Analysis of Static Earthquake Loading Calculations Equivalent with Dynamic Earthquake Calculations (Spectrum Response) Based on Earthquake SNI 1726:2012 in Rising Buildings

[1]Dedi Budi Setiawan
Civil Engineering Department, Semarang State Polytechnic, Indonesia

Abstract:- This research was conducted to determine the extent of the internal forces that occur in a four-storey office building in the Semarang area with equivalent static earthquake loading calculations compared to dynamic earthquake calculations (response spectrum). This is important for students and the construction industry to know in order to apply it in designing earthquake-resistant buildings, especially in the city of Semarang. Some of the problems that will be discussed in this study are as follows: How to calculate the parameter response of a building structure with static equivalent analysis? How to calculate the parameter response of a structure building with response spectrum analysis? What is the accuracy of the static equivalent analysis of the response spectrum analysis from the comparison of the response parameters of the structure of a four- storey office building in the city of Semarang. The limitation of the problem in this study is devoted to the Calculation Analysis ofEquivalent Static Earthquake Loading with Calculation of Dynamic Earthquake Response Spectrum Based on SNI 1726:2012 Earthquake on Buildings Four-storey office building in Semarang City. The purpose of this study was to compare the response parameters of the four-storey office building structure which were analyzed by static equivalent and response spectrum analysis. So that from the analysis it will be obtained the accuracy of the static equivalent analysis of the dynamic analysis of the response spectrum in calculating the response parameters of the structure of a four-storey office building in the city of Semarang. The response parameters of the structure to be compared are beam and column reinforcement, and displacement at the top of the building. Based on the discussion of the research results, the following conclusions can be drawn, Column reinforcement in dynamic and static designs has a ratio of 0.00%, meaning that the reinforcement gets the same results. The shear reinforcement is smaller in the dynamic design by 29.69%. The beam reinforcement for the top reinforcement in the dynamic design is smaller by 18.59%, for the bottom reinforcement it is 10.74% smaller, for the shear reinforcement it is smaller by 16.49%. As for reinforcement, the torsion of the side beams and the torsion of the stirrups are smaller, respectively 4.37% and 12.28%. The difference in deformation is 17.21 mm. The difference ratio on the dynamic design is smaller at 35.29%.

Keywords: *Equivalent Static Analysis, Dynamic Analysis, ResponseSpectrum, SNI 1726: 2012 (SNI Gempa 2012)*

I. INTRODUCTION

An earthquake is a sudden vibration of the ground originating from a wave in a place and spreading from one area to all directions. Each region has different characteristics of earthquakes, because each region has a different shape and type of area. Indonesia is located in an earthquake-prone area, because Indonesia is an archipelagic country which is located at the confluence of four tectonic plates, namely the Asian continental plate, the Australian continental plate, the Indian oceanic plate and the Pacific oceanic plate, therefore in the process of planning a multi-storey building structure requires calculation of an earthquake load. One of the most influential factors in the process of planning a high-rise building structure is the strength of the building structure, such as columns, beams and floor plates. Research on the main structure of this 4-storey office building aims to determine the behavior of the structure in response to a static earthquake load and a dynamicearthquake load.

Indonesia is an archipelagic country located at the confluence of three main tectonic plates, namely the Indian-Australian tectonic plate, the Pacific plate, and the Eurasian plate. The meeting of these three plates causes Indonesia to be seismically active, so the level of risk of an earthquake occurring is very high. With the very high risk of an earthquake occurring in the territory of Indonesia, there is also a very high risk of buildings experiencing structural damage, both due to poor planning and implementation or even not being designed for earthquake resistance at all.

In general, according to UBC 1997 a building is said to be an earthquake resistant building if it meets the following criteria (Badan Standardisasi Nasional, 2010):

- The structure that is planned must have sufficient lateral stiffness to be able to maintain the elastic condition when receiving a small earthquake load.
- The structure that is planned must be able to withstand moderate earthquake loads without causing damage to

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the structural elements. Damage to non-structural elements is allowed to occur. The planned structure is allowed to experience damage to its structural elements when receiving a large earthquake load. But the overall structure is not allowed to collapse.

