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Structural Performance Towards Dynamic Earthquake Spectrum Response According to SNI 1726-2012 and SNI 03-1726-2019 (Study Case Hospital Building in Solo)

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ABSTRACT

Tectonic earthquakes are a type of earthquake that can cause significant damage compared to other earthquakes. These tectonic earthquakes often occur in Indonesia, considering that geographically Indonesia is located between the earth's plates which are still active. So in earthquake-prone areas it is necessary to plan earthquake-resistant building structures, this is done so that if an earthquake occurs the building does not suffer significant damage. The dynamic response spectrum earthquake analysis method produces base shear and displacement of the structure. The response spectrum is a plot of the spectrum presented as a plot or graph between the oscillation periods of the T-structure, as a function of the maximum response to a certain damping rate and earthquake load. This research aims to determine the structural response using 3D modeling of a hospital structure in the city of Solo. The research was carried out to determine the effect of earthquakes on structural performance which was analyzed by referring to the regulations SNI 03-1726-2012 and SNI 03-1726-2019. The modeled building consists of a floor plate frame, beams and columns, each of which will be given a structural element. loads that refer to the regulations SNI 1726-2012 and SNI 03-1726-2019 as a comparison of which is more effective. It was found that the results of using SNI 03-1726-2012 on building structures had better security performance when compared to analysis with SNI 03-1726-2019.

Keywords: SNI**;** earthquake; earthquake planning; dynamic response; structural response.

INTRODUCTION

Indonesia is a country that is very prone to earthquake natural disasters because geographically it is located in the Pacific Ring of Fire region which is the meeting point between tectonic plates such as the Pacific Plate, the Indo-Australian Plate and the Eurasian Plate and there are many volcanoes that are still active. An earthquake is a natural event that cannot be predicted when it will arrive and how strong it will be, so when planning a building it must be designed well so that the building structure can withstand the weight of an earthquake and not cause serious damage that can lead to loss of life. Regardless of earthquake changes, to withstand earthquake loads, building structures need to be designed well. Kurniawan. et al, (2018).

Along with technological developments in the construction sector, several analyzes of structural performance due to earthquake loads have emerged using various methods, one of which is analysis of the influence of soil variability on the variability of earthquake spectrum reactions. The response of buildings due to ongoing earthquakes can be analyzed dynamically. Dynamic analysis is an analysis that can calculate earthquake forces in building plans with a height of more than 40 m or more than 10 levels. This dynamic concept can take into account mass, stiffness and damping. The load formed from dynamic mass can change according to time as well as its direction. Spectrum Response is a plot of a spectrum presented in the form of a graph/plot between periods of vibration of a T structure, versus the maximum responses for a certain damping ratio and earthquake load. (Prawirodikromo, 2017).

Based on the theory above, research was conducted to determine the effect of earthquakes on the structural performance of a hospital in the city of Solo which was analyzed by referring to the regulations SNI 03-1726-2012 and SNI 03-1726-2019.

Building a strong building that can last for years requires a comprehensive approach that considers various aspects of engineering, building materials, design and maintenance. Carry out an in-depth analysis of the loads that will be received by the building, including live loads (occupants, furniture) and dead loads (weight of the structure itself) (Lutfi M et.al, 2024); (Arjon A, Hardjomuljadi S, 2024; (Sari OL et.al, 2023). Using earthquake-resistant design techniques and standards according to the geographical location of the building to reduce the risk of damage due to earthquakes. Applying the principle of redundancy where structural elements have reserve capacity so that if one element fails, other elements can bear the load (Irvania A et.al, 2024); (Putri MC et.al, 2024); (Husin AE et.al, 2024).

Using energy-efficient technology and design such as good insulation, double-glazed windows, and energy-efficient HVAC (Heating, Ventilation, and Air Conditioning) systems. Utilize renewable energy sources such as solar panels and wind turbines to reduce dependence on conventional energy sources. Installing state-of-the-art security systems including CCTV, fire alarms and access control systems (Lutfi M et.al, 2023); (Prastowo FI et.al, 2023); (Amalia N et.al, 2023); (Lutfi M et.al, 2023).

