Plan review two types of earthquake resistant buildings based on SNI 03-1726-2012 with computer programs

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Abstract. Indonesia is one of the countries that have a high earthquake intensity. Therefore, in building structure planning, there needs to be a more in-depth study of the analysis and planning of earthquake-resistant structures. The study aimed to find out the results of the building analysis reviewed in 4 Indonesian cities based on SNI 03-1726-2012 with computer programs. This research is computer-based research, with Microsoft Excel application for wall density index analysis on 1-story and 2-story buildings, and SAP2000 v.20 application on 4-story buildings for static analysis of equivalent lateral forces. In reviewing the building with analysis of wall density index, it was very influential on the magnitude of the spectral acceleration value of the earthquake. The greater of the spectral acceleration value of the earthquake in the city being reviewed, the smaller the value of the seismic capacity control of the building, which affects the level of building safety. In a building review with an equivalent static lateral force analysis, base shear and displacement values were very influential on the magnitude of the earthquake intensity if used as a comparison with other cities. In reviewing buildings with dynamic analysis of spectrum response range, base shear and displacement values were not very influential on the magnitude of the earthquake intensity if used as a comparison with other cities due to the greater burden than the earthquake load.

1. Introduction
Indonesia is one country that has high earthquake intensity; this is due to Indonesia's geographical position. Indonesia is located on the ring of fire in the Pacific region and the meeting of three major tectonic plates of the world, namely the Indo-Australian plate, the Eurasian plate and the Pacific plate [1]. To avoid loss, both material and non-material, which arises when an earthquake occurs, the structure of the building must be designed to be earthquake resistant. According to Imran, [2] buildings that are planned to be earthquake resistant will be able to experience large post-elastic deviations repeatedly and alternately due to earthquake loads and theta structures can stand even though they are within the threshold of collapse.

In Indonesia, there are several regulations about the procedures for planning earthquake resistance, which are contained in SNI 03-17262002 concerning Standard Earthquake Resilience Planning for Building Structures [3]. In 2012, the Indonesian government ratified a new standard for earthquake resilience planning procedures for the structure of buildings and non-buildings, namely SNI 03-1726-2012. It was stated in the standard that the effect of the earthquake plan must be reviewed in the planning and evaluation of the structure of buildings and non-buildings. The planned earthquake force can be calculated using static lateral equivalence analysis and dynamic analysis of various response spectra.
Before the issuance of this regulation several earthquakes were recorded in recent years, such as the Aceh earthquake accompanied by the 2004 tsunami (9.2 Richter scale), Kolaka earthquake in 2006 (5.2 on the Richter scale), Yogyakarta earthquake in 2006 (6.3 on the Richter scale) and the last Padang earthquake in 2009 (7.6 on the Richter scale). The earthquakes caused fatalities, infrastructure damage and collapse, and funds for rehabilitation and reconstruction. Prevention of damage caused by soil movement can be carried out through a good construction planning process and by taking into account a level of seismic load plan.

However, from all the buildings damaged by the earthquake, the damage mostly occurred in simple houses built without planning for earthquake resistance. One method used to calculate earthquake resistance capacity is a wall density index analysis. Current technological developments are many programmers who have created civil engineering software based on the types of civil works that exist such as SAP2000, which serves to calculate the analysis of the structure of a building. The planning of earthquake resistant buildings has a significant influence on the age of the building. Therefore, from this background, the researcher intends to observe the planning review of 2 types of earthquake resistant buildings based on SNI 03-1726-2012 with computer programs.

2. Methods

2.1. Type of research
The type of this research is computer-based research, with Microsoft Excel application for wall density index analysis on 1-story and 2-story buildings, and SAP2000 v.20 applications on 4-story buildings for static analysis of 41-story lateral-style buildings for dynamic analysis of various response spectra.

2.2. Stage of research
The research stages to be carried out are shown in Figure 1.

2.3. Basics of planning
The rules used as guidelines are as follows:
1) SNI 03-1727-2013 concerning Minimum Load for Designing Building Buildings and Other Structures.
2) SNI 03-1726-2012 concerning Procedures for Planning Earthquake Resilience for Building Structure and Non-Building.
3) SNI 2052-2014 concerning Concrete Reinforcing Steel
4) SNI 03-2847-2013 concerning Requirements for Structural Concrete for Building Buildings.
5) Indonesian Load Regulation for Buildings (PPIUG, 1983).