In general, structural analysis of earthquake loads consists of 2 types, namely:

- Equivalent static load analysis is a method of structural analysis in which the effect of an earthquake on a structure is considered as a horizontal static load which is obtained by taking into account only the first vibrational response, and usually this force distribution is simplified as an inverted triangle.

- Dynamic analysis is structural analysis in which the distribution of earthquake shear forces across all stories is obtained by taking into account the dynamic effects of ground motion on the structure. Dynamic analysis is divided into 2 types, namely:

✓ Analysis of the range of response spectrum where the total response is obtained through the superposition of the response of each vibration mode.
✓ Time history analysis is a dynamic analysis in which the structural model is given a record of earthquake records and the response of the structure is calculated step by step at certain intervals.

Dynamic analysis for the design of earthquake resistant structures is carried out if a more accurate evaluation of the earthquake forces acting on the structure is required, as well as to determine the behavior of the structure due to the influence of the earthquake. Dynamic analysis is carried out in the design of high-rise building structures or structures with irregular shapes or configurations. Dynamic analysis can be done by means of elastic or inelastic. In the elastic method, it is divided into Time History Modal Analysis, where in this method it is necessary to record earthquake acceleration and Response Spectrum Modal Analysis, where in this method the maximum response of each vibration variation that occurs is obtained from Plan Response Spectra (Design Spectra). Elastic dynamic analysis is used to obtain structural response due to the influence of a very strong earthquake by means of direct integration (Direct Integration Method). Dynamic-class analysis is used more often because it is simpler. Dynamic analysis aims to determine the distribution of story shear forces due to ground motion by earthquakes and can be done by means of a variety of response spectrum analysis. The division of the story shear force is to replace the distribution of the base shear load due to the earthquake along the height of the building in the equivalent static load analysis.

The main difference between the static and dynamic concepts is in the building characteristics that are taken into account in the analysis. The dynamic concept takes into account mass, stiffness and damping, while the static concept only takes into account mass. In addition, the principle of static equivalent only takes mode 1 into account, so it is only suitable for buildings that tend to be stiff or low buildings (Widodo, 2001).

This research was conducted to determine the extent to which internal forces occur in four-storey office buildings in the Semarang area with equivalent static earthquake loading calculations compared to dynamic earthquake calculations (response spectrum). This is important for students and the construction industry to know in order to apply it in designing earthquake-resistant buildings, especially in the city of Semarang. Some of the problems that will be discussed in this study are How to calculate the parameter response of building structures with static equivalent analysis? How to calculate the parameter response of a building structure with response spectrum analysis?

➢ *Research Purposes*

The purpose of this study was to analyze the response parameters of the four-storey office building structure which were analyzed by static equivalent and response spectrum analysis. So that from the analysis the accuracy of the static equivalent analysis of the dynamic response spectrum analysis will be obtained in calculating the response parameters of the structure of a four-storey office building in the city of Semarang. The response parameters of the structure to be compared are beam and column reinforcement, anddisplacement at the top of the building.

II. LITERATURE REVIEW

A. Equivalent Static Analysis Based on SNI-1726-2012

Equivalent static analysis is a method of analyzing building structures against earthquake loading using equivalent static nominal earthquake loads.

Equivalent static analysis is divided into:

➢ *Seismic Base Shear the Seismic Base Shear, V in the Specified Direction must Conform to the following Equation:*

$$V = Cs.\ W$$

➢ *Calculation of the Seismic Response Coefficient the Seismic Response Coefficient, Cs, must be Determined by the following Equation:*

$$Cs = \frac{S_{DS}}{\frac{R}{I_e}}$$

- *Note:*

✓ SDS = design response spectrum acceleration parameter in the short period range,
✓ R = response modification factor,
✓ Ie = seismic factor The calculated Cs value is appropriate, it does not need to exceed the following:

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$$C_s = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)}$$

