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SEISMIC ANALYSIS USING STRENGTH BASED DESIGN METHOD AND PERFORMANCE BASED DESIGN METHOD: STUDY CASE OF PURI AZIZI PURI HOSPITAL ON MEDAN, NORTH SUMATRA

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ABSTRAK

Analisis seismic menggunakan metode berbasis kekuatan mengikuti standard SNI 1726:2019, sementara metode berbasis performa didasarkan pada regulasi ATC 40. Data analisis yang diperoleh dari kontraktor seperti gambar kerja. Sebelum melakukan analisis, pemodelan struktur dilakukan menggunakan SAP 2000. Metode berbasis kekuatan meliputi melakukan analisis statis linear berdasarkan standard desain bangunan tahan gempa yang mengacu pada SNI 1726:2019. Standar ini memprioritaskan kekuatan dari material dan elemen struktural. Sementara, metode berbasis performa meliputi melakukan Prosedur B Analisis *Pushover* Statis Nonlinear. Analisis ini mempertimbangkan tingkat performa dan sifat struktural dalam keadaan gempa yang berbeda-beda, memanfaatkan kriteria performa sesua standard internasional. Dalam metode berbasis kekuatan, nilai *base shear* (V) didapatkan sebesar 497551.96 kgf. Dalam metode berbasis performa, nilai *base shear* (V) didapatkan sebesar 623230.3 kgf. Studi *pushover* menggunakan prosedur B menghasilkan nila Sa sebesar 0.095 dan nilai sd sebesar 0.023. Berdasarkan spesifikasi ATC-40, level performa dari struktur adalah *Immediate Occupancy Phase.* Kesimpulan ini didasarkan pada deformasi dari struktur. Nilai simpangan total paling besar yang diperbolehkan untuk struktur bangunan adalah fase yang sesuai dengan fase ini.

Kata kunci: Desain Berbasis Kekuatan, Desain Berbasis Performa, SNI 1726:2019, ATC 40, Analisis *Pushover*

ABSTRACT

The seismic analysis employing the Strength Based Design (SBD) technique follows the standards specified in SNI 1726:2019, whereas the technic of Performance Based Design (PBD) method adheres based on regulations outlined in ATC 40. The seismic analysis data is acquired from the contractor such as shop drawing. Prior to conducting the analysis, the modeling will be performed initially using SAP 2000. The Strength Based Design (SBD) technique involves conducting linear elastic analysis according to conventional seismic design standards outlined in SNI 1726:2019. These standards prioritize the strength of materials and structural elements. Meanwhile, the Performance Based Design (PBD) involved conducting a Static Nonlinear Pushover Analysis Procedure B. This analysis considers the degree of performance and structural behavior under different earthquake situations, utilizing performance criteria stated in international standards. In Strength Based Design (SBD), the base shear (V) value obtained is 497551.96 kgf. In Performance Based Design (PBD), the base shear (V) value obtained is 623230.3 kgf. The pushover study using procedure B yielded a Sa value of 0.095 and a sd value of 0.023. According to the specifications of ATC-40, the performance level of the structure is found to be in the Immediate Occupancy phase. This conclusion is based on the deformation of the structure. The greatest total drift that is allowed for building structures is the phase that corresponds to this phase.

Keywords*: Strength Based Design, Performance Based Design, SNI 1726;2019, ATC 40, Pushover Analysis*

INTRODUCTION

Indonesia enclosed by Pacific Ocean's basin and placed in the Ring of Fire, a region prone to regular earthquakes and volcanic eruptions. Located near the point where the Australian, Eurasian, and Pacific plates converge is where Indonesia is located. Because of the ongoing movement and collision of these three tectonic plates, both significant and mild earthquakes may result. Natural catastrophes like

earthquakes are unpredictable in terms of their timing and location and frequently cause a large number of fatalities. They significantly affect structures as well. Planning for earthquake-resistant buildings must be done effectively in order to minimize fatalities.

