Comparison of the design acceleration response spectra in Riau Province between SNI 1726:2019 and SNI 1726:2012 methods

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Abstract. The current SNI 1726:2012 code was developed to be the new Indonesian Seismic Design Code, SNI 1726:2019 based on the 2017 Indonesian Seismic Hazard Maps and the ASCE 7-16. It has a direct impact on the development of seismic resistance code for building design in Indonesia. The new 2019 risk targeted ground motion of spectral acceleration ($S_a$ and $S_1$), and risk coefficients, for both short ($T = 0.2s$) and 1-second ($T = 1s$) periods, respectively have been published. The paper discusses the difference of the design response spectra for building design of seven districts of Riau Province, Indonesia, according to those standard codes. The analysis was performed for three different site soil classes, that is hard (SC), medium (SD), and soft soil (SE). The design response spectra comparison of SNI 1726:2019 and SNI 1726:2012 of even districts in Riau Province, namely Bangkinang, Bengkalis, Pekanbaru, Tembilahan, Pasir Pangaraiian, Dumai, Teluk Kuantan, and Siak were considered to represent the entire territory of Riau, from North to South that chosen as samplings. The purpose of this study is to evaluate the direct impact of the new code SNI 1726:2019 on design response spectra (DRS). Based on the analysis conducted at 8 cities/ districts, the improvement of DRS 2019 compared to DRS 2012 for site classes SC, SD and SE are less than 0.1g except for all site class at Tembilahan and Teluk Kuantan.

1. Introduction

The Ministry of Public Works and Public Housing formed the 2017 Indonesian Earthquake Map Renewal Team and the Preparation of the National Earthquake Study Centre in 2016. One of his tasks is to update the 2010 Indonesian Earthquake Hazard Map. And in 2017 the team has compiled a "2017 Earthquake and Hazard Map of Indonesia" [1]. With the updating of the 2017 Indonesian Earthquake Hazard Map referring to the current conditions, it is necessary to study the differences in the response spectrum between the SNI 2012 Earthquake Map and the 2017 Earthquake Map in the province. Earthquake resistant structure planning must take into account the effect of an earthquake that has occurred on the structure to be planned [2]. This is to anticipate if a similar earthquake occurs, the planned structure will not experience structural damage. The procedure for planning earthquake resistance for building structures and buildings, namely SNI 1726:2019 is a revision of SNI 1726:2012 [3, 4]. The construction industry always welcomes the revised Indonesian Seismic Design Code with...
great enthusiasm. They always want to know immediately, how much the load difference and the changes in the provisions relating to the design and construction. Commercial building developers may immediately take a decision to speed up the project design and construction process if it turns out that the seismic design load rises and/or the requirements are more stringent [5].

One of the important pieces of information needed for building resistance design is the design acceleration response spectrum at the location of building. Peak Ground Acceleration (PGA) or accelerated bedrock acceleration and response spectrum acceleration for short periods (0.2 seconds) and 1 second periods with a probability of 10% exceeding in 50 years (500 year return period), and maybe 2% exceeding in 50 years (2500 year return period) [6]. The source of seismicity used as a Probabilistic Seismic Hazard Analysis input was 81 faults. In SNI 1726:2012, the earthquake plans are set with a probability of exceeding the magnitude of the life span of a 50-year building structure of 2% or an earthquake with a return period of 2500 years. The bedrock acceleration of SNI 2012 can also be done online which is posted on the page http://puskim.pu.go.id/Aplikasi/desain_spektra_indonesia_2011/. In SNI 1726:2019, the PGA or acceleration of bedrock and acceleration of the response spectrum for short periods (0.2 seconds) and 1 second periods with a probability of 7% exceeded in 75 years (1000 return period years), and a 2% probability is exceeded in 50 years (2500 year return period) [7, 8]. The source of seismicity as a Probabilistic Seismic Hazard Analysis (PSHA) input was 251 faults. This paper is intended as a "review" which shows the difference of the design response spectra according to SNI 1726:2019 and SNI 1726:2012 of 8 major cities/ districts which are considered to represent the entire territory of Riau Province, Indonesia, based on verified data provided in condition of the design response spectra of the site class SC (hard soil), SD (medium soil), and SE (soft soil).

