Review of internal force magnitude at the 5-floor hospital in North Sulawesi Province between SNI 1726-2012 and SNI 1726-2019 with response spectrum (2D) method

D J Jaya¹, S Arifah¹ and S Widodo²

¹Student of Technical and Vocational Education Department, Graduate School of Yogyakarta State University, Jl. Colombo No.1, Yogyakarta, 55281, Indonesia
²Lecturer of Civil Engineering and Planning Education Department, Yogyakarta State University, Jl. Colombo No.1, Yogyakarta, 55281, Indonesia

Corresponding author: dhutasoit43@gmail.com

Abstract. Guidelines for building structure planning in Indonesia began to be known in the 1970s in PBI’71 until now. The earthquake loading guidelines begins from special specifications : SNI 1726-2002 to SNI 1726-2019. The latest SNI and its development are affected by the latest findings of National Earthquake study centre which produces an earthquake hazard map for Indonesia in 2017. In this study, the planning method used in the 5-floor hospital building which was located in the Kotamobagu city, and used SNI 2847-2013 as the loading of the structure. It is considered as comparative study since it examined the earthquake load forces using the SNI 1726-2012 and SNI 1726-2019 guidelines. After conducted this study, it was found that there were differences in internal forces in the two planning guidelines. For further studies, it is suggested that the old earthquake-resistant planning guidelines used on the buildings should be reviewed using the new guidelines. Thus, the building's ability to withstand earthquakes is well examined. The research development on earthquake fractures affects the study of giving review related to earthquake resistance in buildings. Therefore, it is supposed to be carried out periodically.

1. Introduction
Guidance on building structure planning in Indonesia began to be known from the 1970s through PBI’71 until now there is SNI 03-2847-2019, while for guidelines on earthquake loading, specifics are set since SNI 1726-2002 to SNI 1726-2019 [1]. Indonesia has its own uniqueness as an area which is in an active high risk tectonic regime that causes several earthquakes and also liquefaction due to the acceleration of its land movements [2,3]. The world community concerns about the liquefaction and earthquake that occurred in Sulawesi. Even in northern Sulawesi is where the four large Indian-Australian plates meet, the Asian, the Pacific, and small plates around it such as the Maluku Sea Plate, the Sulawesi Sea and the interconnected Banggai-Sula micro-continent creates a crossbow in the northern Sulawesi archipelago [4].

The findings showed that this fault were first examined by Irsyam. The revision of the Indonesia’s earthquake data and maps were identified and examined. There were differences between Hazard map 2010 and SNI 1726-2012 from the previous earthquake regulations [5]. A recent study which produced hazard maps 2017 and SNI 1726-2019 about seismicity showed the latest faults in Indonesia,
including in Sulawesi, one of them is in the central and northern part of Sulawesi [6,7]. After the National Earthquake Study Center Team released the 2017 Indonesia Disaster Map, it can be concluded that SNI 1726-2012 was less relevant. Therefore, SNI 1726-2019 was proposed due to its spectral response determination [8,9]. There are several building plans in Indonesia which use SNI 1726-2002 and SNI-1726-2012 (hazard map 2010). It is considered necessary to conduct an evaluation of existing building plans and then compare the building's ability to withstand the earthquake forces based on SNI 1726-2012 and SNI 1726-2019 and minimize the number of casualties when an earthquake occurs.

2. Loadings
In this study, there are two types of loadings: 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 are based on PPIUG 1983 & PPURG 1987 refer to SNI 2847-2013. The dead load and live load serve as distributed loads on buildings.

| Type of Load                      | kN/m² |
|----------------------------------|-------|
| 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 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. However, this study highlights the earthquake load using the spectrum response method between SNI 1726-2012 and SNI 1726-2019.

