Comparison of seismic load calculation based on SNI 1726-2012 and SNI 1726-2019 to capacity of elements on low level building

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Abstract. Buildings are designed to resist earthquake loads. After an earthquake occurs, it is expected that buildings will suffer minimal non-structural and structural damage. In designing earthquake loads on buildings, the regulations used in Indonesia refer to SNI 1726-2012. In 2019, the national standardization body (BSN) issued a new standard in carrying out earthquake load planning on building structures. In this standard there is an update on the latest earthquake map based on past earthquake event data. This paper aims to compare those two standards on low level building in terms of capacity of beams and columns using SAP 2000. The parameter of design spectral response at short periods, $S_{DS}$ and design spectral response at one seconds periods, $S_{D1}$ has been increased as well in SNI 1726-2019 especially in Jakarta area, which resulted in greater base shear, story drift, and internal forces on the beam and columns. The analysis result showed that base shear of low-level building has increased by 4.98% in x-axis and 7.21% in y-axis. The internal forces caused by the earthquake load are compared with the cross-sectional capacities of the beams and columns. Since there are not significant changes in $S_{DS}$ and $S_{D1}$ of Jakarta area, the impact on internal forces are minor which leads to result that all beams and columns still below the cross-sectional capacity of the beam and column.

Keywords: seismic loads, base shear, story drift

1. Introduction

Indonesia has experienced various kinds of natural disasters, especially earthquakes. These events happened because Indonesia is located at the ring of fire, which is a series of active volcanoes in the world. Earthquake is one of unpredictable phenomenon with certainty of place and time. Thus, there must be early warning system for earthquake hazards and put anticipation with the construction of earthquake-resistant buildings[1]. With those reason, BSN has updated seismic standards with the title of SNI 1726-2019 because the previous standard is no longer a suitable guideline for planning earthquake-resistance building according to characteristic earthquakes happened in last 7 years.

Concept of SNI 1726-2019 is mostly same as written in SNI 1726-2012 or ACSE 7-10 although SNI 1726-2019 is based on ASCE 7-16. This standard assumes probability with risk-targeted maximum considered earthquake 2% risk of uniform collapse in 50 years while $MCE_R$ is taken as the smallest of probabilistic and deterministic ground shocks with 84th percentile [2] and [3]. PusGen
updated hazard seismic map in 2017 which will be base of site class in SNI 1726-2019 regarding to spectral acceleration parameter at short periods ($S_S$) and spectral acceleration parameter at one second periods ($S_{1\text{s}}$) values and there is another category for $S_s$ and $S_{1\text{s}}$ compared to SNI 1726-2012 [4]. This study aims to compare those two standards in terms of base shear, story drift, vertical distribution of seismic load, and its element capacity to seismic load on a low-level building, which is built 1990s.

2. Methodology

Response Spectrum Design

In accordance with the provisions in ASCE 7-16, the map of acceleration of the maximum earthquake response spectrum considered (MCE$_R$) with 5% attenuation and a 1% criterion of probability of uniform collapse in 50 years, which has been adjusted for site classes between SB and SC, for short period (0.2 seconds) in Figure 1 (a) hazard seismic map of 2010 and (b) hazard seismic map of 2017 compiled by Indonesian Earthquake Source and Hazard Map Team.

![Hazard Seismic Maps](image)

**Figure 1.** Hazard seismic map (a) SNI 1726-2012, (b) SNI 1726-2019

| Site Profile                       | $S_s (T=0.2\text{ sec})$ |
|-----------------------------------|--------------------------|
|                                   | $S_s \leq 0.25$ | $S_s = 0.5$ | $S_s = 0.75$ | $S_s = 1.0$ | $S_s \geq 1.25$ |
| Hard Rock (SA)                    | 0.8                     | 0.8         | 0.8         | 0.8         | 0.8          |
| Rock (SB)                         | 1.0                     | 1.0         | 1.0         | 1.0         | 1.0          |
| Very Dense Soil and Soft Rock (SC)| 1.2                     | 1.2         | 1.1         | 1.0         | 1.0          |
| Stiff Soil Profile (SD)           | 1.6                     | 1.4         | 1.2         | 1.1         | 1.0          |
| Soft Soil Profile (SE)            | 2.5                     | 1.7         | 1.2         | 0.9         | 0.9          |
| Specific Evaluation Required (SF) | SS                      | SS          | SS          | SS          | SS           |

