T\textsubscript{S}, the design acceleration response spectrum, S\textsubscript{a}, is taken for equation: S\textsubscript{a} = S\textsubscript{D1}/T

Make a graph response to images with the provisions that have been determined SNI 1726-2019.

Period provisions are as follows:

a. For periods smaller than T\textsubscript{0}, the following equation is used S\textsubscript{a} = S\textsubscript{DS} (0.4 + 0.6 T/T\textsubscript{0})

b. For periods greater than or equal to T\textsubscript{0} and smaller than or equal to T\textsubscript{S}, the response spectrum of the design S\textsubscript{a} = S\textsubscript{DS}.

c. For periods greater than T\textsubscript{S}, but smaller than or equal to T\textsubscript{L}, the spectral response of the design acceleration, S\textsubscript{a}, is taken equation S\textsubscript{a} = S\textsubscript{D1}/T

d. For periods greater than T\textsubscript{L}, the spectral response of the design acceleration, S\textsubscript{a}, is taken based on Equation S\textsubscript{a} = (S\textsubscript{D1} \times T\textsubscript{L}) / T^2

e. For the value of T obtained by calculating the fundamental period of the structure (T) based on this equation:
\[
T_a = C_t \cdot h^n_x
\]
\[h_x = \text{the height of the structure (m) above the base to the highest level of the structure, } C_t \text{ and } x \text{ are obtained from the table specified by SNI 1726-2012 and SNI 1726-2019}

f. For the values of T\textsubscript{0} and T\textsubscript{S} can be obtained from the equation:
\[
T_0 = 0.2 \times S_{D1}/S_{DS} \\
T_S = S_{D1}/S_{DS}
\]
g. For T\textsubscript{L} values, obtained from Figure 20 in SNI 1726-2019.

h. In determining the risk category of buildings and earthquake priority factors, it is found that the lecture buildings is categorized as IV and the earthquake priority factor is 1.50

i. Determination of seismic design categories is based on the seismic design category of the acceleration response parameters in the short and 1 second periods

2.3 Internal Force

Internal force is the force that holds the propagation force in the construction to achieve balance. Internal forces include axial forces, latitude forces, and moments [13]. The results that will be obtained from the internal force are the Ultimate Moment (Mu), the Ultimate Shear Strength (Vu), and the Ultimate Pressure (Pu).
3. Method

This study aims to check and evaluate the change in spectrum response in lecture buildings that are still using planning with SNI 1726-2012 and compared with SNI 1726-2019, after counting the response spectrum is followed by running model in SAP with the Dynamic method (Response Spectrum) then compared the values of internal force such as Mu, Pu, and Vu. Modeling in 2D in Structure Analysis Software.

3.1 Preliminary Data

Preliminary data includes general soil data, structural technical data, and earthquake data.

3.1.1 Soil Data.

The lecture building consists of 4 floors with an area of 17 m x 57 m. The N-SPT data is obtained through the assumptions given by (Safwan, 2018) using the CPT and SPT methods. Structural Technical Data.

Lecture buildings withstand structural loads based on Indonesian government standards using SNI 2847-2013. The lecture buildings uses the Reinforcement concrete structure, the foundation uses a cakar ayam. The concrete quality (fc’) used is 25 MPa, the steel quality (fy) is 240 MPa and 400 MPa.

**Table 2. Building structural components size**

| Building Structural Components | Type | Size (cm) |
|-------------------------------|------|-----------|
| BEAM                          | B1   | 35 x 70   |
|                               | B2   | 30 x 40   |
|                               | B2a  | 30 x 40   |
|                               | B3   | 30 x 50   |
|                               | B3a  | 30 x 50   |
|                               | B4   | 30 x 40   |
|                               | B5   | 20 x 40   |
|                               | B5a  | 20 x 40   |
|                               | B5b  | 20 x 40   |
|                               | B5c  | 25 x 40   |
|                               | B5d  | 20 x 40   |
|                               | B5e  | 20 x 40   |
|                               | B6   | 30 x 50   |
|                               | BS   | 25 x 40   |
3.1.2 Earthquake data. The spectrum response value is obtained by following the predetermined stages:

a. The location of the building being reviewed is in DIY.
b. With an SPT value of 18, then determine the class of the land site using the Site Classification table, obtained medium soil (SD)
c. Determination of parameters for earthquake response acceleration based on SNI 1726-2012 and SNI 1726-2019