2.2.1. Design spectrum responses. In this study, SNI 1726-2012 and SNI 1726-2019 were compared and analyzed and being used as the response spectrum of the design. Design Spectrum Response is required in terms of planning multi-storey buildings therefore the ability of building services to withstand earthquake loads and forces that occur at any time [2]. In SNI 1726-2012 and SNI 1726-2019 the Response Spectrum is selected based on the response parameters of the earthquake acceleration $S_1$ and $S_2$ adjusted to the classification of the building site area which results are set forth in a graph between the structural vibration time with the maximum response based on the earthquake and the damping ratio used [2,6].

[6] cites the stages of Response Spectrum design according to the adapted SNI 1726-2012 and SNI 1726-2019:
- Observing the location of the building which is going to be evaluated
- Determining SPT value and classification of soil type
- Determining the acceleration parameters of the maximum earthquake response by considering the risk targeted MCE$_R$ (Maximum Considered Earthquake, Risk Targeted) for short periods of 0.2 seconds ($S_3$) and 1.0 seconds ($S_1$).
- Carrying out the amplification factor of the response parameters of the ground surface acceleration spectrum for short periods (Fa) and 1 second period (Fy).
- Determining the parameters of the acceleration spectrum response ($S_{MS}$ and $S_{M1}$),
  \[ S_{MS} = Fa \times S_3 \]
  \[ S_{M1} = Fy \times S_1 \]
- Determining the parameters of the design acceleration spectrum response ($S_{DS}$ and $S_{D1}$),
S\textsubscript{DS} = 2/3 \times S\textsubscript{MS}

S\textsubscript{D1} = 2/3 \times S\textsubscript{M1}

- Making a graph response to images with the provisions that have been examined between SNI 1726-2012 and SNI 1726-2019.

![Graph of response spectra in SNI 1726-2012](image1)

**Figure 1.** Graph of response spectra in SNI 1726-2012

Conditions:
- For the periods which are smaller than T\textsubscript{0}, the design acceleration response spectrum, S\textsubscript{a}, should be taken from Equation S\textsubscript{a} = S\textsubscript{DS} (0.4 + 0.6 (T/T\textsubscript{0}))
- For the periods which are 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}.
- For periods which are greater than T\textsubscript{s}, the design acceleration response spectrum, S\textsubscript{a}, taken for equation: S\textsubscript{a} = S\textsubscript{D1}/T

While the following graph represents SNI 1726-2019:

![Graph of response spectra in SNI 1726-2019](image2)

**Figure 2.** Graph of response spectra in SNI 1726-2019
Period provisions are explained further as follows:

- For periods which are smaller than $T_0$, the following equation use $S_a = S_{DS} (0.4 + 0.6 \frac{T}{T_0})$
- For periods which are greater than or equal to $T_0$ and smaller than or equal to $T_s$, the response spectrum of the design is $S_a = S_{DS}$
- For periods which are greater than $T_s$ but smaller than or equal to $T_L$, the spectral response of the design acceleration, $S_a$, is taken equation $S_a = \frac{S_{DI}}{T}$
- For periods greater than $T_L$, the spectral response of the design acceleration, $S_a$, is taken based on Equation $S_a = (\frac{S_{DI} \times T_L}{T^2})$

- For the value of $T$ is obtained by calculating the fundamental period of the structure (T) based on this equation:
  \[ T_a = C_t \cdot h_n \times x \]
  $h_n$ = the height of the structure (m) above the base to the highest level of the structure, $C_t$ and $x$ are obtained from the table specified by SNI 1726-2012 and SNI 1726-2019

- For the values of $T_0$ and $T_s$ can be obtained from the equation:
  \[ T_0 = 0.2 \times \frac{S_{DI}}{S_{DS}} \]
  \[ T_s = \frac{S_{DI}}{S_{DS}} \]

- For $T_L$ values are obtained from Figure 20 about SNI 1726-2019.

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

- 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. Axial and shear forces, and moments are categorized as the internal force [3]. Factored moment ($M_u$), ultimate shear strength ($V_u$), and factored axial force ($N_u$) are the result of internal force.