An increasing number of high-rise buildings have been constructed in recent years. This is a result of Indonesia's rapidly expanding population and scarce land supply. On the other hand, a structure's susceptibility to seismic forces increases with height. As a result, designing high-rise structures to withstand earthquakes is an important assignment in Indonesia. Demand and capacity are the two factors that determine PBD performance levels. Demand represents the ground motion during an earthquake, whereas capacity represents a structure's resistance to demand. In the meanwhile, Indonesia is controlled by regulations that are referred to as the Indonesian National Standards. These standards are based on the Strength Based Design (SBD) approach and mandate that every structure must be designed in such a way that it is capable of withstanding the fundamental shear loads that are caused by earthquakes.

Strength-based design method is still used for earthquake planning according to SNI 1726:2019, the Standard for Earthquake Resistant Design of Buildings. This method guarantees that the structure is protected against complete collapse brought on by a significant earthquake, even though it suggests that the performance criteria to be met are not mentioned clearly. This force-based design method has successfully decreased the number of casualties.

One alternative solution to anticipate the aforementioned issues is to utilize the performance-based design method. The technic of Performance-based design (PBD) is a relatively new method ithat has been developed in recent years for structural design. Buildings are designed by determining the deflection of the structure. This loading method is commonly used for earthquake-resistant buildings due to its ability to calculate the non-linear behaviour of structures caused by seismic forces. This method can more accurately estimate the behaviour of the building during an earthquake and identify which parts of the structure are likely to fail first. The concept of performance-based design combines aspects of resilience and functionality. An extension of the performance-based design (PBD) concept, performance-based earthquake-resistant design (PBD) is a process that can be utilized for the design of new buildings with a realistic understanding of the potential risks to life, occupancy readiness, and economic losses that may occur as a result of future earthquakes (Pranata, 2006).

The Puri Azizi Hospital Building, which can be found in Jl. Kapten Sumarsono Ds. Helvetia in Sunggal District, Deli Serdang Regency, Medan, serves as the research object that is utilized in this thesis. There are a total of six floors in the building. A software tool called SAP 2000 will be utilized in order to conduct an analysis of the structural reaction of the structure to seismic loads. The strength-based design technique, which is based on the regulations presented in SNI 1726 2019, and the performance-based design method, which is based on the guidelines presented in ATC 40, will be utilized in the process of conducting the analysis.

METHOD

This research attempted to evaluate the building's performance during earthquakes using two different approaches: strength-based design and performance-based design. Strength-based design prioritizes the building's structural ability to resist seismic forces. It aims to ensure that the building complies with precise strength standards and code regulations. Performance-based design considers the behaviour and reactivity of the entire building system under seismic stresses in a complete manner. The focus is on both the strength of individual elements and the overall performance, considering issues such building deformation, displacement, and energy dissipation. This methodology attempts to evaluate the building's ability to sustain its operation and ensure occupant safety both during and after an earthquake.

The researchers choose to use the SAP2000 application to conduct the analysis with these approaches. The choice of SAP2000 was based on its robust ability to accurately simulate the intricate behaviour of structures under seismic loads. The program utilizes advanced modelling approaches and algorithms to enable accurate analysis of structural response, including nonlinear behaviour, plastic deformation, and failure processes.

Seismic analysis using strength-based design will be based on SNI 1726:2019, while performance-based design analysis will be based on ATC 40 procedure B. The end result of storey displacement of each method is going to be compared to each other.

Data Collection

The information obtained from Puri Azizi Hospital consists of shop drawings and technical details of the structure. The seismic study investigation will especially focus on collecting data related to the structural components of the structure, including beams, slabs, and columns.

