Comparative study of internal force at lecture building in special region of Yogyakarta between 2D and 3D models with response spectrum method based on SNI 1726-2019

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Abstract. One of the important things in structural planning is structural analysis. Indonesia has earthquake resistance guidelines for building structures starting from SNI 1726-1989 to the latest version, namely SNI 1726-2019. Yogyakarta Special Region is an active and complex seismic area due to tectonic plate collision activity accompanied by local fault activity on the mainland, so it has a high level of seismic activity, therefore structural planning must pay attention to seismic aspects. Not all buildings in the special area of Yogyakarta use the latest earthquake-resistant building structure guidelines, so a review of the structure must be reviewed. In analyzing the structure, there are two models, namely, 2D and 3D structural analysis using structural analysis software to obtain the internal force value. The study of internal force comparison between 2D and 3D models of dynamic response spectrum method according to SNI 1726-2019 is carried out on the 4-floor lecture building structure used to determine the advantages and disadvantages of the two models. The results of the internal force structure analysis show that the value of the internal force with the 2D model is greater than the 3D model due to differences in the distribution of the working load.

1. Introduction

One of the important things in structural planning is structural analysis, be it building structures, waters, or transportation [1]. Indonesia has earthquake resistance guidelines for building and non-building structures, starting with SNI 1726-1989 [2] to the latest version, namely SNI 1726-2019. This guideline to prevent building collapse and structural failure was created because Indonesia is a country at high risk of earthquakes because of its location through which a specific ring of fire is surrounded by the Pacific plate, the Philippines plate, the Eurasian plate, and the Indo-Australian plate, and is located on the point where the tectonic plates collide with each other [3].

Changes to the guidelines for earthquake resistant buildings in Indonesia began with the tsunami in Aceh and the Yogyakarta earthquake and earthquakes in other regions which alerted several seismic experts in Indonesia to map Indonesia's national earthquake hazard [4]. With the release of the results of the research center for earthquake studies which produced earthquake hazard maps in Indonesia in 2010 which changed the previous guideline, namely SNI 1726-2002 to SNI 1726-2012 with the addition of several indicators for consideration of earthquake resistant buildings [5]. As time goes by,
new local faults are found caused by the movement of tectonic plates in Indonesia, from these findings the latest earthquake hazard map in Indonesia which was released in 2017 [6] is increasingly proven after the earthquake Palu-Donggala and the West Nusa Tenggara area, which made the SNI 1726-2019 guideline immediately released so that the buildings that are planned to be built in the future can minimize the impact of the earthquake hazard in Indonesia.

Special Region of Yogyakarta and its surroundings are seismically active and complex areas due to tectonic plate collision activity and the result of local fault activity on the mainland so that they have a high level of seismic activity in Indonesia [7]. When the earthquake happened there is often damage to building structures and a lot of incurring losses, therefore the structural analysis in structural planning must pay attention to seismic aspects [8]. A structure can be said to be earthquake resistant if it is not damaged and does not collapse in the event of an earthquake, not only because the planning has been calculated using earthquake loads [9].

Because there are still many buildings built based on previous earthquake resistant building guidelines, a review of the structure of the building needs to be done so that the ability of the building to withstand the forces of an earthquake is known. To analyze the structure, there are two ways that can be used, namely, 2D and 3D structural analysis. 2 dimensions is a simplification in calculating structural analysis and will be different from the original conditions, namely 3 dimensions. Simplification with 2D conditions will reduce the amount of force acting on the modeling of the building structure and will greatly affect the resistance of the building to withstand earthquake forces. Then a review is carried out to find out whether there are differences in internal forces acting on the two models. The evaluation is carried out by calculating the response spectrum ie various natural frequencies are damped due to a ground shaking of a single freedom system which represents the maximum response [10]. Using structural analysis software to perform structural analysis using the dynamic response spectra method and then comparing Mu, Pu, and Vu to find out the differences in internal forces acting on the structure by means of 2D and 3D modeling.

2. Method

The subject of this research is a 4-floor lecture building in Yogyakarta. This study uses dynamic response spectrum analysis. A comparative study of the internal force in the 4-floor lecture building was conducted by conducting a comparative analysis of 2D and 3D calculations using SNI 1726-2019 which aims to determine the advantages and disadvantages between 2D and 3D systems by comparing the results of Mu, Pu and Vu. The structural model is assisted by using structure analysis software. Figure 1 shows flow chart diagram.

