Seismic performance of the inpatient building of Goeteng Hospital, Purbalingga, Indonesia

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Abstract. The inpatient building of Goeteng Hospital, Purbalingga, Indonesia, which was built in 2012, is a building with risk category IV. Due to the irregular configuration of the structure, this building has considerable earthquake vulnerability. This study aims to evaluate the symmetrical performance of the Goeteng Hospital inpatient building using pushover analysis. The results of the study show that the basic shear force received by the inpatient building of Goeteng Hospital is equal to 10064.421 and 5655.626 kN in the X and Y directions, respectively. The structure deviation ratio that occurs below 1% is 0.17% for the X direction and 0.24% for the Y direction. Thus, the seismic performance of the Goeteng Hospital inpatient building is categorized as immediate occupancy, where it is predicted that there is no damage, meaning that its structure, strength, and stiffness are about the same as the conditions before the earthquake. Non-structural components are still in place and most are still functioning if the utility is available. The building can still function without the need for repair work.

1. Introduction
Earthquakes are a type of natural disaster that needs to be monitored. Earthquakes often cause significant loss, including loss of life, damage to houses and buildings of public facilities, and other physical infrastructure [1]. The level of earthquake risk is determined by two main factors, namely, the magnitude of the hazard level and the level of vulnerability. The level of threat cannot be reduced because it is a natural phenomenon. Thus, the level of earthquake risk can only be reduced by reducing the level of vulnerability [2][3]. Indonesia is a region traversed by the meeting of the world's active plates, meaning that the intensity of earthquakes is high. Changes in earthquake intensity demand regulatory changes in earthquake planning for buildings due to an increase in spectrum design response for all classes of land sites throughout Indonesia [4].

Changes to this regulation have resulted in many studies on the effect of regulatory changes on the magnitude of the earthquake force that occurred and its impact on the performance of building structures. One study conducted by Arfiadi and Satyarno [5] discusses the comparison of the design spectrum of several major cities in Indonesia in SNI 03-1726-2012 [6] and SNI 1726: 2002 [7]. They report that for cities that experience an increase in the spectrum of designs, both in short periods (which affect buildings of two to eight floors) or a period of 1 s (which affects buildings of ten floors or more), buildings in
these cities need to be evaluated for their resistance to earthquakes, especially hospitals and other important buildings.

Based on the Indonesian earthquake hazard map [8], for rock types in the form of sites, Purbalingga has a spectrum response acceleration in short periods, 0.2 s, (Ss) of 0.760 g and accelerated spectrum response at period 1 s, (S1) of 0.311 g, as can be seen in Figure 1. Thus, Purbalingga is a region with moderately high seismic potential because it has an accelerated spectrum response in a shorter period, 0.2 s, (Ss) higher or equal to 0.5 g but lower than 1.0 g, and acceleration of the spectrum response at 1 s period, (S1) higher or equal to 0.2 g but lower than 0.4 g [9].

![Figure 1. Short period (Ss) and long period (S1) spectral acceleration in Purbalingga, Indonesia](image)

The inpatient building of Goeteng Hospital, Purbalingga, which was built in 2012, is a risk category IV building and has an unregulated structure configuration. The behavior of buildings during an earthquake depends on several factors, including whether the shape is simple and symmetrical. Buildings that have both vertical and horizontal irregularities are more susceptible to earthquakes [2]. Some buildings can even behave very poorly when hit by an earthquake caused by the irregular shape of the building [10]. This study aims to evaluate the seismic performance of the Goeteng Hospital inpatient building using a pushover analysis.

Kharwar and Lhonde [11] argue that there are levels of structural analysis that are suitable for performance-based structural analysis. Each higher level procedure is a more accurate method of determining the actual performance of buildings due to earthquake loads, but requires greater effort in terms of data preparation, time and computing. Pushover analysis is a popular method recommended for evaluating both long standing and new structural performance [12] because of its simplicity [13]. Pushover analysis can provide adequate information regarding the seismic demand imposed by ground motion design on the system structure and its components. Existing buildings can be categorized as insufficient in seismicity due to the seismic regulatory requirements that are continually being improved in addition to advances in knowledge in the engineering field

2. Methodology

2.1. Structural modelling

Building specification data:
Building Function : Hospital
Material: Steel ST37, Concrete K-275
Roof: Cold form steel
Plate Thickness: 120 mm
1st floor column: 0.45 m x 0.45 m
2nd floor column: 0.30 m x 0.30 m
Beam: (Table 1)

**Table 1. Beam dimensions.**

| Type | Dimension (m²) |
|------|---------------|
| G1   | 0.35 x 0.70   |
| G2   | 0.30 x 0.60   |
| G3   | 0.30 x 0.40   |
| B1   | 0.25 x 0.50   |
| B2   | 0.25 x 0.40   |
| B3   | 0.20 x 0.40   |
| B4   | 0.15 x 0.30   |
| BP   | 0.15 x 0.20   |

The plan structure of the inpatient building model of Goeteng Hospital is shown in Figure 2. The two-dimensional structure is presented in Figure 3, while the three-dimensional model can be seen in Figure 4.