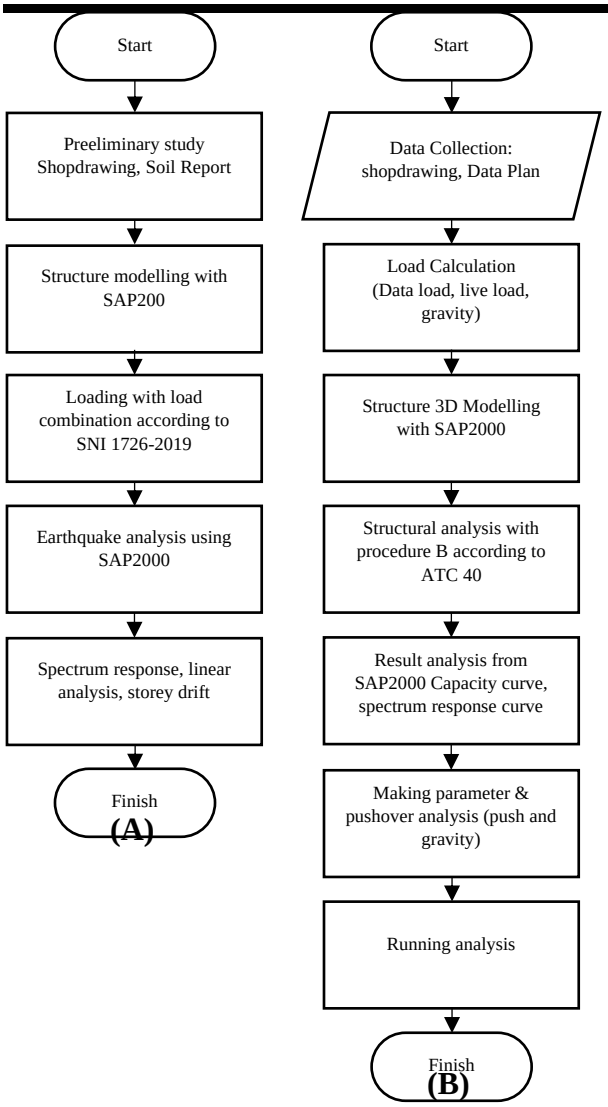

Figure 1 (A) Flowchart SBD (B) Flowchart PBD

RESULT AND ANALYSIS

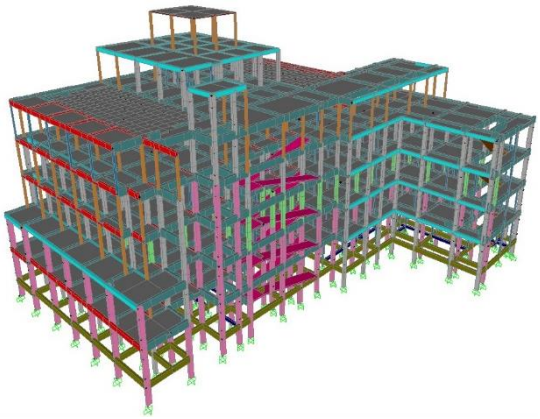

Figure 2 Structure Perspective 3D Model

Strength-Based Design

Various earthquake response variables needed to be calculated and adjusted to the location of the building being reviewed. For Puri Azizi Hospital, here are the value for each variable:

Table 1 Seismic Calculation Summary

No	Variable	Soft Soil
1	SS	0,6
2	S1	0,35
3	PGA	0,3
4	CRS	1,025
5	CR1	0,97
6	FPGA	1,6
7	Fa	1,5
8	Fv	0,35
9	Sa	0,24
10	SMS	0,9
11	SM1	0,91
12	SDS	0,6
13	SD1	0,607
14	T0	0,2
15	TS	1,01
16	TL	20

Source: Personal Documentation

These data are then inputed to SAP 2000 where this procedure is performed by accurately inputting the values of the primary vibration period (T), initial period (T0), and transition period (Ts) derived from the response spectrum, along with the spectral acceleration (Sa) values that correspond to the seismic attributes at the building's site.

Further calculations are done to find the vertical distribution factor which can be seen in the table below.