2. Spectra response of acceleration refer to SNI 03-1726-2019

The response spectrum is a fundamental tool in earthquake engineering research and practice, because it shows the maximum dynamic response of single degree of freedom (SDOF) system subjected to specified earthquake ground motion and its time period and damping ratio [9]. The new Indonesian seismic code introduces a long transition period ($T_L$) for developing the new DRS 2019. The MCE$_R$ (risk-targeted maximum considered earthquake) maps were developed with a grid interval of 0.1° and consist of approximately 96,000 data for each spectral response acceleration at short periods, $S_r$ and for spectral response acceleration at a 1-second period, $S_I$. This MCE$_R$ map will be refined and posted on the PU PUSKIM (Center for Research and Development on Housing of the Ministry of Public Works) website to be freely used by public, namely http://rsapuskim2019.litbang.pu.go.id. By using the weighted average of soil parameters for a total depth of not more than 30 m, the definition of Hard Soil, Medium Soil and Soft Soil is shown in Table 1. Values of short-period site coefficient ($F_a$), long period site coefficient ($F_v$), and PGA site coefficient at proposed SNI-1726-2019 have been updated with partial reference to ASCE 7-16 [10, 11]. The updated values of $F_a$, $F_v$, and $F_{PGA}$ coefficient are shown in Table 2 to 4. In principle, the spectral response acceleration values, $S_r$ and $S_I$, are obtained from the MCE$_R$ maps for 0.2 seconds periods (Figure 1) and a 1-second period (Figure 2), which are then multiplied by the seismic amplification factors $F_a$ and $F_v$ producing the spectral response acceleration parameters corresponding to the soil site class, namely $S_{MS}$ and $S_{M1}$, as illustrated in Equations 1 and 2. The value of the design spectral response acceleration at short periods ($S_{DS}$), and the value at a 1-second period ($S_{DI}$) illustrated in Equations 3 and 4.

$$S_{MS} = F_a \cdot S_r$$
$$S_{M1} = F_v \cdot S_r$$
$$S_{DS} = \frac{2}{3} S_{MS}$$
$$S_{DI} = \frac{2}{3} S_{M1}$$

The DRS for building resistance design is developed using two $S_{DS}$ and $S_{DI}$ values which represent short and long period design spectra acceleration respectively. For periods smaller than $T_{05}$, the spectral response acceleration $S_r$ is calculated using Equation 5.

$$S_r = \frac{1}{2} F_a \cdot S_{DS}$$

$$S_I = \frac{2}{3} F_v \cdot S_{DI}$$
\[ S_a = S_{DS} \left( 0.4 + 0.6 \frac{T}{T_0} \right) \]  \hspace{1cm} (5)

For periods greater than or equal to \( T_0 \) and smaller or equal to \( T_S \), the \( S_a \) is equal to \( S_{DS} \). For periods greater than the \( T_S \), the \( S_a \) is taken based on Equation 6.

\[ S_a = \frac{S_{D1}}{T} \]  \hspace{1cm} (6)

For periods greater than \( T_L \), the \( S_a \) is taken based on Equation 7.

\[ S_a = \frac{S_{D1}T_L}{T^2} \]  \hspace{1cm} (7)

\( S_{DS} \) is an acceleration response spectra parameter in short period, \( S_{D1} \) is an acceleration response spectra parameter at a period of 1 second, \( T \) is a fundamental vibration period of structure, and

\[ T_0 = 0.2 \frac{S_{D1}}{S_{DS}} \]  \hspace{1cm} (8)

\[ T_S = \frac{S_{D1}}{S_{DS}} \]  \hspace{1cm} (9)

Design spectra in SNI 1726:2019 can be determined by referring to Figure 3, where the abscissa is the period of structural vibration, \( T \), and the ordinate is the maximum response in the form of maximum acceleration (spectral acceleration, \( S_a \)) [12].