![Figure 1. Flow chart diagram](image_url)
3. Results and Discussion

Technical Data The structure of the lecture building is a 4-storey building in Yogyakarta using the SPRMK frame design, with a land area of 12 m x 45 m, a structure height of 18.3 m with medium soil type. Quality of concrete columns and beams fc' = 25 Mpa. Quality of concrete plate and Tie beam f'c = 25 MPa, Quality of reinforcing steel D16, D19, D22 and BJTP - 24 and BJTD - 40. Using SNI 1726-2019 for earthquakes and load combinations using SNI 2847-2013 as a load-bearing structure standard. Table 1 shows beam and column size.

Table 1. Beam and column size

| Beam       | Column       |
|------------|--------------|
| Beam B1 = 35 x 70 cm | Column C1 = 40 x 70 cm |
| Beam B2 = 30 x 40 cm | Column C2 = 40 x 40 cm |
| Beam B3 = 30 x 50 cm | Column C3 = 20 x 40 x 40 cm |
| Beam B4 = 30 x 40 cm | Column C4 = 24 x 40 x 40 cm |
| Beam B5 = 20 x 40 cm | Column C5 = 30 x 30 cm |
| Beam B6 = 30 x 50 cm | Column C6 = 30 x 30 cm |
| Beam B7 = 25 x 25 cm | Column C7 = 25 x 25 cm |

3.1. Analysis of Response Spectrum Based on SNI 1726-2019

Obtained SPT value 18 is included in the classification of medium soil sites. Using the 2017 hazard map for a short period of 5% attenuation to determine the spectral response acceleration parameters MCE Ss = 0.75g and the 1 second period S1 = 0.3 g. The lecture building is in category IV with an earthquake priority factor value of 1.50. The seismic design category is based on the acceleration response parameter over a short period of 0.50 ≤ SDS. Acceleration parameter in a period of 1 second 0.20 ≤ SDS. Table 2 shows response spectrum SNI 1726-2019.

Table 2. Response Spectrum SNI 1726-2019

| Response Spectrum with SNI 1726-2019 |
|--------------------------------------|
| SD1 = 0.4                              |
| SDs = 0.6                              |
| T0 = 0.13                              |
| Ts = 0.6                               |
| Sa = SDS (0.4 + 0.6 x T / T0) = 2.004  |
| Sa = SDS                               |
| Sa = SD1 / T                           |
| T = 0.637                              |
| Sa for 0 = 0.24                        |
| Sa = (SD1 x TL) / T ^ 2 = 19.71565102  |
| TL = 20                               |
Figure 1 shows SNI 1726-2019 Response Spectrum Graph at \( t = 4 \) seconds, and Figure 2 shows SNI 1726-2019 Response Spectrum Graph at \( t \geq 4 \) seconds.

### 3.2. Structure Analysis

The analysis and modeling of the structure were carried out with 2-dimensional (Figure 5) and 3-dimensional models using the structure analysis software (Figure 6). The part that was chosen to be styled was As D.
Figure 4. Lecture building sketch

Figure 5. 2D Analysis Structure Modeling

Figure 6. 3D Analysis Structure Modeling

3.3. The workload on Lecture Building Structure
The calculation of the earthquake load acting on the structure using PPIUG 1983 & PPURG 1987 refers to SNI 1727-2013. Table 3 shows loading dimensions As D and Table 4 shows loading 3 dimensions.

Table 3. Loading 2 Dimensions As D

| Description          | 2D       |
|----------------------|----------|
|                      | DL (kg/m) | LL (kg/m) |
| 2nd Floor, Elevation +4.20 m |
| Classroom            | 11.26     | 42.67      |
| Corridor             | 11.26     | 84.89      |
Table 4. Loading 3 Dimensions

| Description                    | 3D Load Area | Load Evenly |
|--------------------------------|--------------|-------------|
|                                | DL (kg/m²)   | LL (kg/m²)  | DL (kg/m) |
| 2nd Floor, Elevation +4.20 m   |              |             |           |
| Classroom                      | 50,66        | 192,00      |           |
| Corridor                       | 50,66        | 382,00      |           |
| Platform                       | 288,00       |             |           |
| Wall                           |              |             | 925,00    |
| 3rd Floor, Elevation +8.40 m   |              |             |           |
| Classroom                      | 50,66        | 192,00      |           |
| Corridor                       | 50,66        | 382,00      |           |
| Platform                       | 288,00       |             |           |
| Wall                           |              |             | 925,00    |
| 4th Floor, Elevation +12.60 m  |              |             |           |
| Classroom                      | 50,66        | 192,00      |           |
| Corridor                       | 50,66        | 382,00      |           |
| Platform                       | 288,00       |             |           |
| Wall                           |              |             | 925,00    |
| Top Beam, Elevation +16.80     |              |             |           |
| Water tank                     | 74,07        |             |           |
| Platform                       | 288,00       |             |           |
| Roof Load                      |              |             | 1345,89   |
By using SNI 1726-2019 and defined load, calculations are carried out using structure analysis software by looking for the values of Mu, Pu, Vu and the results of the calculations obtained are shown in table 5. Table 6 shows advantages and disadvantages of 2d and 3d structural analysis.