By considering all of the above factors, a building can be designed and built to last, provide comfort and safety for its occupants, and remain efficient and environmentally friendly for many years (Napitupulu RVM, Trarasati AD, 2022); (Lutfi M et.al, 2021).

Using activities outside the home to maintain life inside the home is a concept that involves integration between the outdoor and indoor environments to improve comfort, health and sustainability of life (Syaiful S, Suherman S, 2024); Syaiful S et.al, 2023).

RESEARCH METHODS

Data collection in this research was obtained from structural drawing data and architect's drawings according to As-built drawings of the building and then 3D modeling was carried out using the help of a structural analysis computer program. Detailed data on structure, materials and construction are adjusted to existing technical documents. Three-dimensional modeling of the building structure is as shown in the model in Figure 1. Meanwhile, the complete research flow chart is as shown in Figure 2.

Figure 1. Structural modeling of a hospital building in structural analysis software.

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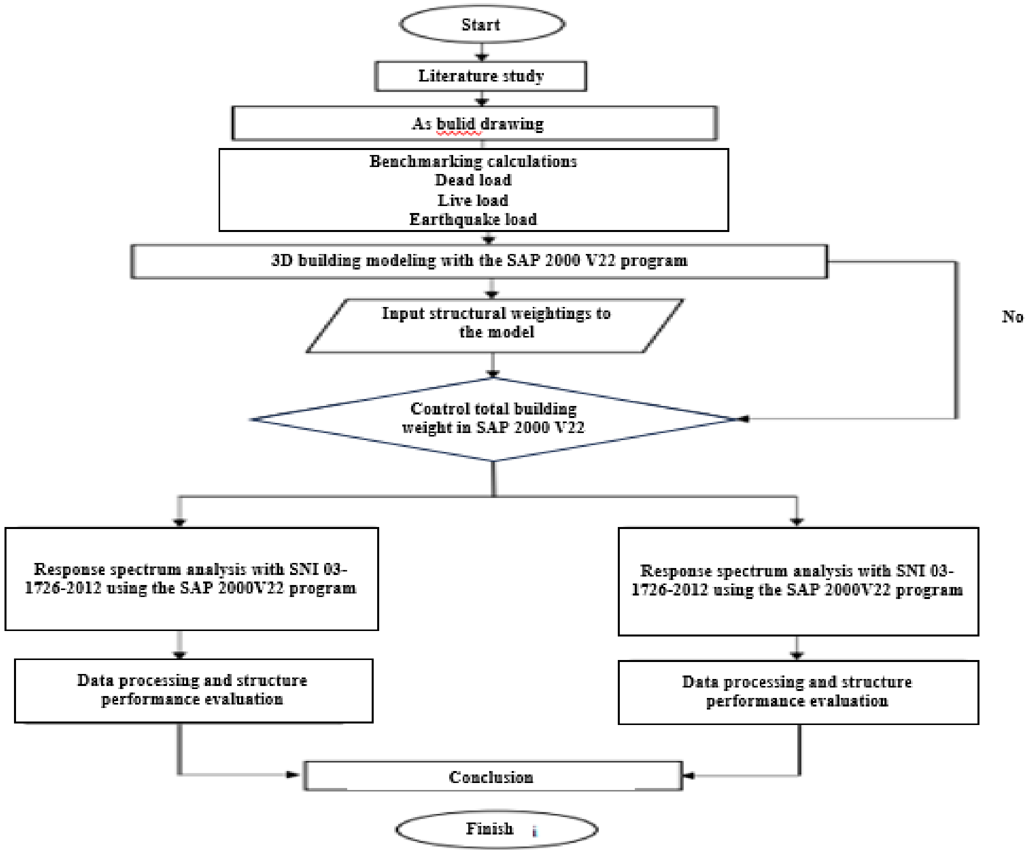

Figure 2. Research Flow Diagram

Loading Calculation

Loading on structures is one of the most basic and most important things in building planning. Therefore, the planned building structure must comply with applicable regulations and be able to withstand loads such as dead loads, live loads and earthquake loads acting on the building structure in order to obtain a constructionally safe building structure.