Vertical Distribution of Seismic Forces the Lateral Seismic Forces (Fx) (Kn) Occurring at all Stories must be Determined from the following Equation:

$$FX = CV\ V \text{and}$$

$$C_{VX} = \frac{w_x \cdot h_x^k}{\sum_{i=1}^{n} w_i \cdot h_i^k}$$

- *Note:*

- ✓ C_{vx} = vertical distribution factor,
- ✓ V = total design lateral force or shear at the base of the structure, expressed in kilonewtons (kN),
- ✓ wi and wx = part of the structure's total effective seismic weight (w) placed or imposed on level i orx,
- ✓ hi and hx = height from the base to level i or x, expressed in meters (m).
- ✓ For k= the exponent associated with the period of the structure as follows: for structures that have a period of 0.5 seconds or less,
- ✓ k=1 for structures that has a period of 2.5 or more,
- ✓ k = 2 for structures that have a period between 0.5 and 2.5 seconds,
- ✓ k must be 2 or determined by linear interpolation between 1 and 2.

Horizontal Distribution of Seismic Forces:

The earthquake design level shear at all levels (V_X) (kN) must be determined from the following equation:

$$V_x = \sum_{i=x}^{n} F_i$$

Note: F_i = part of the seismic base shear (V) that occurs at level i, expressed in kilonewtons (kN).

B. Spectrum Response Dynamic Analysis

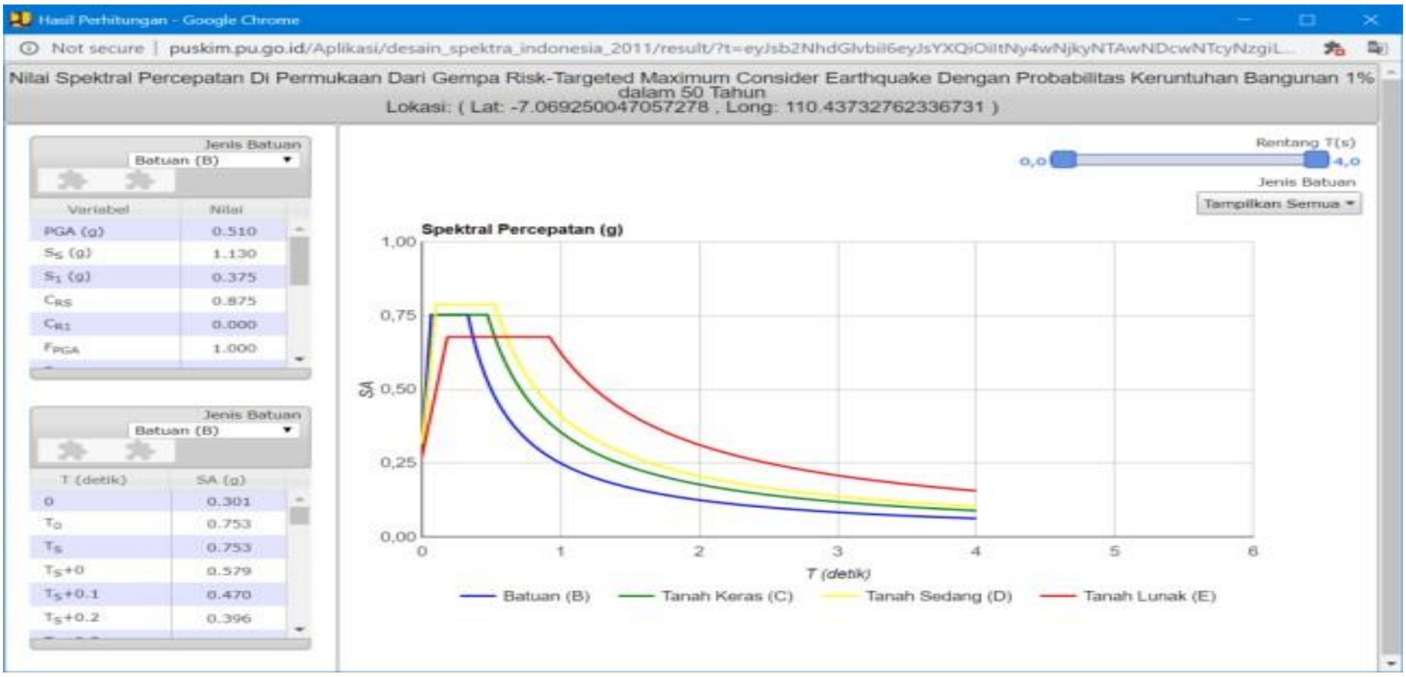

Fig 1 Response Spectrum of Semarang City(Lawangsewu)
Source: http://puskim.pu.go.id/Aplikasi/desain_ spektra _ indonesia_2011/