**Figure 1.** Map of spectral acceleration at \( t = 0.2s \) of Indonesia for 2% probability of exceedance in 50 year. \( s_s \) mce, ground motion parameter for Indonesia for 0.2 s spectral response acceleration (5% of critical damping), site class b [4].

**Figure 2.** Map of spectral acceleration at \( t = 1.0s \) of Indonesia for 2% probability of exceedance in 50 year. \( s_s \) mce, ground motion parameter for Indonesia for 1.0 s spectral response acceleration (5% of critical damping), site class b [4].
Table 1. Soil categories (SNI 1726-2019) [4].

| Soil Category | Average shear wave velocity vs $v_s$ (m/sec) | Average standard penetration N | Average undrained shear strength $S_u$ (kPa) |
|---------------|-----------------------------------------------|-------------------------------|---------------------------------------------|
| SC (Hard Soil)| $350 \leq v_s < 750$                          | $N > 50$                      | $S_u \geq 100$                               |
| SD (Medium Soil)| $175 \leq v_s < 350$                        | $15 \leq N \leq 50$           | $50 \leq S_u < 100$                          |
| SE (Soft Soil)| $v_s < 175$                                     | $N < 15$                      | $S_u < 50$                                   |
| SF (Special Soil)| Or, any soil profile with more than 3 m of soft clays with PI $> 20$, wn $\geq 40\%$ and $S_u < 25$ | | |

Table 2. Short-period site coefficient, $F_a$ (SNI 1726-2019) [4].

| Site Class | Mapped Risk-Targeted Maximum Considered Earthquake (MCE$_R$) Spectral Response Acceleration Parameter at Short Period, $T = 0.2s$ |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------|
|            | $S_r \leq 0.25$ | $S_r = 0.5$ | $S_r = 0.75$ | $S_r = 1.0$ | $S_r = 1.25$ | $S_r \geq 1.5$ |
| SA         | 0.8             | 0.8          | 0.8          | 0.8          | 0.8          | 0.8          |
| SB         | 0.9             | 0.9          | 0.9          | 0.9          | 0.9          | 0.9          |
| SC         | 1.3             | 1.3          | 1.2          | 1.2          | 1.2          | 1.2          |
| SD         | 1.6             | 1.4          | 1.2          | 1.1          | 1.0          | 1.0          |
| SE         | 2.4             | 1.7          | 1.3          | 1.1          | 0.9          | 0.8          |

Table 3. 1-Second Period Site Coefficient, $F_v$ (SNI 1726-2019) [4].

| Site Class | Mapped Risk-Targeted Maximum Considered Earthquake (MCE$_R$) Spectral Response Acceleration Parameter at 1-Second Period, $T = 1s$ |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------|
|            | $S_1 \leq 0.1$ | $S_1 = 0.2$ | $S_1 = 0.3$ | $S_1 = 0.4$ | $S_1 = 0.5$ | $S_1 \geq 0.6$ |
| SA         | 0.8             | 0.8          | 0.8          | 0.8          | 0.8          | 0.8          |
| SB         | 0.8             | 0.8          | 0.8          | 0.8          | 0.8          | 0.8          |
| SC         | 1.5             | 1.5          | 1.5          | 1.5          | 1.5          | 1.4          |
| SD         | 2.4             | 2.2          | 2.0          | 1.9          | 1.8          | 1.7          |
| SE         | 4.2             | 3.3          | 2.8          | 2.4          | 2.2          | 2.0          |

Table 4. Site Coefficient, $F_{PGA}$ (SNI 1726-2019) [4].