In this research, the live load and dead load use the SNI 1727 2020 regulations. The factored combination load refers to SNI 1727-2012 and SNI 1727-2019 as well as SNI 1726 of 2019 concerning Procedures for Earthquake Resistance Planning for Building and Non-Building Structures regulating earthquake load planning.

Dynamic Analysis of Response Spectrum

Response Spectrum Analysis is a method of dynamic analysis of structures where a mathematical model of the structure is applied to a planned earthquake response spectrum and based on this the spectrum response to the planned earthquake is determined through the superposition of the responses of each variety. At this stage the analysis used is dynamic analysis of the spectrum response method based on SNI 03-1726-2012 and SNI 03-1726-2019.

RESEARCH RESULT

Dead Load

The dead load included in the analysis consists of two loads, namely the structural load called dead loads and additional dead loads or component loads defined as super dead loads. Additional loads of building components used in table 1 below.

Table 1. Dead Load

Name	Heavy
Reinforced concrete	2.32kN/m3
Ceiling	0.2kN/m2
Sand	0.14kN/m2
Specifications (cm)	0.24kN/m2
Waterproof coating	0.14kN/m2
Plumbing and Me	0.5kN/m2
Ceramics	0.24kN/m2
Brick couple	2.46kN/m2
Gypsum partition	0.04998kN/m2
5mm glass	0.454936kN/m2
Curtain walls 10mm	1.091845kN/m2

Living Burden

Considering that the building which is the object of this research functions as a hospital, the live loads on the building floors used refer to the Standard Planning Procedures for Houses and Buildings SNI 1727 2020, as in table 2 below.

Table 2. Value of Hospital Living Burden

Hospital	Evenly distributed, Lo psf (kN/m2)
Operating room, laboratory	60 (2.87)
Patient room	40 (1.92)
Corridor above the first floor	80 (3.83)

Earthquake Data

The following is earthquake data obtained from the official website (http://rsa.buatkarya.pu.go.id/2010/) which is used as a reference in earthquake evaluation as follows:

Name City	= Surakarta		
Longitude	= 110.789857 Degrees		
Latitude	= -7.550378 Degrees		
Value PGA	= 0.357000 g	Value PGAm	= 0.440727 g
Value CRs	= 0.000000	Value CR1	= 0.000000
Value Ss	= 0.744000g	Value S1	= 0.392903 g
Value Fa	= 1.176233		
Value Fv	= 1.907097	Value SMS	= 0.952063 g
Value Sm1	= 0.749304 g	Value Sds	= 0.634708 g
Value Sd1	= 0.499536 g	Value T0	= 0.157406 second
Value Ts	= 0.787032 second	Situs class	= SD – medium soil
Value R	= 8 (Table 1, Factor R, Cd, and Ω0 for spectrum response design)		
Value I	= 1,5 (major factors in earthquakes)		

Spectrum Response Design

Spectrum response design data based on the planned earthquake spectrum response in the Solo area with moderate ground conditions is shown in the following figure 3 below.

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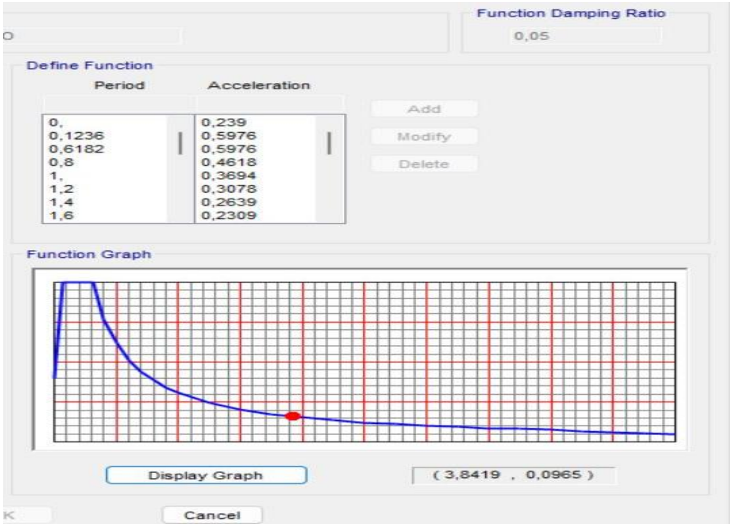

Figure 3. Spectrum Response Design

The spectrum response value must be multiplied by a scale factor of the same magnitude = g x 1.5/6 with g = gravitational acceleration (g = 9.81 m/sec^2).