Table 3. The parameter of acceleration of spectrum response earthquake is based on SNI 1726-2012 and SNI 1726-2019

| Parameters | SNI 1726-2012 | SNI 1726-2019 |
|------------|---------------|---------------|
| Ss         | 0.75          | 0.75          |
| S1         | 0.3           | 0.3           |
| F\text{a}  | 1.2           | 1.2           |
| F\text{v}  | 1.8           | 2.0           |
| S_{\text{MS}} | 0.9          | 0.9           |
| S_{\text{MI}} | 0.54         | 0.6           |

4. Result and Discussion

4.1 Loading.

*Loading the structure of the lecture buildings using a standard combination of structural loads SNI 2847-2013. Standard response of earthquake response spectrum using SNI 1726-2012 and SNI 1726-2019.*

4.2 Structure Analysis.

Analysis of lecture buildings structure using computer software, SAP 2000. Part to be reviewed is selected the longest transverse side to be given evenly distributed force and if it is drawn it will be like the Figure 2.
4.3 Calculation of Earthquake Loading.

For earthquake loading we use response spectrum method between SNI 1726-2012 and SNI 1726-2019. From the initial spectrum response data, an acceleration calculation is performed to obtain the spectrum response spectrum using two different standards, namely SNI 1726-2012 and SNI 1726-2019.

4.3.1 SNI 1726-2012 and SNI 1726-2019.

Spectrum response graphs are obtained based on the spectrum response method specified in SNI 1726-2012 and SNI 1726-2019, the values obtained are then entered into SAP software to get the spectrum response graphs used to determine earthquake resistance of buildings.

Table 4. The value used to make response spectrum graph based on SNI 1726-2012 and SNI 1726-2019

| Parameters          | SNI 1726-2012 | SNI 1726-2019 |
|---------------------|---------------|---------------|
| SD₁                 | 0.36          | 0.4           |
| SDₛ                | 0.6           | 0.6           |
| T₀                 | 0.12          | 0.133         |
| Tₛ                 | 0.6           | 0.667         |
| Sa = SDₛ (0.4+0.6 x T/Tₛ) | 1.752         | 1.604         |
| Sa = SDₛ           | 0.6           | 0.816         |
| Sa = SD₁/T         | 0.714         | 0.794         |
| T                  | 0.504         | 0.504         |
| TL                 | 20            |               |

From the SNI 1726-2012 and SNI 1726-2019 methods, the spectrum response graphs in figures 3 and 4 are obtained.
With static load and spectrum response of SNI 1726-2012 and SNI 1726-2019 which have been defined, SAP2000 calculation can be done. Then after the SAP2000 results table is obtained, then compare the values of Mu, Pu, Vu.