The response spectrum is a spectrum presented in the form of graphs/plots between the vibrational period of the structure T, against the maximum responses based on the damping ratio and certain earthquakes. Maximum responses can be either maximum displacement (spectral displacement, SD) maximum velocity (SV) or maximum acceleration (spectral acceleration, SA) of the mass of a single degree of freedom (SDOF) structure. The spectrum value is affected by the vibration period, damping ratio, ductility level, and soil type. Solving the equations that exist in SDOF and MDOF in this final project will be solved by the response spectrum method. This method does not include time history analysis, because only the maximum values are calculated.

This is possible because the response spectrum values (deviation, velocity, and acceleration) are the maximum values.

The accelerated design spectra for the 2012 SNI Earthquake were taken based on the Indonesian Spektra Design software (2013), which can be seen on the website http://puskim.pu.go.id/Aplikasi/desain_spektra_indonesia_2011/.

C. Earthquake Load

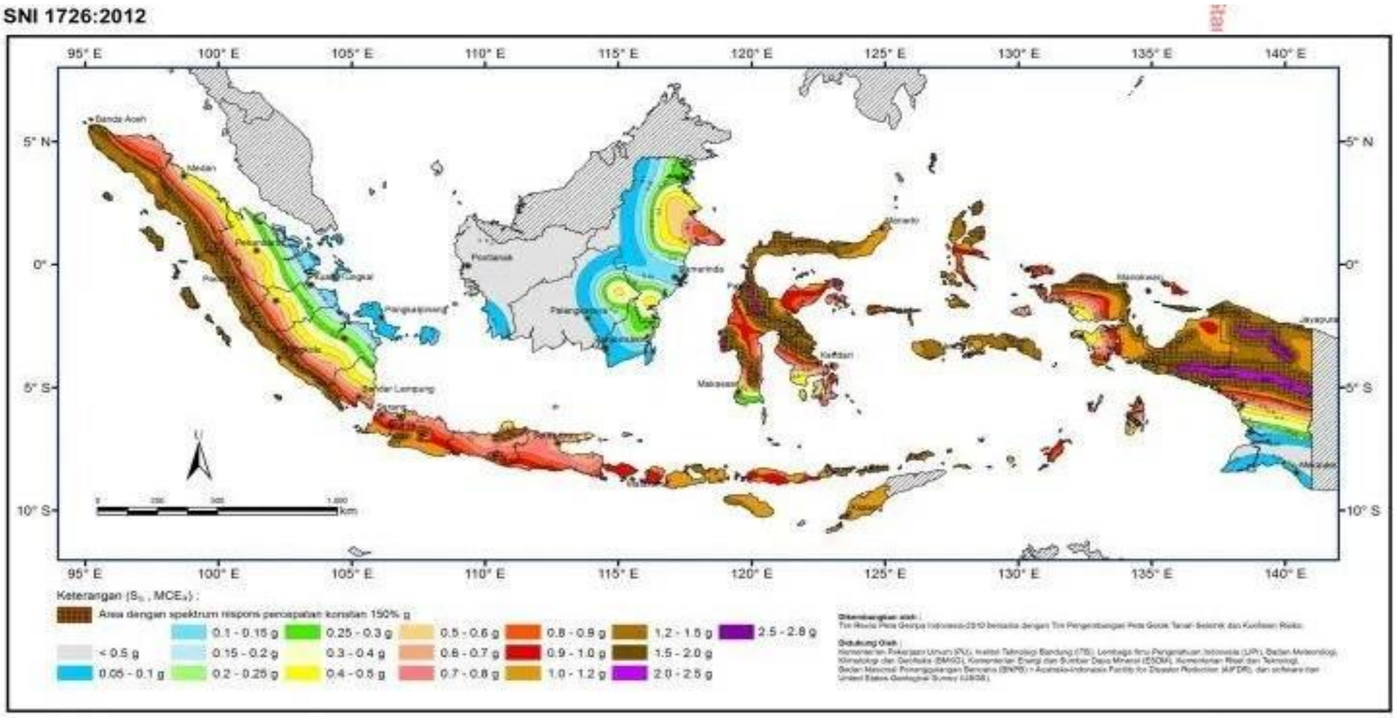

Fig 2 Earthquake Map of Indonesia SNI 2012 Earthquake loads are calculated based on the Earthquake