Scale factor = $9{,}81\ x\ \frac{1{,}5}{6} = 2{,}45$

The scale factor value of 2.943 is then used as a multiplier factor in the SAP 2000 V22 software as in Figure 4 Input the scale factor for the planned earthquake spectrum as follows:

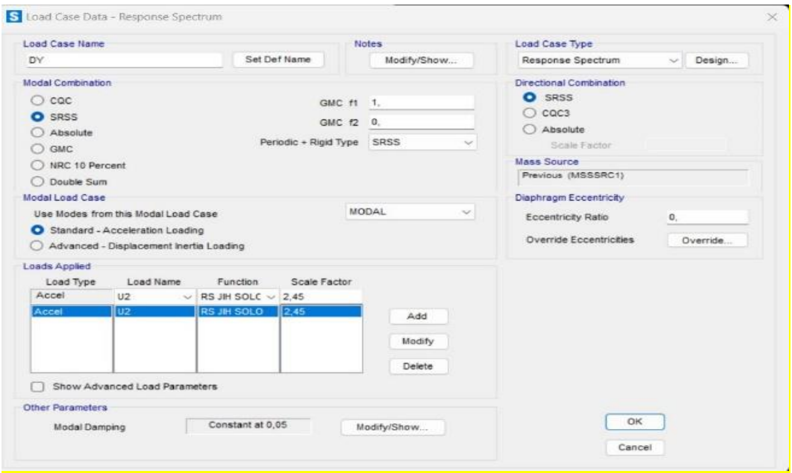

Figure 4. The input scale factor for the planned earthquake spectrum

Results of Horizontal Deviation Analysis with Load Combinations

The requirements for deviation between levels of a building structure must not exceed the requirements for the distance between levels (SNI 03-1729-2019), the results of horizontal deviation analysis with load combinations are shown in Table 3 below.

Table 3. Horizontal Deviation with Load Combinations

Horizontal deviation SAP 2000 output

Floor	Drif X (m)	Drif Y (m)
Roof	0,05858	0,08416
9	0,05496	0,07614
8	0,04934	0,06577
7	0,04287	0,0569
6	0,03574	0,04745
5	0,02816	0,03769
4	0,02039	0,02803
3	0,0129	0,01852
2	0,00648	0,0992
1	0,00214	0,0033
Base	0	0

Inter-Level Deviation Control

According to SNI 03-1729-2019, the requirements for deviations between levels of a building structure are as follows.

$\Delta_X < \Delta_a$

$\Delta_X = \frac{(\delta^{on} - \delta^{lower}) x\, Cd}{I}$

$\Delta_a = 0{,}010 h_{sx}$ (table 3 deviation between levels)

The results of deviation control calculations between structural levels in the X and Y directions are then presented in Figures 5 and 6.