Table 5. Comparison of internal force between SNI 1726-2012 and SNI 1726-2019

| Element | Internal Force | SNI 1726-2012 | SNI 1726-2019 |
|---------|----------------|---------------|---------------|
| Pu      | 690,763        | 686,537       |
| Mu      | 70,657         | 67,089        |
| Vu      | 172,1175       | 169,0223      |
| Element | Internal Force | SNI 1726–2012 | SNI 1726–2019 |
|---------|----------------|---------------|---------------|
| Pu      | 379,035        | 376,789       |
| 2       |                |               |               |
| Mu      | 117,948        | 115,218       |
| Vu      | 240,4284       | 234,3186      |
| Pu      | 68,031         | 67,318        |
| 3       |                |               |               |
| Mu      | 56,025         | 55,246        |
| Vu      | 159,2193       | 159,3401      |
| Pu      | 905,821        | 905,824       |
| 4       |                |               |               |
| Mu      | 65,656         | 61,599        |
| Vu      | 153,2118       | 148,7618      |
| Pu      | 505,857        | 505,866       |
| 6       |                |               |               |
| Mu      | 110,533        | 107,071       |
| Vu      | 224,6619       | 217,1748      |
| Pu      | 102,924        | 102,866       |
| 7       |                |               |               |
| Mu      | 47,275         | 45,974        |
| Vu      | 134,3179       | 133,4362      |
| Pu      | 587,956        | 586,477       |
| 8       |                |               |               |
| Mu      | 10,206         | 8,93          |
| Vu      | 24,0414        | 21,8352       |
| Pu      | 365,74         | 364,956       |
| 9       |                |               |               |
| Mu      | 16,599         | 15,106        |
| Vu      | 33,8702        | 30,9141       |
| Pu      | 148,699        | 148,464       |
| 10      |                |               |               |
| Mu      | 13,77          | 12,976        |
| Vu      | 27,9843        | 26,1933       |
| Pu      | 369,001        | 366,265       |
| 11      |                |               |               |
| Mu      | 15,784         | 14,822        |
| Vu      | 37,4508        | 36,0967       |
| Pu      | 232,306        | 230,841       |
| 12      |                |               |               |
| Mu      | 24,641         | 23,688        |
| Vu      | 50,2218        | 48,4214       |
| Pu      | 94,404         | 93,985        |
| 13      |                |               |               |
| Mu      | 23,104         | 22,664        |
| Vu      | 48,1577        | 47,0064       |
| Pu      | 52,926         | 52,5          |
| 14      |                |               |               |
| Mu      | 283,562        | 281,695       |
| Vu      | 419,6176       | 411,3436      |
| Pu      | 57,972         | 52,168        |
| 15      |                |               |               |
| Mu      | 282,363        | 33,869        |
| Vu      | 412,8216       | 62,5742       |
| Pu      | 52,423         | 52,168        |
| 16      |                |               |               |
| Mu      | 34,583         | 33,869        |
| Vu      | 65,8575        | 62,5742       |
| Pu      | 5,772          | 5,245         |
| 17      |                |               |               |
| Mu      | 96,471         | 94,602        |
| Vu      | 70,2832        | 67,1624       |
| Pu      | 2,147          | 1,793         |
| 18      |                |               |               |
| Mu      | 98,916         | 97,343        |
| Vu      | 73,2599        | 70,6706       |
| Pu      | 11,12          | 11,093        |
| 19      |                |               |               |
| Mu      | 53,011         | 52,356        |
From Table 5 it is known that the results of the internal forces (Pu, Mu, and Vu) as a whole show that SNI 1726-2019 is smaller than the results of SNI 1726-2012 in the earthquake spectrum response method. So, from the calculation of internal forces, the structure of this lecture building can be categorized as able to withstand earthquake forces based on the latest SNI 1726-2019 planning method. But that the structure of this building needs to be given rehabilitation in order to be able to withstand the earthquake loads that will occur, both mild to heavy rehabilitation because of the changes of the hazard map Indonesia. This is reinforced by [10] if the values of Pu, Mu, and Vu at SNI 1726-2012 are lower, it is necessary or not to re-check the buildings that have been built in accordance with SNI 1726-2002.

From the findings of previous research, many buildings have to be given structural rehabilitation to avoid structural damage because in the planning they still use old methods such as SNI 1726-2002 which later in the SNI 1726-2012 method experienced changes in working methods. additional labor or labor so that the structure is considered unable to withstand the load anymore [9][12][15].

5. Conclusion

Based on the above discussion, the conclusion is that there is an effect of changing the planning plan of SNI 1726-2012 to SNI 1726-2019 even though the calculation of the force in the structure of the lecture building still uses the SNI 1726-2012 planning but it meets the safe limits using planning with the SNI 1726-2019 method. But this does not guarantee that the building can withstand earthquake forces based on the SNI 1726-2019 method, this is due to map changes due to new discoveries in Indonesia, as well as the influence of the increasing age of the building which causes a shrinkage of the strength of the building structure at age. certain. Therefore, buildings that are given a small safe limit in planning with the SNI 1726-2012 method greatly affect the assessment of the building style against the seismic force that works based on the new planning method SNI 1726-2019, this building with a small safe limit can certainly be rehabilitated so that able to withstand earthquakes that will occur at a later date. In this study, the limitation of researchers is data that supports overall structural planning due to the Covid-19 pandemic, so not all data obtained are primary data. It is hoped that in other studies the same but with different variables can find a more effective method in collecting data supporting building structures. In addition, changes in earthquake faults in Indonesia which are fairly fast also affect changes in earthquake maps and planning for earthquake-resistant buildings that will be used in the future. Therefore, other research to assess earthquake resistance in buildings will always be asked to do so that preventive solutions for earthquake-affected buildings can be provided.

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