| Site Profile                       | $S_s (T=0.2\text{ sec})$ |
|-----------------------------------|--------------------------|
|                                   | $S_s \leq 0.25$ | $S_s = 0.5$ | $S_s = 0.75$ | $S_s = 1.0$ | $S_s = 1.25$ | $S_s \geq 1.5$ |
| Hard Rock (SA)                    | 0.8                     | 0.8         | 0.8         | 0.8         | 0.8         | 0.8          |
| Rock (SB)                         | 0.9                     | 0.9         | 0.9         | 0.9         | 0.9         | 0.9          |
| Very Dense Soil and Soft Rock (SC)| 1.3                     | 1.3         | 1.2         | 1.2         | 1.2         | 1.2          |
| Stiff Soil Profile (SD)           | 1.6                     | 1.4         | 1.2         | 1.1         | 1.0         | 1.0          |
| Soft Soil Profile (SE)            | 2.4                     | 1.7         | 1.3         | 1.1         | 0.9         | 0.8          |
| Specific Evaluation Required (SF) | SS                      | SS          | SS          | SS          | SS          | SS           |
Table 1 shows criteria of $F_a$ in each $S_s$ value, which can be calculated with a simple interpolation. On the contrary, Table 2 shows criteria of $F_a$ in each $S_s$ value with the addition of new category where $S_s$ is greater than 1.5. That new feature is one of significant changes in SNI 1726-2019 in designing response spectrum of certain point because $F_a$ effects on $S_{DS}$ value in the end which finally leads to changing of $T$.

### Table 3. Site coefficient for 1 second period $F_v$, SNI 1726-2012

| Site Profile                                      | $S_{I} \leq 0.1$ | $S_{I} = 0.2$ | $S_{I} = 0.3$ | $S_{I} = 0.4$ | $S_{I} \geq 0.5$ |
|--------------------------------------------------|------------------|----------------|----------------|----------------|------------------|
| Hard Rock (SA)                                   | 0.8              | 0.8            | 0.8            | 0.8            | 0.8              |
| Rock (SB)                                        | 1.0              | 1.0            | 1.0            | 1.0            | 1.0              |
| Very Dense Soil and Soft Rock (SC)               | 1.7              | 1.6            | 1.5            | 1.4            | 1.3              |
| Stiff Soil Profile (SD)                          | 2.4              | 2.0            | 1.8            | 1.6            | 1.5              |
| Soft Soil Profile (SE)                           | 3.5              | 3.2            | 2.8            | 2.4            | 2.4              |
| Specific Evaluation Required (SF)                | SS               | SS             | SS             | SS             | SS               |

### Table 4. Site coefficient for 1 second period $F_v$, SNI 1726-2019

| Site Profile                                      | $S_{I} \leq 0.1$ | $S_{I} = 0.2$ | $S_{I} = 0.3$ | $S_{I} = 0.4$ | $S_{I} = 0.5$ | $S_{I} \geq 0.6$ |
|--------------------------------------------------|------------------|----------------|----------------|----------------|----------------|------------------|
| Hard Rock (SA)                                   | 0.8              | 0.8            | 0.8            | 0.8            | 0.8            | 0.8              |
| Rock (SB)                                        | 0.8              | 0.8            | 0.8            | 0.8            | 0.8            | 0.8              |
| Very Dense Soil and Soft Rock (SC)               | 1.5              | 1.5            | 1.5            | 1.5            | 1.5            | 1.4              |
| Stiff Soil Profile (SD)                          | 2.4              | 2.2            | 2.0            | 1.9            | 1.8            | 1.7              |
| Soft Soil Profile (SE)                           | 4.2              | 3.3            | 2.8            | 2.4            | 2.2            | 2.0              |
| Specific Evaluation Required (SF)                | SS               | SS             | SS             | SS             | SS             | SS               |

Table 3 shows criteria of $F_v$ in each $S_s$ value, which can be calculated with a simple interpolation. On the contrary, Table 4 shows criteria of $F_v$ in each $S_s$ value with the addition of new category where $S_s$ is greater than 0.6. That new feature is one of significant changes in SNI 1726-2019 in designing response spectrum of certain point because $F_v$ effects on $S_{DS}$ value in the end which finally leads to changing of $T$.