3. Method
This study aims to check and evaluate the change in spectrum response in hospital buildings. It is examined by compare those buildings which still use SNI 1726-2012 and SNI 1726-2019. The first stage is counting the response spectrum, running model using software for analysing the structure with the Dynamic method for the following stage. Then, the values of internal force such as factored moment, ultimate shear strength, and factored axial force ($N_u$) are compared. For the last step, modeling in 2D in software for analysing the structure.

![Flow chart diagram](image)
3.1. Preliminary data
Preliminary data includes the data of general soil, the structural technical, and the earthquake.

3.1.1. Soil data. The hospital building consists of 2 towers, with large 49.5 x 27 m for each. The structure height is 24 meters and consist of 5 floors. The N-SPT data were obtained through assumptions given by Randyanto [10]. It used the meyerhoff method in North Sulawesi with medium soil conditions that were exactly as same as the the hospital with an N-SPT value of 97. It could be used as an assumption in this data. In the RT/ RW of Bolaang Mongondow Regency [11] and the RPIJM 2015-2019, Bolaang Mongondow Regency [12] describes the city area of Kotamobagu as a lowland surrounded by two mountain chains stretching east-west and close to the Dumoga-Pusian plain.

3.1.2. Structural technical data. Hospitals withstand structural loads based on Indonesian government standards using SNI 2847-2013. The reinforcement concrete structure is used for The hospital building and the boerpile cap is used for the foundation. The compressive strength of concrete (fc') used is 22.83 MPa, yield strength of longitudinal or transverse (shear) reinforcement (fy) is 320 MPa, and the reinforcement is 240 MPa.

| Type of Beam | Size (cm) | Type of Column | Size (cm) | Type of Sloof | Size (cm) |
|--------------|-----------|----------------|-----------|---------------|-----------|
| B1           | 80 x 40   | K1             | 65 x 65   | S1            | 60 x 30   |
| B2           | 60 x 30   | K2             | 65 x 40   | S2            | 50 x 25   |
| B3           | 50 x 30   | K3             | 40 x 40   | S3            | 40 x 20   |
| B4           | 40 x 25   | K4             | 40 x 30   | S4            | 30 x 15   |
| B5           | 30 x 20   | K5             | 30 x 15   |               |           |
| B6           | 30 x 15   |               |           |               |           |

3.1.3. Earthquake data. The spectrum response value is obtained by following the predetermined stages:
- a. The location of the building which being reviewed is in North Sulawesi,
- b. With an SPT value of 97, the class of the land site is examined 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

| Parameters | SNI 1726-2012 | SNI 1726-2019 |
|------------|---------------|---------------|
| Ss         | 1.2           | 1.2           |
| S1         | 0.5           | 0.5           |
| Fa         | 1.02          | 1.02          |
| Fv         | 1.5           | 1.8           |
| S_Ms       | 1.224         | 1.224         |
| S_Mt       | 0.75          | 0.9           |
4. Result and discussion

4.1. The loading rules used.
Loading the structure of the hospital use a standard combination of structural loads SNI 2847-2013. Meanwhile, SNI 1726-2012 and SNI 1726-2019 are used for Standard response of earthquake response spectrum.

4.2. Structure analysis.
The software for analysing the structure is used to analyze the hospital structure. It includes the primary structure, the main column (K1) and beam (B1 and B2). The longest transverse side to be given evenly distributed force is the part to be reviewed. It is shown in the following picture:

![Figure 4. Sketch of hospital building](image)

![Figure 5. Modelling 2D in software for analysing the structure](image)
4.3. The calculation of earthquake loading.

For earthquake loading, the response spectrum analysis method is used based on the SNI 1726-2012 and SNI 1726-2019 guidelines. Furthermore, the acceleration calculation is carried out in order to obtain a response graph based on both guidelines.