| Site Class | PGA $\leq 0.1$ | PGA $= 0.2$ | PGA $= 0.3$ | PGA $= 0.4$ | PGA $= 0.5$ | PGA $\geq 0.6$ |
|------------|----------------|-------------|-------------|-------------|-------------|----------------|
| SA         | 0.8            | 0.8         | 0.8         | 0.8         | 0.8         | 0.8            |
| SB         | 0.9            | 0.9         | 0.9         | 0.9         | 0.9         | 0.9            |
| SC         | 1.3            | 1.2         | 1.2         | 1.2         | 1.2         | 1.2            |
| SD         | 1.6            | 1.4         | 1.3         | 1.2         | 1.1         | 1.2            |
| SE         | 2.4            | 1.9         | 1.6         | 1.4         | 1.2         | 1.1            |
3. Spectra response design of cities and districts in Riau Province based on site classes

The design response spectrum plots based on SNI 1726:2019 and SNI 1726:2012 for two cities and six districts selected in Riau Province are presented simultaneously in Figures 5 to 12. The design response spectra of the SNI 1726:2019 are shown in solid curve lines, while the design response spectra of the SNI 1726:2012 are shown in intermittent curve lines. Blue, green, and red curves represent hard soil (SC), medium soil (SD), and soft soil (SE) site classes, respectively.

As can be seen in Figure 6, there is no significant improvement in the DRS for Bengkalis for site class SC, SD, and SE. For site class SC and SD the DRS 2019 are slightly bigger than the DRS 2012, with an increase around 0.017g and 0.007g, respectively (1g = 9.81 m/s²). However, for site class SE, the DRS 2019 are slightly lower than the DRS 2012.

As can be seen in Figure 7, for site class SD and SE the DRS 2019 for Dumai are slightly lower than for DRS 2012. For site class SC the DRS 2019 of Dumai are bigger than the DRS 2012. The improvement of the DRS 2019 compared to the DRS 2012 for site class SC is less than 0.01g. However, the maximum reduction of DRS 2019 compared to DRS 2012 for site class SD and SE is less than 0.05g. The calculation of $S_{DS}$ and $S_{DY}$ for the development of DRS 2019 depends not only on the $S_3$ and $S_I$ values but also depends on the site factor $F_a$ and $F_v$ values. The $F_a$ and $F_v$ value for
specific site soil class (SC, SD, and SE) are usually developed by linear interpolation and depends on the $S_S$ and $S_1$ values.

In Figure 8, for site class SC and SE the DRS 2019 of Pasir Pangaraian are slightly bigger than the DRS 2012. However, for site class SD, the DRS 2019 is slightly lower than the DRS 2012. The maximum improvement (increasing or decreasing) of DRS 2019 compared to DRS 2012 is less than 0.1 g. The improvement of DRS for Tembilahan is slightly bigger than Pasir Pangaraian. Table 5 shows ratio of $S_S$, $S_1$, and $PGA$ calculation for eight cities/districts in Riau Province. By using SNI 1726:2019, the $S_S$, $S_1$, and $PGA$ values of Tembilahan are 0.249g, 0.225g, and 0.125g respectively. The $S_S$, $S_1$, and $PGA$ values of Pasir Pangaraian are 0.741g, 0.418g, and 0.324g respectively. The $S_S$, $S_1$, and $PGA$ values of Siak are 0.252g, 0.229g, and 0.128g respectively.