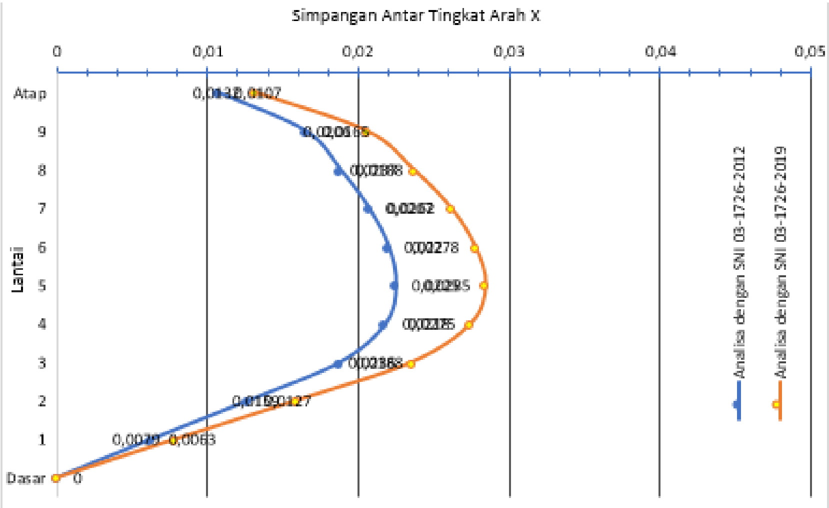

Figure 5. Inter-Level Deviation Diagram in X Direction

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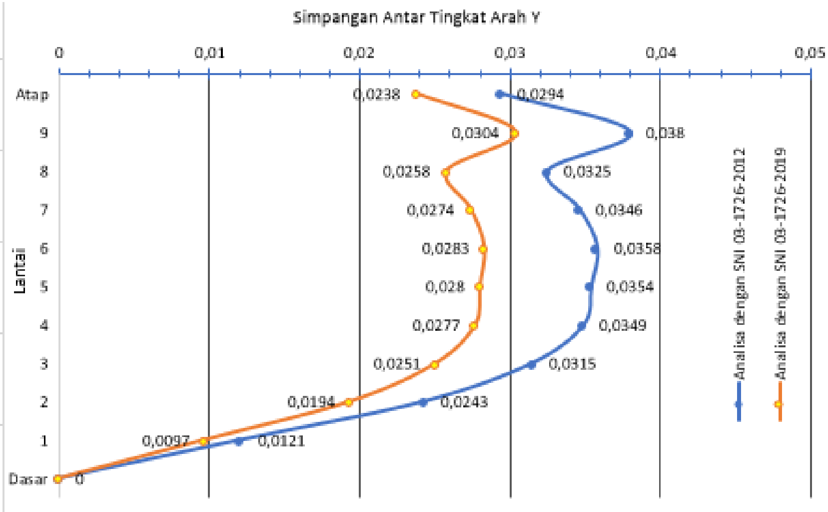

Figure 6. Interlevel Deviation Diagram in Y Direction

Service Limit Performance of Building Structures

Performance requirements for the serviceability limit of building structures, in all cases the deviation between levels calculated from the horizontal deviation of the building structure must not exceed 0.03/R x height of the level concerned or 30mm, whichever is the smallest.

Service limits used:

$\delta_m = (\delta^{on} - \delta^{lower})$

$\delta_m < \frac{0,03}{6} x\ 4$

δ_m < 0,024m

The performance calculation results of the building structure's serviceability limits in the X and Y directions are then presented in Figures 7 and 8.