2.4. Data processing
The steps taken to process the data are in three models. They are the one-story building model, the two-story building model, and the four-story building model.

2.4.1. The one-story building model
The steps in this analysis are as follows:
1) Analyzing the building plan model 1 floor by AutoCAD program,
2) Perform analysis calculations with Microsoft Excel,
3) Evaluation of the basic seismic load structure resulting from the calculation of structural loads by considering the natural vibration time of the structure by the regulations, then obtaining seismic shear forces,
4) Calculate wall density (d) by using the wall density index method.
5) Calculate the building structure load according to the material used in the building,
6) Calculating seismic capacity control using the wall density index method
7) Calculate the control of wall density index requirements for gravity loads,
8) Evaluate the control of the ability of the wall carrying capacity for walls critical of earthquake loads,
9) The analysis is carried out based on SNI 03-1726: 2012
10) Perform planning analysis in 4 Indonesian cities
11) Perform analysis of results from the wall density index method,
12) Conclusions in the form of buildings studied meet earthquake requirements or not

Figure 1. Flow Chart of Research
2.4.2. The two-story building model
The steps in this analysis are as follows:
1) Analyze the floor plan model of the building by AutoCAD,
2) Analyze calculations with Microsoft Excel,
3) Evaluation of the basic seismic load structure resulting from the calculation of structural loads by considering the natural vibration time of the structure in accordance with the regulations, then obtaining seismic shear forces,
4) Calculate wall density (d) by using the wall density index method,
5) Calculate the building structure load according to the material used in the building,
6) Calculating seismic capacity control using the wall density index method,
7) Calculate the control of wall density index requirements for gravity loads,
8) Evaluate the control of the ability of the wall carrying capacity for walls critical of earthquake loads,
9) The analysis is carried out based on SNI 03-1726-2012,
10) Perform planning analysis in 4 Indonesian cities,
11) Perform analysis of results from the wall density index method,
12) Conclusions in the form of buildings studied meet earthquake requirements or not

2.4.3. The four-story building model
The steps in this analysis are as follows:
1) Calculate the effective seismic weight of the building (Wt).
2) Calculating the limits of the fundamental period of structure (T).
3) Calculating seismic base shear (V).
4) Calculate the distribution of earthquake forces (Fi).
5) Inputting the distribution of earthquake force (Fi) at each level (m), at SAP2000 and changing the definition of material mass is changed to zero, then static analysis can be done.
6) The final step can be carried out by ordinary static analysis and at the same time can design the structure of the building, whether with reinforced concrete structures or with steel structures.
7) Analysis is carried out based on SNI 03-1726-2012.
8) Conduct planning analysis in 4 Indonesian cities.
9) Conclusions in the form of buildings studied meet earthquake requirements or not

2.5. Analysis of equivalent static lateral force
2.5.1. Seismic Base Sliding Style
Seismic base shear is obtained from the multiplication of seismic response coefficients with effective seismic weight as shown in Equation (3.1).
\[ V = C_s \times W \] (3.1)
Where:
V : Seismic base shear.
Cs : Seismic response coefficient
W : Effective seismic weight.

2.5.2. Seismic Response Coefficient
The seismic response coefficient, $C_s$, is calculated by Equation (3.2). The value of Equation (3.2) does not need to exceed the value of Equation (3.3) and must not be less than Equation (3.4) (SNI Article 7.8.1.1).

\[
C_s = \frac{S_{DS}}{(R / I_e)} \quad (3.2)
\]
\[
C_s = \frac{S_{D1}}{T (R / I_e)} \quad (3.3)
\]
\[
C_s = 0.044 S_{DS}, I_e \geq 0.01 \quad (3.4)
\]

Where:
- **SDS**: Parameters accelerating the design response spectrum in a short period of time.
- **$S_D$**: The maximum response spectrum acceleration parameter.
- **$R$**: Response modification factor.
- **$I_e$**: The primacy factor of the earthquake.
- **SD1**: Parameter accelerates the design response spectrum in 1.0 seconds.
- **$T$**: Fundamental period of structure (seconds).