Table 6 illustrates the improvement of $S_{DS}$, $S_{D1}$, $T_0$ and $T_s$ values for site classes SC, SD and SE respectively and calculated for developing DRS 2019 and DRS 2012 for cities/districts in Riau Province. Compared to $S_{DS}$ 2012, the $S_{DS}$ 2019 of Teluk Kuantan is increasing 16% and 5% for site classes SC and SE respectively. However, for site class SC the $S_{DS}$ value for Pekanbaru is decreases 2%. For Tembilahan the $S_{DS}$ 2019 value for site classes SC, SD and SE are decreased 67%, 54% and 48%, respectively. Compared to DRS 2012, the $S_{D1}$ values for site class SC, SD and SE of DRS 2019 for Bengkalis are increased 12%, 4% and -1% respectively. For Pasir Pangaraian, the $S_{D1}$ value for DRS 2019 increased by 9%, 1% and 8% for site classes SC, SD and SE respectively. The $S_{DS}$ and $S_{D1}$ values of DRS 2019 at these three cities (Pasir Pangaraian, Teluk Kuantan and Tembilahan) are larger than the $S_{DS}$ and $S_{D1}$ of DRS 2012. The $S_{DS}$ values are increased in between 0.005g and 0.086g and the $S_{D1}$ values are increased in between 0.005g and 0.1g. The most significant improvement is detected at site class SC. However, the improvements of $S_{DS}$ and $S_{D1}$ for site classes SD and SE at the cities are smaller than for site class SC and it is lower than 0.08g. All three cities are located less than 50 km distance from the West Sumatera Province (high seismic zone). Dumai, Tembilahan, Siak, Pekanbaru, and Bengkalis are located at the east of Riau Province. However, another three cities, Teluk Kuantan, Bangkinang and Pasir Pangaraian are located at the west of Riau Province. As can be seen in Table 6 the largest improvement of $S_{DS}$ value at Tembilahan is close to 0.1 g (57%) and the improvement of $S_{D1}$ value at this city is 0.102 g (38.7%).

Figure 5. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Bangkinang. Figure 6. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Bengkalis.
Figure 7. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Dumai.

Figure 8. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Pasir Pangaraian.

Figure 9. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Pekanbaru.

Figure 10. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Teluk Kuantan.

Figure 11. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Tembilahan.

Figure 12. DRS adopting SNI 1726:2012 and SNI 1726:2019 for Siak.
Table 6. The ratio of spectrum parameter value between SNI 1726:2019 with SNI 1726:2012 for Cities/Districts in Riau Province.