4.3.1. SNI 1726-2012 and SNI 1726-2019. The spectrum response graph is based on the spectrum response method, specified in the SNI 1726-2012 and SNI 1726-2019 guidelines. The obtained values will be inserted into the software for analysing the structure in order to analyze the earthquake resistance of buildings.

| Value          | SNI 1726-2012 | SNI 1726-2019 |
|----------------|---------------|---------------|
| $S_{DS}$       | 0.816         | 0.816         |
| $S_{D1}$       | 0.5           | 0.6           |
| $T_0$          | 0.1225        | 0.147         |
| $T_S$          | 0.6127        | 0.735         |
| $T_a$          | 0.814         | 0.814         |
| $T$            | 0.814         | 0.814         |
| $S_a = S_{DS}$ | 3.579         | 3.036         |
| $S_a = S_{DS} (0.4 + 0.6 \times (T/T_0))$ | 0.816 | 0.816 |
| $Sa = S_{D1}/T$ | 0.614         | 0.737         |
| $T_L$          | -             | 12            |

The spectrum response graphs based on the SNI 1726-2012 and SNI 1726-2019 are represented in Figures 6 and 7.

Figure 6. SNI 1726-2012 response spectrum graph
### Tabel 5. Comparison of internal force between SNI 1726-2012 and SNI 1726-2019

| Element | Factored Axial Force (Nu) | Ultimate Shear Strength (Vu) | Factored Moment (Mu) |
|---------|---------------------------|------------------------------|----------------------|
|         | SNI 1726-2012 | SNI 1726-2019 | SNI 1726-2012 | SNI 1726-2019 | SNI 1726-2012 | SNI 1726-2019 |
| 1       | 582.741       | 584.44           | 48.366       | 51.191          | 98.8725       | 105.0313       |
| 2       | 446.574       | 446.984          | 29.815       | 30.449          | 63.1272       | 64.9589        |
| 3       | 288.888       | 288.991          | 32.494       | 32.541          | 67.3095       | 67.3319        |
| 4       | 120.615       | 120.615          | 29.326       | 29.353          | 66.7165       | 66.7919        |
| 6       | 1720.137      | 1721.417         | 78.397       | 81.428          | 176.1959      | 181.8968       |
| 7       | 1290.962      | 1291.34          | 78.131       | 78.61           | 159.7105      | 161.0473       |
| 8       | 903.41        | 903.514          | 81.4         | 81.412          | 167.7332      | 167.7424       |
| 9       | 534.468       | 534.513          | 66.927       | 66.942          | 154.5404      | 154.5794       |
| 10      | 192.812       | 192.824          | 124.235      | 124.353         | 194.9142      | 194.9289       |
| 11      | 2866.568      | 2866.587         | 41.479       | 44.328          | 88.9885       | 95.1779        |
| 12      | 2227.774      | 2227.805         | 9.15         | 9.743           | 27.8567       | 29.6019        |
| 13      | 1591.15       | 1591.162         | 3.337        | 3.419           | 7.2727        | 7.5104         |
| 14      | 955.286       | 955.292          | 1.493        | 1.499           | 4.1431        | 4.1648         |
| 15      | 345.097       | 345.099          | 4.204        | 4.209           | 8.0154        | 8.0195         |
| 16      | 2867.566      | 2867.63          | 44.034       | 46.929          | 93.3158       | 99.5639        |
| 17      | 2224.553      | 2224.578         | 8.941        | 9.514           | 27.2772       | 28.9309        |
| 18      | 1588.804      | 1588.81          | 3.776        | 3.836           | 7.8254        | 7.9984         |
| 19      | 954.193       | 954.196          | 1.972        | 1.976           | 5.2833        | 5.2988         |
| 20      | 344.798       | 344.799          | 4.855        | 4.856           | 9.0194        | 9.0207         |
| 21      | 1542.784      | 1543.294         | 82.062       | 84.663          | 187.2056      | 191.7397       |
| 22      | 1205.2        | 1205.29          | 94.798       | 95.569          | 206.0902      | 208.4172       |
| 23      | 866.367       | 866.416          | 85.125       | 85.256          | 173.1408      | 173.2632       |
| 24      | 527.229       | 527.257          | 65.551       | 65.571          | 153.8609      | 153.9302       |
| 25      | 192.998       | 193.007          | 122.356      | 122.361         | 188.0341      | 188.0498       |
| 26      | 0             | 0                | 111.565      | 113.653         | 117.4184      | 120.267        |
| 27      | 0             | 0                | 109.172      | 109.497         | 113.9631      | 114.4992       |
| 28      | 0             | 0                | 121.204      | 121.255         | 133.4468      | 133.5058       |
| 29      | 0             | 0                | 63.584       | 63.619          | 66.7165       | 66.7667        |