Table 2 Vertical Distribution Factor

Storey	wx	hx	hx^k	wx.hx^k	cvx	Fx
6	5061,646	24	35,143	1777880,5	0,224	1094,12
5	6791,58	20	28,652	194591,7	0,245	1196,91
4	7812,708	16	22,316	174347,6	0,220	1072,39
3	8257,879	12	16,169	133521,6	0,168	821,28
2	8484,825	8	10,267	87118,15	0,110	535,85
1	5463,769	4	4,724	25810,68	0,033	158,76
Summary				193269,3	1,000	

Source: *Personal Doumentation*

Performance-Based Design

The performance-based design technique method with B procedure is totally calculated using software (SAP 2000). Once the building structure has been designed using SAP2000 software, in compliance with relevant regulations, such as the concrete quality for plates, beams, columns, and shear walls specified in the material properties section, we must also input the quality of the reinforcement used.

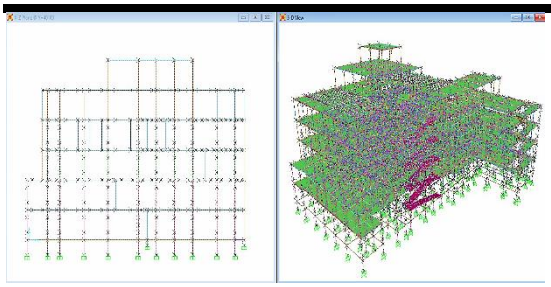

Figure 3 2D and 3D hinge in beam and column

Pushover analyses are then performed to obtain pushover graph where we can see the relationship between base shear and roof displacement and a capacity spectrum graph from ATC-40 which depicts the performance of the Puri Azizi Hospital structure.

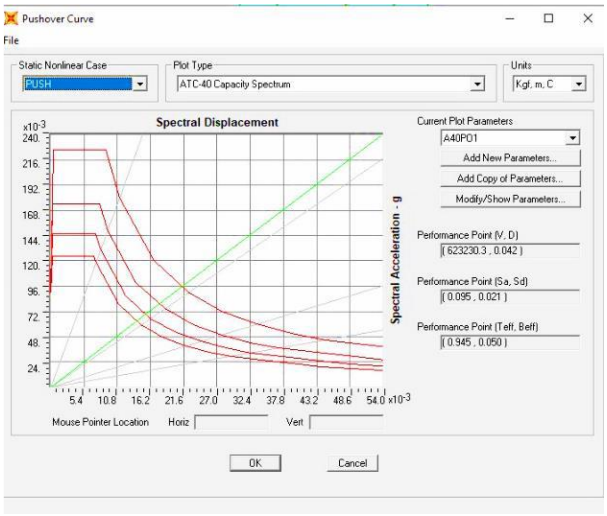

Figure 4 Spectrum capacity curve

In this analysis, the term "level of serviceability" as defined by ATC-40 refers to the maximum allowable total drift of building structures. To assess the structural performance, it is essential to compute the maximum total drift. This is done by dividing the drift value of the structure by the overall height of the structure.

$$drift = \frac{D}{H} \quad (1)$$

$$drift = \frac{0.042}{28} \quad (2)$$

$$drift = 0.0015 \quad (3)$$

If the structural performance standards are met, the building is considered to be within the Immediate occupancy (IO) range, this means that if it occurs earthquake, the building did not experience structural and non-structural damage, so the building remains safe to use

Displacement Comparisson

The determination of displacement in strength-based design is derived from SAP 2000, employing a more cautious linear elastic technique. On the other hand, performance-based design utilizes nonlinear structural behaviour.

Table 3 Calculation of structural drift control

Storey	Height of Storey (m)	Displacement of SBD (m)	Displacement of PBD (m)	Allowable (m)
1	4	0,0158	0,05	0,04
2	4	0,0078	0,0214	0,04
3	4	0,0104	0,0282	0,04
4	4	0,0070	0,0194	0,04
5	4	0,0495	0,1391	0,04
6	4	0,0223	0,0946	0,04

Source: Personal Documentation

The table above displays are displacement on each floor (story) of a multi-storey building with a consistent floor height of 4 meters. The term "Displacement of SBD" refers to the displacement that is computed using the SBD method. Similarly, the term "Displacement of PBD" refers to the displacement that is calculated using the PBD method. The term "Allowable" refers to the maximum permissible displacement limit, which is set at 0.04.