Resistance Planning Procedure for Buildings (SNI 03-17262012) with 2 methods, namely the equivalent static method, dynamic method with Spectrum Response Analysis. From the results of the analysis in these two ways, it will be seen how the structure behaves in response to a given load. In the analysis of structures against earthquake loads, the mass ofthe building determines the magnitude of the inertial force dueto the earthquake. In the modal analysis for determining the natural/fundamental vibration time of the structure, shape mode and dynamic analysis with Response Spectrum, the additional mass inputted into SAP 2000 includes mass due to additional dead loads and reduced live loads with a reduction factor of 0 ,5. In this case the mass due to the self weight of the structural elements (columns, beams and plates) has been calculated automatically because the self weight multiplierfactor in the Static Load Case for BS is = 1.

In the structural analysis of earthquake loads, floor slabs are considered to be very rigid diaphragms in their planes, so that each storey story is defined as a rigid diaphragm. The center of mass of the story floor which is the point of capture of the equivalent static earthquake load on each floor of the diaphragm.

D. SAP2000 Programs

SAP2000, Structural Analysis Program is a civil engineering application program that can perform static or dynamic structural analysis calculations and structural design in various types of buildings (generally buildings, bridges, towers and others). The main principles of using the SAP2000 program are structural modeling, analysis execution, and design inspection or optimization, all of which are carried out in one step or one view.

III. RESEARCH METHODS

➢ *Stages of Analysis*

This research method is modeling the structure using the SAP2000 program. The output results from the SAP2000 program for the structure of a four-floor office building were analyzed by static equivalent and dynamic response spectrum analysis. So that from the analysis the accuracy of the static equivalent analysis of the response spectrum analysis will be obtained in calculating the response parameters of the structure of a four-story office building in the city of Semarang. The response parameters of the structure to be compared are beam and column reinforcement, and displacement at the top of the building.

➢ *Flow Charts*

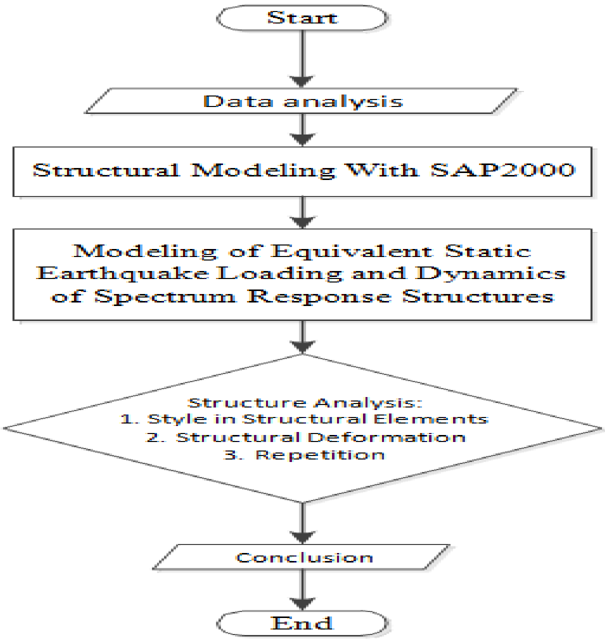

Fig 3 Flowchart Analysis of Calculation of Static Earthquake Loading Equivalent to Dynamic Earthquake Calculations (Spectrum Response) Based on Earthquake SNI1726:2012

According to the earthquake resistance planning procedures for building and non-building structures, SNI 1726:2012, the equivalent nominal static base shear load V occurring at the base level can be calculated by steps 1 to 4. Seismic base shear Seismic base shear, V in the direction set. Seismic response coefficient calculation Seismic response coefficient, Cs. Vertical distribution of seismic forces Lateral seismic forces (Fx) (kN) that occur at all levels. Horizontal distribution of seismic forces.