**Figure 7.** SNI 1726-2019 response spectrum graph

$$Sa = S_{DS}$$

$$Sa = S_{DS} \cdot (0.4 + 0.6 \cdot \frac{T}{T_0})$$

$$Sa = S_{DI}/T$$

$$Sa = \left(\frac{S_{DI}}{T_L}\right)/T^2$$
After the static loading and response spectrum based on the SNI 1726-2012 and SNI 1726-2019 guidelines are obtained, the software for analysing the structure which then produces a table of the results of the software for analysing the structure should be carried out. After that, the values of factored moment (Mu), ultimate shear strength (Vu), and factored axial force (Nu) should be compared.

From Table 5, it can be concluded from the ratio of the factored moment (Mu), ultimate shear strength (Vu), and factored axial force (Nu), the internal force value of SNI 1726-2019 is greater than the result of SNI 1726-2012 by using the earthquake spectrum response method. It is an evidence that the building is not able to withstand earthquake forces based on SNI 1726-2019 guidelines. Therefore, it is necessary to strengthen the structure of the building to anticipate damage to the building structure due to an earthquake. Furthermore, the hospital building should be taken into account since it has a vital role in society. Strengthening structures can be carried out by shortening the span (inject column) and increasing the ability of the concrete compressive strength of concrete (concrete jacketing) [13]. [14] states that there is no significant difference between dynamic response spectrum analysis and equivalent static analysis. Therefore, the use of these two methods are allowed for earthquake-resistant building structure planning.

From the results of this study also found similarities with research which revealed that buildings that are still using the old method are recommended to be given strengthen structural reinforcement to be able to withstand the strength of earthquake-resistant building planning based on the new method [1,15,16,17]. Due to Indonesia's geographical conditions which are in an earthquake-prone area that often causes casualties [18] conducted research in all earthquake-prone areas in Indonesia and produced earthquake hazard maps in 2010 and 2017 which were used for earthquake-resistant building planning. So the development of earthquake-prone maps and planning guidelines for earthquake-resistant building structures will always experience changes or additional forces acting on the structure that allow the building not to collapse following the latest findings from the earthquake-prone map [1,9,16].

5. Conclusions
Based on the results of the study, it can be concluded that there is an effect of planning changes based on the earthquake hazard map SNI 1726-2012 to the latest SNI 1726-2019 guidelines. This change occurred due to the discovery of a new earthquake fault that changed the regulations for earthquake
resistant buildings in Indonesia. The old regulations which remain used for Earthquake-resistant buildings are required to be checked and evaluated by using the latest guidelines. Furthermore, it is suggested that the structure should be strengthened. In this case, the hospital building are supposed to conduct an earthquake resistance study therefore the casualties can be minimized due to the earthquake. In addition, the researchers have limitations in collecting primary data due to the Covid-19 pandemic in this study. Thus, this limitation can be studied further and find more effective methods to collecting the data of supporting building structures. Due to the changes that can occur in earthquake faults in Indonesia, it is suggested that the earthquake resistant structures needs to be carried out periodically to minimize collapsed buildings which cause casualties.

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