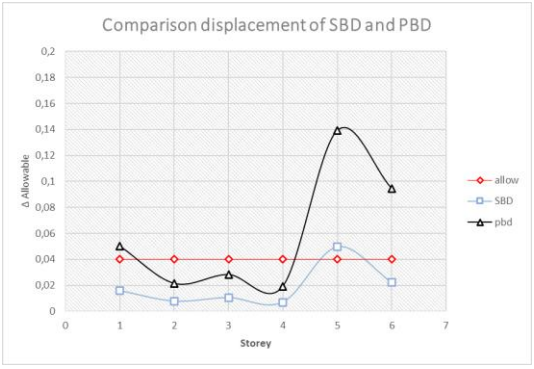

Figure 5 Storey drift comparison

The Red Line represents the maximum authorized mobility restriction (0.04) for each floor. Subsequently, the blue line illustrates the displacement experienced on each floor, as determined by the SBD method. Lastly, the black line illustrates the displacement on each floor, as determined by the PBD approach.

The displacement computed using the PBD approach typically surpasses the displacement computed using the SBD method, particularly on the 5th and 6th floors, where the PBD displacement significantly exceeds the SBD displacement. The displacement permit limit, calculated using the SBD method, is below the maximum permissible limit of 0.04. Conversely, the displacement on floors 5 and 6,

calculated using the PBD method, exceeds the maximum permissible limit. This indicates potential failure or the need for redesign on those floors.

CONCLUSION

Based on the research conducted, the conclusion of the study are as follow:

1. The earthquake analysis of Puri Azizi Medan Hospital distinguishes between strength-based and performance-based design methods. The strength-based design method ensures the structure can withstand calculated earthquake forces to prevent collapse, using linear elastic and response spectrum analysis as per SNI 1726:2019. In contrast, the performance-based design method assesses structural performance and damage levels during earthquakes, employing nonlinear pushover analysis as outlined in ATC 40.
2. Strength-based design is straightforward and efficient, adhering to national norms and ensuring minimum safety criteria. However, it does not account for post-seismic behavior or potential structural damage. Performance-based design, while more complex and resource-intensive due to nonlinear simulations and multiple performance assessments, provides a thorough examination of the hospital's structural behavior, mitigating both structural and non-structural damage.
3. The strength-based method meets national standards with reduced displacements for most floors, proving cost-effective. Performance-based design, however, indicates higher displacements, necessitating design interventions to ensure safety.
4. The performance point value, based on a maximum total drift of 0.0015, falls under the Immediate Occupancy category per ATC-40 requirements. This results in minimal structural damage, with no significant horizontal displacement or permanent deflection in columns, beams, slabs, walls, and pilasters. Non-structural elements, including doors, ceilings, and utilities, sustain minimal damage and remain functional.
5. Based on the analysis results from SAP 2000, the coordinates of spectral acceleration (Sa): 0.095; and spectral displacement (Sd): 0.023; with base shear (V): 623230.3 kgf; Active period (Teff): 0.945; Active dumping (βeff): 0.050

RECOMMENDATION

Based on this study, there are some recommendation to be made for future similar study:

1. Potential areas for future research include deepening our comprehension of earthquake-resistant design and exploring different modelling techniques for various forms and types of structures.
2. 2. It is imperative to reassess the structural performance level using alternative seismic analysis methodologies to achieve improved outcomes in understanding the behaviours of structures during earthquakes and predicting potential collapse.
3. 3. Proficiency in SAP 2000 is essential to accurately interpret output results for linear and nonlinear analysis conducted using SAP 2000.
4. 4. Conduct additional research on financial analysis to determine the costs associated with using strength-based design and performance-based design for earthquake analysis.

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