Calculation of dynamic earthquake load parameter Spectrum Response is carried out by determining the following things, Building Location, Building Height, Building Designation, Earthquake Load Parameters, Determination of Structural System, Structure Fundamental Period, Parameters of Earthquake Load Calculation Procedure "Equivalent Lateral Force" , Earthquake Load Calculation Parameters "Variety Response Spectrum" Procedure, Design Acceleration Response Spectrum Table (Sa) to Period (T) and Design Acceleration Response Spectrum Table for input in SAP.

IV. RESULTS AND DISCUSSION

➢ *Research Result*

A 4-storey office building located in the city of Semarang with soft soil conditions, will be planned with a concrete structure, planning system with SRPMK (Special Moment Resisting Frame System). with the following specifications:

- *Concrete*
- ✓ concrete compressive strength, fc' = 25 Mpa
- ✓ Modulus of elasticity of concrete, Ec = 4700√fc' = 23500Mpa
- ✓ concrete Poisson ratio, νc = 0,2
- ✓ specific gravity of concrete, λc = 24kN/m^3

- *Reinforcing steel*
- ✓ Longitudinal Reinforcement, BJ57 fy = 400 Mpa, fu = 570Mpa
- ✓ transverse reinforcement / stirrups, BJ39 fy = 240Mpa fu = 390Mpa
- ✓ Poisson ratio steel, νs = 0,3
- ✓ steel specific gravity, λs = 78,5kN/m^3

- *Structural Section*
- ✓ Floor Blocks 2 – 4 = B1 20 x 45cm
- ✓ Roof Beam = B2 20 x 35 cm
- ✓ Column (K1) = K1 45x45cm
- ✓ Column(K2) = K2 40x40cm
- ✓ Column (K3) = K3 35x35cm
- ✓ Floor plate = plate 12cm
- ✓ Roof Plate = plate 10cm

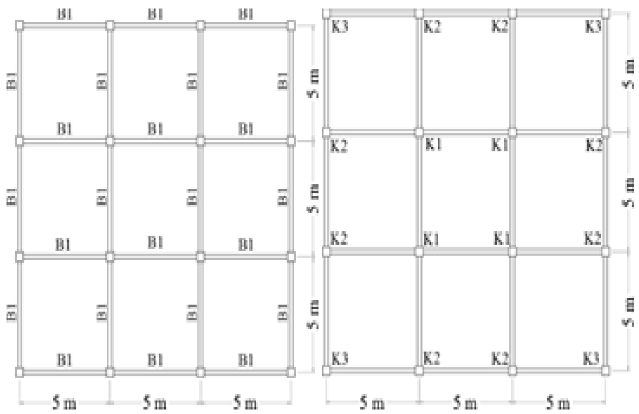

Fig 4 Detailed Plans for Beams LT.2 – 5 and Columns

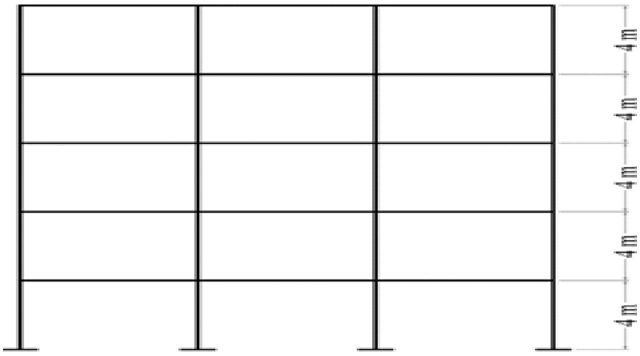

Fig 5 Modeling Plan for Office Building Structures

- ✓ The weight of waterproofing with 2 cm thick asphalt = 0.02 x 14 = 0.28 kN/m^2
- ✓ Ceiling and hanger loads = 0.2kN/m^2
- ✓ ME Installation Weight = 0.25 kN/m^2
- ✓ Total dead load on slab = 0.73 kN/m^2

- *Dead Load on Beam*

  The dead load acting on the beam includes:

  Masonry wall load ½ stone (3.5m-0.35)x 2.50 = 7.75kN/m The wall of this building is located on the edge beam around the building on 2nd floor to 4th floor.