**Numerical Modeling**

The analysis of seismic loads from various seismic combinations on each section of building carried out with SAP 2000. Grid data and dimension of beams and columns are obtained from validation of shop-drawing based data and actual measurement data with digital meter to minimize inaccuracy. There are several steps to complete before running the model analysis such as input seismic data, grid, defining materials and frame sections, load combinations based on both standards [5] [6].
Figure 2. Running analysis of response spectrum of section H SNI 1726-2012

(a) Running model in X-axis
(b) Running model in Y-axis

Figure 3. Running analysis of response spectrum of section H SNI 1726-2019

(c) Running model in X-axis
(d) Running model in Y-axis

Figure 4. Seismic loads on elements of section H

The analysis was conducted for each section of building, which is consisted of section H, J, K, and L and run the model to obtain the result occurred by seismic load as shown in Figure 3 and Figure 4. The result from the analysis includes base shear force, story drift, internal forces on beams and columns. Those outputs from SAP 2000 will be continued to Microsoft Excel to sort and to find out the maximum internal forces on each section and each floor. After that, base shear force and story drift will be compared to each other to confirm the difference between two and safety of the building. For internal forces, there will be comparison between applied force by seismic loads and its own capacity.

3. Results and Discussion

In Figure 5 shows the graph of response spectrum from each standard based on site coefficient of Jakarta. It can be seen that shape of graph is almost symmetrical at $T = 0.2$ second and it begins to
separate when $T = 0.25$ second till $T = 0.8$ sec. From the graph can be known that the site acceleration of SNI 1726-2019 ($S_a$) is greater than SNI 1726-2012, which indicates there will be greater seismic loads as well on SNI 1726-2019 model.

![Response spectrum design](image)

**Figure 5.** Response spectrum design

![Graph of base shear force in each storey](image)

**Figure 6.** Graph of base shear force in each storey

From Figure 5 can be seen that impact of response spectrum design on vertical distribution lateral force which is proportionally related to height and $k$ exponential value [7]. $K$ value is obtained from interpolation in range of 1 to 2 with $t$. Since response spectrum design on SNI 1726-2019 is greater, there is an increase in base shear force of 4.98% in x axis and 7.21 % in y-axis.
(a) Story drift in section H

(b) Story drift in section J

(c) Story drift in section K
Figure 7. Story drift comparison between SNI 1726-2012, SNI 1726-2019 and its threshold

Figure 7 shows the graph about displacement in each storey. (a) Storey Drift in Section H, showing that there is a slight difference in displacement in X and Y axis. Both SNI 1726-2012 and SNI 1726-2019 based calculation does not exceed threshold (green line). (b) is also showing that there is enough difference in displacement at SNI 1726-2019 based calculation. However, displacement in SNI 1726-2019 result almost reached its threshold. Plus, result of SNI 1726-2019 is smaller than SNI 1726-2012. (c) is showing the same pattern as shown in (b) graph but displacement occurred in SNI 1726-2019 is greater than SNI 1726-2012 due to direction seismic combination and location of section K. (d) is showing that displacement occurred in SNI 1726-2019 is greater than SNI 1726-2012 but their displacement is far from threshold, based on previous study by Said [8], which means results are still safe from seismic loads.

Table 5. Comparison of ultimate moment from SAP 2000 result with capacity of beam