2.6. Parameters of spectral design acceleration

The spectral acceleration parameters of SDS and SD1 designs are calculated by Equation (3.5) and (3.6) (SNI article 6.3) with SMS and SM1 values calculated by Equations (3.7) and (3.8) (SNI article 6.2).

\[
s_{DS} = \frac{2}{3} s_{MS} \quad (3.5)
\]
\[
s_{D1} = \frac{2}{3} s_{M1} \quad (3.6)
\]
\[
s_{MS} = F_\alpha (a X S_s) \quad (3.7)
\]
\[
s_{M1} = F_\nu (v X S_1) \quad (3.8)
\]

2.7. Fundamental period approach

The fundamental period of the structure cannot be determined, for this reason it is necessary to determine the estimated fundamental period, $T_a$. This $T_a$ value can be calculated by equation (3.9) (SNI Article 7.8.2.1) by first determining the $xt$ from Table 2.10.

\[
T_a = C_t x h_n ^ x \quad (3.9)
\]

The fundamental period of structure ($T$) used:
- If $T_c > C_u$, then use $T = C_u T_a$
- If $T_a < T_c < C_u$, then use $T = T_c$
- If $T_c < T_a$, then use $T = T_a$

2.8. Earthquake style distribution

2.8.1. Vertical distribution of earthquake forces

The lateral earthquake force ($F_x$) that arises at all levels must be determined from the following equation:

\[
F_x = C_{vx} V \quad (3.10)
\]
\[
C_{vx} = \frac{(w_x h_x ^ k)}{\sum (i = 0) ^ n \left[ w_i h_i ^ k \right]} \quad (3.11)
\]

Where:
- **$C_{vx}$**: Vertical distribution factor.
- **$V$**: Lateral style of total design or sliding at the base of the structure.
- **$W_i$ and $W_x$**: Effective seismic weight imposed at level $i$ or $x$.
- **$h_i$ and $h_x$**: Height from base to level $i$ or $x$.
- **$k$**: Exponents related to the period of the structure.

2.8.2. Horizontal distribution of earthquake forces

Slide the earthquake design level at all levels ($V_x$), must be determined by the following equation:

\[
V_x = \sum (i = x) ^ n F_i \quad (3.12)
\]

Where:
Fi: Part of seismic base shear arising at level i.

2.9. Variety response spectrum dynamic analysis

These conditions include:

For periods smaller than $T_o$, the $S_a$ response acceleration spectrum must be taken from the following equation.

$$S_a = S_{DS} \left( 0.4 + 0.6 \frac{T}{T_o} \right) \quad (3.13)$$

For periods greater than or equal to and smaller than or equal to, the design acceleration spectrum is the same as $S_{DS}$.

For periods greater than, the spectrum of the acceleration response of design A is taken based on the following equation.

$$S_a = \frac{S_D1}{T} \quad (3.14)$$

Information:

$S_{DS}$: design acceleration response parameters for short periods.

$S_D1$: the design acceleration response parameter for 1 second

$T$: a period of the fundamental vibration of the structure

$$T_o = \frac{0.2S_{D1}}{S_{DS}} \quad (3.15)$$

$$T_s = \frac{S_D1}{S_{DS}} \quad (3.16)$$

In SAP2000, response spectrum analysis is done by input graphic design response spectrum. The thing that must be considered in the input on SAP2000 is the input scale / scale factor. The input scale for earthquake response spectrum loads is as follows.

$$f = \frac{I_e}{R} \quad (3.17)$$

Information:

$f$: scale factor

$I_e$: Factors are primarily earthquake

$R$: response modification coefficient

The scale factor value is expressed in the earth's gravitational acceleration (g) which is 9.81 m / sec.

2.10. Analysis of the Wall Density Index

Wall density can be calculated from the wall density index, d, with the same:

$$d = \frac{A_w}{A_p} \quad (3.18)$$

with conditions for the value of d must be greater than 2.5% for 1-story buildings and 4.5% for 2-story buildings.

2.10.1. Calculation of earthquake load

Based on SNI 03-1726-2012, to determine the response of the earthquake acceleration spectrum MCER at ground level, a seismic amplification factor is required for a period of 0.2 seconds and a period of 1 second. The parameters of the acceleration response spectrum in the short period (SMS) and period of 1 second (SM1) are adjusted to the effect of site classification, with the equation:

$$SMS = Fa.Ss \quad (3.19)$$

$$SM1 = Fv.S1 \quad (3.20)$$

The spectral acceleration parameters for the short period, $SD_{DS}$ and period 1 seconds, $S_{D1}$, are determined by the equation:

$$SDs = SMS \quad (3.21)$$

$$SD1 = SM1 \quad (3.22)$$

Seismic base shear force, V, is determined by the equation:

$$V = C_s WT \quad (3.23)$$

By calculating the seismic response coefficient, $C_s$, is determined by the equation:

$$C_s = S_{Ds} / \left( \left( R / I_e \right) \right) \quad (3.24)$$

With the condition that the value of $C_s$ does not exceed the equation:

$$C_s = \frac{S_D1}{T} \left( R / I_e \right) \quad (3.25)$$
The $T_a$ itself is derived from the equation:

$$T_a = C_t h_n^x$$  \(3.26\)