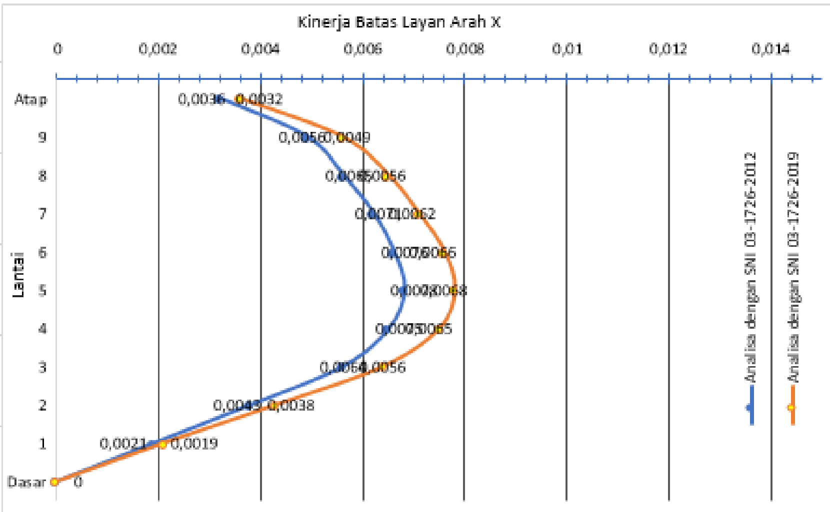

Figure 7. X-Direction Service Limit Performance Diagram

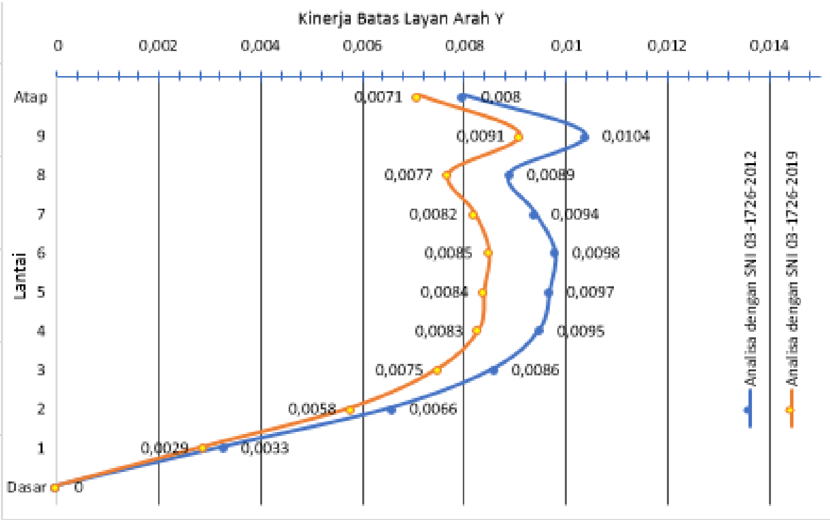

Figure 8. Y-Direction Service Limit Performance Diagram

Ultimate Limit Performance of Building Structures

To meet the performance requirements of the building's ultimate service limits, the deviation between stories calculated from the horizontal deviation of the structure (δm× ξ) must not exceed 0.02 times the height of the story concerned.
Ultimate limit used:
$\delta_m \times \xi < 0{,}02h$
$\delta_m \times$ (0,7 R / scale factors) < 0,02 h
$\delta_m \times (0{,}7 \times 6/2{,}45) < 0{,}02 \times 4$

2,2857. $\delta_m < 0{,}08$m

The performance calculation results of the building's ultimate serviceability limits in the X and Y directions are then presented in Figures 9 and 10.