Table 5. Comparative Study of Internal Force Results for 2D and 3D Structures using SNI 1726-2019 and using PPIUG 1983 & PPURG 1987 referring to SNI 1727-2013

| Type of Testing | Column | Beam |
|-----------------|--------|------|
| Pu (Kn)         | Mu (Kn)| Vu (Kn) | Mu (Kn) |
| 2d              | 715.04 | 489.81 | 172.83 | 373.75 |
| 3d              | 498.03 | 291.94 | 50.67  | 84.56  |

Table 6. Advantages and disadvantages of 2D and 3D structural analysis

| No. | 2D structure | 3D structure |
|-----|---------------|--------------|
| 1   | Running structure analysis software process is faster ± 2 Seconds | Running structure analysis process takes time ± 2 minutes |
| 2   | The loading system can only be done in an open frame | Loading system can be done in open frame or shell |

4. Conclusion

Comparison of internal forces between 2D and 3D structures according to SNI 1726-2019 with analysis using structure analysis software has a relatively large difference in results. The difference between 2D and 3D calculation results at the column moment 197.87 kN, the axial force 217.01 kN, the column moment 289.19 kN, and the shear force 122.16 kN. This is due to the difference in load distribution between 2D and 3D structures. Therefore, it is highly recommended in earthquake resistant building planning to use 3D modeling because it will be more accurate in calculating the forces acting on the building structure. In addition, due to Indonesia's unique geographical conditions, the development of Indonesia's earthquake hazard maps will always change and will be followed by changes in the planning guidelines for earthquake resistant buildings from one time to another. So research studies like this are expected to continue following the circumstances at that time.

5. Reference

[1] National Standards Agency. (2019). SNI 1726: 2019. Earthquake Resistance Planning Procedures for Building and Non-Building Structures.

[2] Widyarini, G., Pithaloka, L. D., Sukamta., & Sabdono, P. (2013). Comparative Study of Two-Dimensional (2D) and Three-Dimensional (3D) Analysis of a 14-storey Building Structure Case Study of the Holiday Inn Express Semarang Hotel. Journal of Civil Engineering Works, UNDIP: Semarang.

[3] Faizah, R. (2015). Comparative Study of Equivalent Static Earthquake Loading and Dynamic Time History in Multi-storey Buildings in Yogyakarta. Semesta Teknika Scientific Journal. Vol 18/2, 190-199.

[4] Dharmawansyah, D., Irsyam, M., Asrurifak, M., & Simatupang, P. (2014). Studi Pembuatan Peta Percepatan Puncak di Permukaan Tanah dan Peta Resiko Gempa Akibat Gempa Benioff di DKI Jakarta untuk Penunjang Pembuatan Peta Mikrozonasi Jakarta.

[5] Tim Revisi Peta Gempa Indonesia. (2010). Ringkasan Hasil Studi Tim Revisi Peta Gempa Indonesia 2010. BNPB, AIFDR, RISTEK, DPU, BMKG, LIPI, ESDM: Jakarta.

[6] Tim Pusat Studi Gempa Indonesia Tahun 2017. (2017). Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017. Pusat Penelitian dan Pengembangan Perumahan dan Permukiman: Bandung.
[7] Sucipto, D. Map of the Sleman Earthquake Area. http://mgm.slemankab.go.id/tag/peta-kawasan-gempa-bumi/

[8] Fajarrachman, I., Erizal., & Widyarti, M. (2018). A Comparison of Rusunawa A4 IPB Building Storey Shear using Seismic Code of SNI 1726-2002 and SNI 1726-2012. Asian Journal Applied Sciences (ISSN: 2321-0893), Vol 06, hal 112-118.

[9] Tjokrodinuljo. (2007). Concrete Technology. Publishing bureau: Yogyakarta.

[10] Asfurifak. (2018). Response Spectrum for Bridge Design. Bandung Institute of Technology: Bandung.