And $C_s$ is not less than the equation:

$$C_s = 0.044 S_D1.1 \geq 0.01$$  \(3.27\)

2.10.2. Wall density index

This method is used to calculate wall density index ($d$). The development of this method is governed by the assumption that building security is regulated based on shear failure on the wall, cross section and column bonds which are assumed to be able to withstand the flexural strength of the building [9].

- Seismic capacity control uses the wall density index method

Buildings are assumed to remain safe when exposed to earthquake forces provided that the seismic shear force on each floor ($F_\text{RVR}$) is greater than the seismic shear force ($F_\text{VC}$) as the following equation:

$$V_R / V_U \geq F_C / F_R = F_s$$  \(3.28\)

With $F_s$ is a security factor. $F_s = 1.1 / 0.7 = 1.6$

For seismic shear forces on each floor ($V_R$) can be calculated in each direction of the building by multiplying the strength of the shear wall with the total effective area as in the following equation:

$$V_R = v.A_w$$  \(3.29\)

With the $v$ value of the equation:

$$v = (0.5 v_m + 0.3 \sigma) \leq 1.5 v_m$$  \(3.30\)

To calculate the average compressive stress on the bearing capacity of the wall due to gravity ($\sigma$) or it can be called $\sigma_u$ with the equation:

$$\sigma = w_T / (\Sigma A_w)$$  \(3.31\)

- Wall density requirements for gravity loads

Simple control of the average normal voltage, used equation:

$$\sigma_R / \sigma_U \geq F_C / F_R = F_s$$  \(3.32\)

With $F_s$ is a security factor

$F_s = 1.4 / 0.6 = 2.33$

For compressive strength ($\sigma_R$) calculated based on the equation:

$$\sigma_R = F_e + (f_m' + 4)$$  \(3.33\)

With the statement that the interior wall $F_e$ is 0.7 and $F_e$ for the exterior wall is 0.6, while the value $f_m'$ is 15 kg/cm$^2$.

1) Control the strength of carrying capacity of each wall

Control of the carrying capacity of each wall is not enough just by the wall can withstand gravity because it only considers the average normal stress on each floor. The safety of buildings for gravitational forces is regulated by the greatest gravitational force per length on the critical wall. The correct approach is the security control of each wall. With the following equation, we can know the carrying capacity of each wall.

$$P_R / P_U \geq F_C / F_R = F_S$$  \(3.34\)

With $F_s$ is a safety factor, $F_s = 1.4 / 0.6 = 2.33$

For PU values obtained from the load received by the wall, while the PR value uses the equation:

$$P_R = \sigma R A$$  \(3.35\)

While the ability of wall carrying capacity ($PR$) is obtained by multiplying the compressive strength ($\sigma R$), wall thickness ($t$) and wall length ($L$) in the following equation:

$$PR = Fe (f_m' + 4) t L$$  \(3.36\)

3. Results and Discussion

3.1. The earthquake data
3.2. Building Data

3.2.1. The one-story building
1. Risk Category : 2, For Housing
2. Priority Factors (Ie) : 1, For Residential Houses
3. Medium Land Classification : (SD)
4. Structure : Reinforced Concrete
5. Beam size : 15 x 30 cm (Ringbalk)
   : 20 x 30 cm (Lateri beam)
6. Column size : 15 x 15 cm (K1)
   : 15 x 25 cm (K2)
7. Building height : 4 m
8. Type of roof : a shield with an angel 35°

3.2.2. The two-story building
1. Risk Category : 2, For Housing
2. Priority Factors (Ie) : 1, For Residential Houses
3. Medium Land Classification : (SD)
4. Structure : Reinforced Concrete
5. Beam size : 15 x 15 cm (Ringbalk)
   : 20 x 15 cm (Lateri beam)
6. Column size : 15 x 15 cm (K1)
   : 15 x 20 cm (K2)
7. Building height : 4 m (first floor)
   : 4 m (second floor)
8. Type of roof : a shield with an angel 35°
3.2.3. *The four-story building*