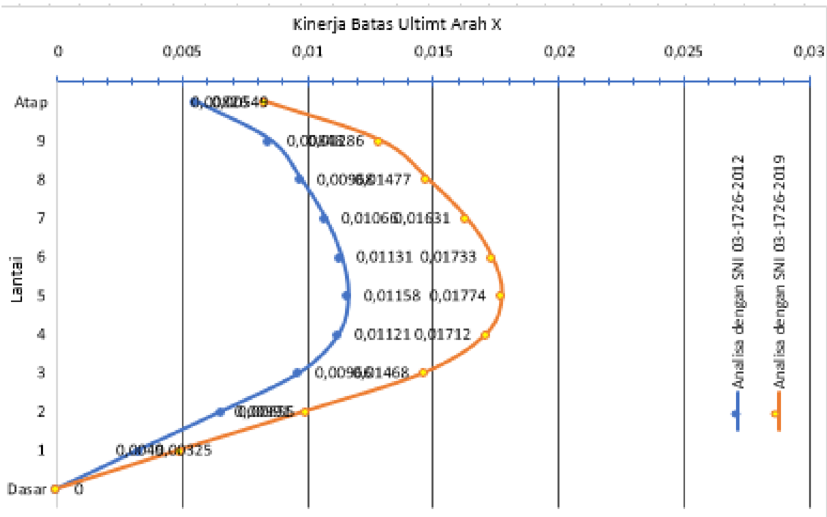

Figure 9. Ultimate limit performance of the building in the X direction

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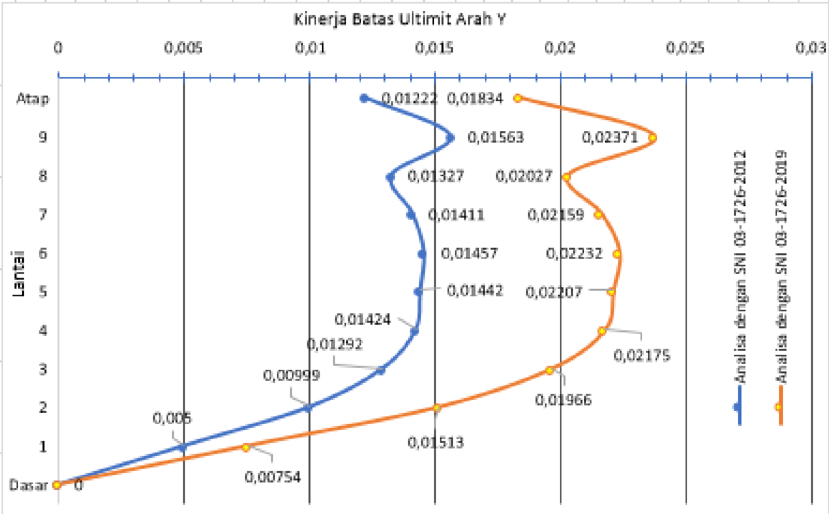

Figure 10. Ultimate limit performance of the building in the Y direction

CONCLUSION

Based on the results of the earthquake analysis of various spectra on the structures of the buildings analyzed, several conclusions can be drawn as follows. The structure's resistance to combined earthquake loads is by SNI 1726: 2012 regulations with a maximum value of the structure's horizontal deviation in the maximum value of the horizontal deviation of the structure in the 04 m, which has a maximum value of 0.0225m and a minimum value of 0.0063m so it can be declared to meet the requirements. The deviation value between levels using SNI 03-1726-2012 regulations in the Y direction cannot exceed 0.04 m, which has a maximum value of 0.0304 m and a minimum value of 0.0097m so that it can be declared to meet the requirements. The serviceability limit performance value using SNI 03-1726-2012 regulations in the X direction cannot exceed 0.02 m, which has a maximum value of 0.0068m and a minimum value of 0.0019m so it can be declared to meet the requirements. The serviceability limit performance value using SNI 03-1726-2012 regulations in the Y direction cannot exceed 0.02m, which has a maximum value of 0.0091m and a minimum value of 0.0029m so that it can be declared to meet the requirements. The ultimate limit performance value using SNI 03-1726-2012 regulations in the X direction cannot exceed 0.08m, which has a maximum value of 0.01158m and a minimum value of 0.00325m so it can be declared to meet the requirements. The ultimate limit performance value with a shear wall in the Y direction cannot exceed 0.08 m, which has a maximum value of 0.01563m and a minimum value of 0.00500 m so that it can be declared to meet the requirements. The effectiveness of building structure resilience using SNI 03-1726-2019 regulations shows that. The deviation between levels due to the X-direction earthquake after using the SNI 03-1726-2019 regulations increased by an average of 18.534%. The deviation between levels due to the Y-direction earthquake after using the SNI 03-1726-2019 regulations increased by an average of 18.479%. The serviceability limit deviation due to the X-direction earthquake after using the SNI 03-1726-2019 regulations increased by an average of 44.54%. The serviceable limit deviation due to the Y direction earthquake after using the SNI 03-1726-2019 regulations increased by an average of 44.56%. The ultimate limit deviation due to directional earthquakes after using SNI 03-1726-2019 regulations increased by an average of 31.13%. The ultimate limit deviation due to an earthquake in the Y direction after using the SNI 03-1726-2019 regulations increased by an average of 31.13%. From the results of the comparison above, it can be concluded that the use of SNI 03-1726-2019 in the structure of the JIH Solo Hospital building has a greater difference in planned earthquakes than SNI 03-1726-2012. The use of SNI 03-1726-2012 in building structures has better security performance when compared to analysis with SNI 03-1726-2019. Building structures built before the implementation of SNI 03-1726-2019 need attention because there are quite significant differences in terms of structural service limits.

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