- *Live Load*

  Live load is the load acting on the floor of the building depending on the function of the space used. The magnitude ofthe live load of the floor of the building according to the Planning Procedure.

Table 1 Live Load for Buildings

No.	Live Load Type	Burden	Unit
1	On the roof of the building	1	kN/m^2
2	Residential home	2	kN/m^2
3	Offices, schools, hotels, markets,hospitals	2,5	kN/m^2
4	Hall, stairs, corridor, balcony	3	kN/m^2
5	Sports halls, factories, cinemas,workshops, library, place of worship, parking, hall	4	kN/m^2
6	Audience stage	5	kN/m^2

Regulations and Planning Standards used SNI03-1726-2012 Earthquake Resistant Planning Regulations for Buildings, Procedures for Calculation of Concrete Structures for Buildings SNI03-2847-2013. Loading Planning Guidelines for Houses and Buildings PPPURG 1987.

Types of loads acting on buildings include: Dead loads of structural elements (Dead Load). Includes: beams, columns, shear walls, and plates. Dead load of additional elements (Super Dead Load) Includes: walls, ceramics, plaster, plumbing, ME (mechanical electrical), and others. Live Load: Includes: area load per m² which is reviewed based on the function of the building. Earthquake Load: Includes: equivalent static and dynamic earthquake loads (response spectrum).

- ➢ *Determining Load Distribution on the StructureDead Load on Floor Slabs*

  The dead load acting on the floor slab includes:

- Weight of sand 1 cm thick = 0.01 x 16 = 0.16 kN/m^2
- Species weight 3 cm thick = 0.03 x 22 = 0.66 kN/m^2
- Weight of ceramic 1 cm thick = 0.01 x 22 = 0.22 kN/m^2
- Weight of ceiling and hangers = 0.2kN/m^2
- ME Installation Weight = 0.25 kN/m^2
- Total dead load on slab = 1.49 kN/m^2

- *Dead Load on Roof Slab*

  The dead load acting on the floor slab includes:

Earthquake load analysis is carried out in 2 ways, namely static equivalent and dynamic response spectrum. In defining the earthquake load for the Semarang area, beforehand it could refer to the Procedures for Earthquake Resistant Planning for SNI 03-1726-2012 Buildings.

- *Equivalent Static Earthquake*

  The equivalent static earthquake load is a simplification of the actual earthquake load calculation, with the assumption that the subgrade is considered fixed (not vibrating), so that the earthquake load is equivalent to a static lateral load acting on the center of mass of the structure of each floor of the building. Equivalent static earthquake calculations can be performedautomatically with Auto Lateral Loads and manually by inputting the magnitude of the earthquake load to the center ofmass of the structure for each floor. An illustration of earthquake planning using the equivalent static method is shown in Figure 6 below.