**Figure 2.** Plan structure of Goeteng Hospital inpatient building
2.2. Pushover analysis

Pushover analysis is a performance-based evaluation that aims to determine the capacity of a structure. Basically, pushover analysis is carried out by giving lateral loads whose values are increased incrementally proportionally to the structure until it reaches the target displacement or reaches a mechanism on the threshold of collapse due to the occurrence of plastic joints on beam elements and columns. The analysis procedure explains how to identify structural elements that will fail first. Along with the increase in load, there are melting elements and inelastic deformations, which result in reduced structural stiffness. With pushover analysis, the characteristics of the relationship of non-linear displacements can be determined, as typically shown in Figure 5.
Figure 5. Generalized force-displacement attribute of frame element [14]

Figure 5 shows that the linear response starts from point A (unloaded component) and melting starts at point B. The response from point B to point C is a plastic elastic response. Point C is a point indicating nominal strength, and the axis that is a deformation indicates the commencement of the degradation of the structural element’s strength (C-D line). At point D, the structural response substantially decreases the strength to point E. For deformations greater than point E, the strength of the structural element becomes zero.

2.3. Structural performance

The structure evaluated in this study is a hospital building and the required performance is at the level of immediate occupancy. The seismic performance of a structure can be done by comparing the structure and demand capacity. Demand is a representation of the movement of land due to the earthquake so that the parameters used are the displacement of the structure, while the structural capacity is a representation of the ability of the structure to carry seismic demand. The structure performance level matrix is shown in Figure 6.

Figure 6. Structural performance level matrix.

Based on FEMA 451 [15] and ATC 40 [16], the seismic performance of the structure is categorized into the operational, immediate occupancy, life safety and prevention collapse levels. At the operational level, there is no damage, meaning that both the structure and non-structure of the building can still function. The immediate occupancy level indicates that after an earthquake occurs, the structure does not suffer significant damage, its strength and stiffness are approximately the same as the conditions before the earthquake. Non-structural components are still in place and most are still functioning if the utility is available. Buildings can continue to function and not be bothered by repair problems. At the life safety level, a structural collapse occurs when an earthquake occurs but the building does not collapse, the non-structural components are not functioning but can still be reused after repairs. The degree of collapse prevention means that there is significant damage both to the structural and non-
structural components, where the condition of the building has almost collapsed due to reduced structural strength and stiffness. An illustration of the building seismic performance can be seen in Figure 7.

![Figure 7. Illustration of building seismic performance [14]](image)

3. Result and discussion

The performance point, which is the intersection of the capacity spectrum curve with the demand spectrum curve, as a result of the pushover analysis for the Goeteng Hospital inpatient building is shown in Figure 8. From the results of this pushover analysis, we can find the basic shear force (V) and displacement value (D). The values of $S_a$, $S_d$, effective natural vibration time ($T_{eff}$) and effective viscous attenuation ($\beta_{eff}$) can also be known. The results are presented in Table 2, which shows that the basic shear force received by the building is 10064.421 and 5655.626 kN for the X and Y directions, respectively. The displacement (D) that occurs is 0.00712 m for direction X and 0.01000 m for direction Y. Ductility of the structure occurs, which is the ultimate displacement ratio ($\delta_u$) and yield displacement ($\delta_y$), for the X and Y directions, respectively, 2.74 and 4.46, as can be seen in Table 3.

![Figure 8. Performance point of Goeteng Hospital inpatient building in X and Y directions](image)

| Parameter | X Direction | Y Direction |
|-----------|-------------|-------------|
| $V$ (kN)  | 10064.421   | 5655.626    |
| $D$ (m)   | 0.00712     | 0.01000     |
| $S_a$     | 0.352       | 0.275       |
| $S_d$     | 0.00383     | 0.00485     |
| $T_{eff}$ | 0.204       | 0.258       |
The structural performance is determined based on the drift ratio, namely, the ratio of the control point displacement (roof) with its height. The results of the pushover analysis for the inpatient building of Goeteng Hospital show that the drift ratio that occurs is 0.17% for the X direction and 0.24% for the Y direction, as shown in Table 4, while the drift ratio curve can be seen in Figure 9.

### Table 4 Structural performance.

| Direction | Dt (m) | H (m) | Drift Ratio (%) | Performance |
|-----------|--------|-------|-----------------|-------------|
| X         | 0.00712| 8.4   | 0.17            | IO          |
| Y         | 0.01000| 8.4   | 0.24            | IO          |

**Figure 9.** Drift ratio of Goeteng Hospital inpatient building in X and Y directions

### 4. Conclusions

It can be concluded that the basic shear force received by the inpatient building of Goeteng Hospital is equal to 10064.421 and 5655.626 kN for the X and Y directions, respectively. The structural ductility for the X and Y directions, respectively, are 2.74 and 4.46. The structure drift ratio that occurs below 1% is 0.17% for the X direction and 0.24% for the Y direction. Thus, the seismic performance of the Goeteng Hospital inpatient building is categorized as immediate occupancy, where it is predicted that there is no damage, means that the structure, strength and stiffness are about the same as the conditions before the earthquake. Non-structural components are still in place and most are still functioning if the utility is available. The building can still function and not be bothered by repair problems.
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