| Story | Beam | SNI 2012 | Mu | SNI 2019 | Mu | Diff. |
|-------|------|---------|-----|---------|-----|------|
| 1st Floor | 450x850 | Positive | 440,223 | 266,901 | Safe | 440,223 | 276,632 | Safe | 3,518 |
| | | Negative | 686,848 | 608,281 | Safe | 686,848 | 646,252 | Safe | 5,876 |
| | 350x750 | Positive | 192,810 | 18,685 | Safe | 192,810 | 20,757 | Safe | 61,162 |
| | | Negative | 192,810 | 40,236 | Safe | 192,810 | 51,461 | Safe | 21,814 |
| | 150x300 | Positive | 18,906 | 7,114 | Safe | 30,483 | 8,042 | Safe | 11,539 |
| | | Negative | 30,483 | 22,475 | Safe | 30,483 | 23,371 | Safe | 5,876 |
| 2nd Floor | 450x850 | Positive | 440,223 | 267,785 | Safe | 440,223 | 280,482 | Safe | 4,527 |
| | | Negative | 686,848 | 596,101 | Safe | 686,848 | 635,783 | Safe | 6,242 |
| | 350x750 | Positive | 192,810 | 31,051 | Safe | 192,810 | 33,609 | Safe | 7,598 |
| | | Negative | 192,810 | 40,683 | Safe | 192,810 | 51,461 | Safe | 4,806 |
| | 150x300 | Positive | 18,906 | 7,114 | Safe | 18,906 | 11,716 | Safe | 3,500 |
| | | Negative | 30,483 | 22,475 | Safe | 30,483 | 23,371 | Safe | 5,876 |
| 3rd Floor | 450x850 | Positive | 440,223 | 275,244 | Safe | 440,223 | 281,688 | Safe | 2,444 |
| | | Negative | 686,848 | 454,983 | Safe | 686,848 | 475,963 | Safe | 4,980 |
| | 350x750 | Positive | 192,810 | 49,379 | Safe | 192,810 | 25,845 | Safe | 5,675 |
| | | Negative | 192,810 | 34,022 | Safe | 192,810 | 33,825 | Safe | 2,605 |
| | 150x300 | Positive | 18,906 | 7,114 | Safe | 18,906 | 7,594 | Safe | 1,198 |
| | | Negative | 30,483 | 20,425 | Safe | 30,483 | 23,371 | Safe | 2,826 |

Table 6 shows comparison of ultimate moment occurred by seismic load with capacity of beam, the capacity of each beam is reduced with reduction factor which is 0.8 and ultimate moment (M_u) is
obtained from SAP analysis. As shown in the table, there is not any ultimate moment that exceeds its own capacity. The 1st storey beam with 350x750 dimension has the greatest increase in ultimate moment by 41.162% which is still safe from failure.

Table 6. Comparison of Shear Force from SAP 2000 Result with Capacity of Beam

| Story   | Beam    | SNI 2012 | SNI 2019 | Diff. |
|---------|---------|----------|----------|-------|
|         | kN.m    | kN.m     | Result   | kN.m  | kN.m     | Result   | %       |
| 1st Floor| 450x850 | 285,065  | 262,415  | Safe  | 296,627  | 271,087  | Safe   | 3,199  |
|         | 350x750 | 122,891  | 30,840   | Safe  | 122,891  | 30,840   | Safe   | 0,000  |
|         | 150x300 | 33,724   | 30,357   | Safe  | 34,548   | 30,975   | Safe   | 1,995  |
| 2nd Floor| 450x850 | 283,462  | 261,213  | Safe  | 297,376  | 270,433  | Safe   | 3,409  |
|         | 350x750 | 122,891  | 35,509   | Safe  | 122,891  | 37,219   | Safe   | 4,594  |
|         | 150x300 | 34,050   | 30,602   | Safe  | 34,886   | 31,229   | Safe   | 2,008  |
| 3rd Floor| 450x850 | 250,521  | 236,507  | Safe  | 259,155  | 241,767  | Safe   | 2,176  |
|         | 350x750 | 122,891  | 31,102   | Safe  | 122,891  | 32,189   | Safe   | 3,377  |
|         | 150x300 | 32,237   | 29,242   | Safe  | 32,820   | 29,679   | Safe   | 1,472  |

As shown in table 6, there is comparison about nominal shear force with given shear force due to seismic loads, as a result, it can be stated that all beams are able to withstand shear force in SNI 1726-2012 and SNI 1726-2019.

(a) ColumnInteractionDiagram in Section H (SNI 2012 and SNI 2019)

(b) ColumnInteractionDiagram in Section J (SNI 2012 and SNI 2019)
The interaction diagram explains easily about result of axial forces and ultimate moments applied in each column. The orange dots indicate axial force and ultimate moment due to seismic loads, however, the blue boundary indicates its maximum capacity. Since all orange dots are located in the capacity of each column, it can be stated that all columns in each section are safe from failure.

4. Conclusion

There is an increase in site coefficient of $F_a$ and $F_v$ between SNI 1726-2012 and SNI 1726-2019, which gives fundamental impact into designing response spectrum, base shear force, story drift, and internal forces on beams and columns. Base shear tends to be increased by 4.98% in x-axis and 7.21% in y-axis compared to result of SNI 1726-2012. Story drift in section J decreased over the result of SNI 1726-2012 it might happened because of direction of seismic load combination but overall, all storeys are stated safe according to its guideline. It is concluded that columns and beams are still able to withstand the internal forces occurred by seismic loads.

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