1. Risk Category: 2, For Factories
2. Priority Factors (Ie): 1, For Factories
3. Medium Land Classification: (SD)
4. Structure: Steel Frame

![Figure 3](image)

**Figure 3.** Design for the one-story house

![Figure 4](image)

**Figure 4.** The four-story building

3.3. *Results of analysis*

3.3.1. *The one-story building*

| Parameter Type 90          | Aceh City | Kolaka City | Yogyakarta City | Padang City | Standard |
|---------------------------|-----------|-------------|-----------------|-------------|----------|
| **Wall Density Index**    |           |             |                 |             |          |
| Dx                        | 3.6 %     | 3.6 %       | 3.6 %           | 3.6 %       | > 2.5%   |
| Dy                        | 4.2 %     | 4.2 %       | 4.2 %           | 4.2 %       |          |
| **Seismic capacity control** | $V_R/V_U$ | 3.119       | 3.654           | 2.647       | > 1.6    |
| **Control of Wall Density Index to** | $\sigma_R/\sigma_U$ | 9.587       | 9.587           | 9.587       | > 2.33   |
Based on the results of the analysis, it was found that for the 1-story building type reviewed from 4 cities fulfilled the earthquake resistance capacity based on the wall density index method. The difference only occurs in seismic capacity control this is because the buildings reviewed are the same for each city but still meet the security factors that have been indicated.

### 3.3.2. The two-story building

#### Table 2. The analysis of the two-story buildings

| Parameter Type 90 | Floor | Aceh City | Kolaka City | Yogyakarta City | Padang City | Standard |
|-------------------|-------|-----------|-------------|-----------------|-------------|----------|
| Wall Density Index | Dx    | 1         | 5.0 %       | 5.0 %           | 5.0 %       | > 4.5%   |
|                   | Dy    | 2         | 4.6 %       | 4.6 %           | 4.6 %       |          |
|                   |       |           | 4.7 %       | 4.7 %           | 4.7 %       |          |
|                   |       |           | 5.1 %       | 5.1 %           | 5.1 %       |          |
| Seismic capacity control | $V_R$ | 1         | 1.726       | 2.022           | 1.465       | 1.289    |
|                   | $V_U$ | 2         | 1.335       | 1.546           | 1.113       | 0.997    |
| Control of Wall Density Index to the gravitational force | $\frac{\sigma_R}{\sigma_U}$ | 1         | 4.053       | 4.053           | 4.053       |          |
|                   |       | 2         | 8.170       | 8.170           | 8.170       |          |
|                   |       |           | 8.170       |                |             |          |
| Bearing capacity control of each wall | $\frac{P_R}{P_U}$ | 1         | 2.842       | 2.842           | 2.842       |          |
|                   |       | 2         | 5.736       | 5.736           | 5.736       |          |

Based on the results of the analysis, it was found that for the 2-story building type reviewed from 4 cities, it did not meet the earthquake resistance capacity based on the wall density index method. Differences occur in seismic capacity control; this is due to buildings being reviewed the same for each city, but the buildings reviewed do not meet the security factors that have been hinted or not exceeding the security factor.

### 3.3.3. The four-story building

The results of the analysis of earthquake analysis with an equivalent static method to be reviewed are the displacement between floors and the shear-force of each floor due to the earthquake.

### 3.3.4. The intersection between floors (Displacements)

#### a. Direction X
b. Direction Y

Based on the results of the analysis, it was found that for the 4-story building type reviewed from 4 cities, it did not meet the earthquake resistance capacity based on the equivalent static force analysis method. Differences occur in the control of intersections between floors both x-direction and y-direction, this is because the building data reviewed are the same for each city, but the buildings are reviewed in 4 cities that have different earthquake intensity.

4. Conclusion
In reviewing the building with the wall density index method, it is very influential on the model of building one floor and two floors. The greater the value of earthquake spectral acceleration in the city being reviewed, the smaller the control value of building seismic capacity that affects the level of
building security. In reviewing buildings with static lateral force analysis equivalent to the base shear value and displacement, it is very influential on the magnitude of the earthquake intensity if used as a comparison with other cities. In reviewing buildings with a dynamic analysis of the range of responses to the spectrum of base shear and displacement values it is not very influential on the magnitude of the intensity of the earthquake if used as a comparison with other cities due to the greater burden than the earthquake load.

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