| Cities/ Districts     | Spectrum Response Parameter | Hard Soil (SC) for SNI 1726 | Medium Soil (SD) for SNI 1726 | Soft Soil (SE) for SNI 1726 |
|------------------------|-----------------------------|-----------------------------|-------------------------------|-------------------------------|
|                        | 2019 (a) | 2012 (b) | Ratio (a/b) | 2019 (c) | 2012 (d) | Ratio (c/d) | 2019 (e) | 2012 (f) | Ratio (e/f) |
| Bangkinang             |          |          |             |          |          |             |          |          |             |
| S_{DS} (g)             | 0.463    | 0.446    | 1.04        | 0.493    | 0.511    | 0.97        | 0.590    | 0.593    | 0.99        |
| S_{D1} (g)             | 0.367    | 0.331    | 1.11        | 0.473    | 0.390    | 1.21        | 0.620    | 0.599    | 1.03        |
| T_{0} (sec)            | 0.159    | 0.149    | 1.06        | 0.192    | 0.153    | 1.25        | 0.210    | 0.202    | 1.04        |
| T_{S} (sec)            | 0.793    | 0.743    | 1.07        | 0.959    | 0.763    | 1.26        | 1.051    | 1.009    | 1.04        |
| Bengkalis             |          |          |             |          |          |             |          |          |             |
| S_{DS} (g)             | 0.157    | 0.140    | 1.12        | 0.193    | 0.186    | 1.04        | 0.289    | 0.291    | 0.99        |
| S_{D1} (g)             | 0.183    | 0.177    | 1.03        | 0.272    | 0.233    | 1.17        | 0.421    | 0.358    | 1.18        |
| T_{0} (sec)            | 0.233    | 0.254    | 0.92        | 0.283    | 0.250    | 1.13        | 0.291    | 0.246    | 1.18        |
| T_{S} (sec)            | 1.167    | 1.269    | 0.92        | 1.413    | 1.250    | 1.13        | 1.456    | 1.232    | 1.18        |
| Dumai                 |          |          |             |          |          |             |          |          |             |
| S_{DS} (g)             | 0.226    | 0.221    | 1.02        | 0.276    | 0.291    | 0.95        | 0.412    | 0.445    | 0.93        |
| S_{D1} (g)             | 0.217    | 0.220    | 0.98        | 0.313    | 0.274    | 1.14        | 0.465    | 0.438    | 1.06        |
| T_{0} (sec)            | 0.192    | 0.199    | 0.96        | 0.226    | 0.189    | 1.20        | 0.226    | 0.197    | 1.15        |
| T_{S} (sec)            | 0.960    | 0.996    | 0.96        | 1.132    | 0.943    | 1.20        | 1.129    | 0.985    | 1.15        |
| Pasir Pangaraiy       |          |          |             |          |          |             |          |          |             |
| S_{DS} (g)             | 0.594    | 0.545    | 1.09        | 0.596    | 0.596    | 1.00        | 0.649    | 0.602    | 1.08        |
| S_{D1} (g)             | 0.418    | 0.379    | 1.10        | 0.524    | 0.433    | 1.21        | 0.658    | 0.653    | 1.01        |
| T_{0} (sec)            | 0.140    | 0.139    | 1.01        | 0.176    | 0.145    | 1.21        | 0.203    | 0.217    | 0.93        |
| T_{S} (sec)            | 0.702    | 0.695    | 1.01        | 0.879    | 0.726    | 1.21        | 1.014    | 1.086    | 0.93        |
| Pekanbaru             |          |          |             |          |          |             |          |          |             |
| S_{DS} (g)             | 0.401    | 0.409    | 0.98        | 0.441    | 0.476    | 0.93        | 0.557    | 0.573    | 0.97        |
| S_{D1} (g)             | 0.337    | 0.304    | 1.11        | 0.441    | 0.364    | 1.21        | 0.596    | 0.565    | 1.05        |
| T_{0} (sec)            | 0.168    | 0.148    | 1.14        | 0.200    | 0.153    | 1.31        | 0.214    | 0.197    | 1.09        |
| T_{S} (sec)            | 0.840    | 0.742    | 1.13        | 1.000    | 0.765    | 1.31        | 1.070    | 0.986    | 1.09        |
| Teluk Kuantan         |          |          |             |          |          |             |          |          |             |
| S_{DS} (g)             | 0.497    | 0.428    | 1.16        | 0.522    | 0.495    | 1.06        | 0.612    | 0.584    | 1.05        |
| S_{D1} (g)             | 0.403    | 0.312    | 1.29        | 0.510    | 0.372    | 1.37        | 0.644    | 0.576    | 1.12        |
| T_{0} (sec)            | 0.162    | 0.146    | 1.11        | 0.195    | 0.151    | 1.29        | 0.210    | 0.197    | 1.07        |
| T_{S} (sec)            | 0.811    | 0.729    | 1.11        | 0.976    | 0.753    | 1.30        | 1.052    | 0.986    | 1.07        |
4. Conclusions

The design acceleration response spectrum for eight cities/districts in Riau Province, Indonesia, was performed in this study due to the improvement of the Seismic Hazard Maps of Indonesia 2017. The design response spectrum (DRS) 2019 for site classes SC, SD, and SE were developed using the same method proposed by SNI 1726:2012 and ASCE/SEI 7-16. On average the DRS 2019 developed at eight cities/districts in Riau Provinces are almost equal compared to the DRS 2012. Based on the analysis, the improvement of the DRS 2019 compared to the DRS 2012 for site classes SC, SD and SE are less than 0.1 g except for site class SC at Tembilahan and Teluk Kuantan. The largest improvement of $S_{DS}$ value at Tembilahan is close to 0.1 g (57%) and the improvement of $S_{D1}$ value at this city is 0.102 g (38.7%).

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