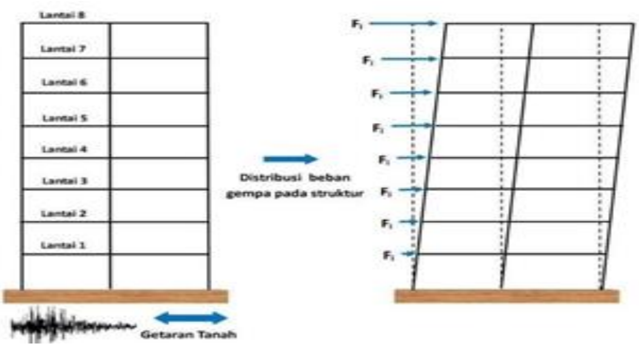

Fig 6 Illustration of Earthquake Analysis with Equivalent Static Method

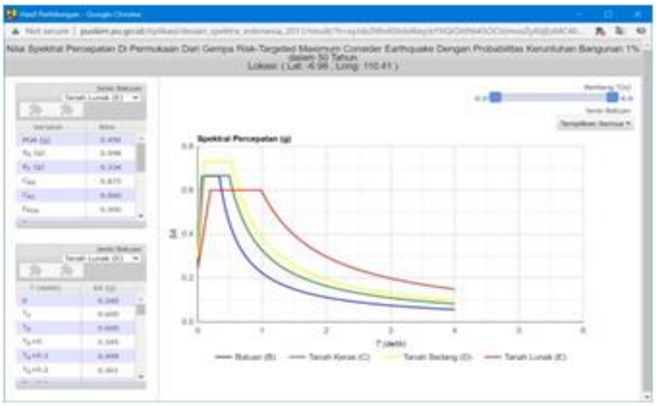

Fig 7 Ss and S1 values Information

- ✓ 0.2 Sec Spectral Accel,Ss = **0.998** (basestone acceleration of 0.2 seconds) (http://puskim.pu.go.id/Application/design_spektra _indonesia_ 2011/)
- ✓ 1 Sec Spectral Accel,S1 = **0.334** (bedrock acceleration period 1 second) (http://puskim.pu.go.id/Application/designspektra _ indonesia_ 2011/)
- ✓ Long-period Transition Period = **4** (long-term transition period)
- ✓ Site Class = **E** (site class)
- ✓ Response Modification, R = **8** (value of the SRPMK earthquake reduction factor)
- ✓ System Over strength, Omega = **3** (the value of thestrong factor is more)
- ✓ Deflection Amplification, Cd = **5.5** (deflection magnification factor value).

- *Earthquake Dynamic Response Spectrum*

The spectrum response is a spectrum presented in the form of graphs/plots between the vibrational period of the T structure, versus the maximum responses based on certain damping and earthquake ratios. The maximum responses can be the maximum displacement (spectral displacement, SD), maximum velocity (SV) or maximum acceleration (spectral acceleration, SA) of the structure's mass with a single degree offreedom (SDOF).

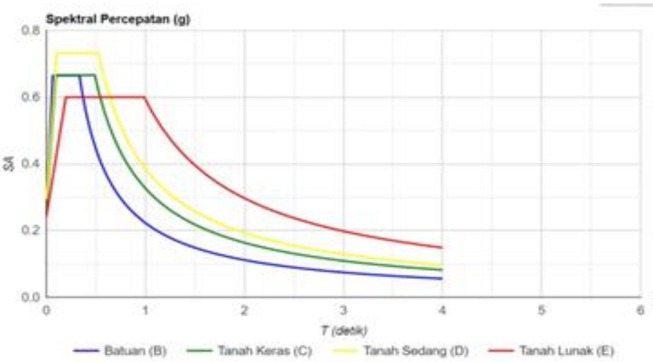

Fig 8 Spectrum Response Graph

➢ *Discussion*

Preparation of a schedule for periodic inspection activities as well as maintenance and care activities based on the time setby the author taking into account the conditions of the Gets Hotel Semarang Building and the Minister of Public Works Regulation Number 16/PRT/M/2010 concerning Technical Guidelines for Periodic Building Inspection of Buildings. The timeframe decision taken by the author considers several things, including:

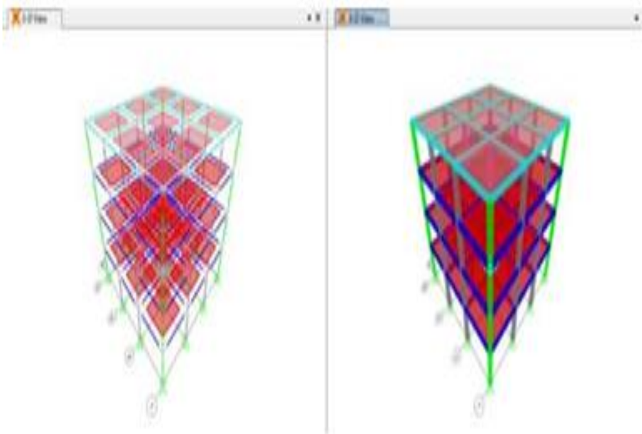

Fig 9 Earthquake Resistant Building Modeling

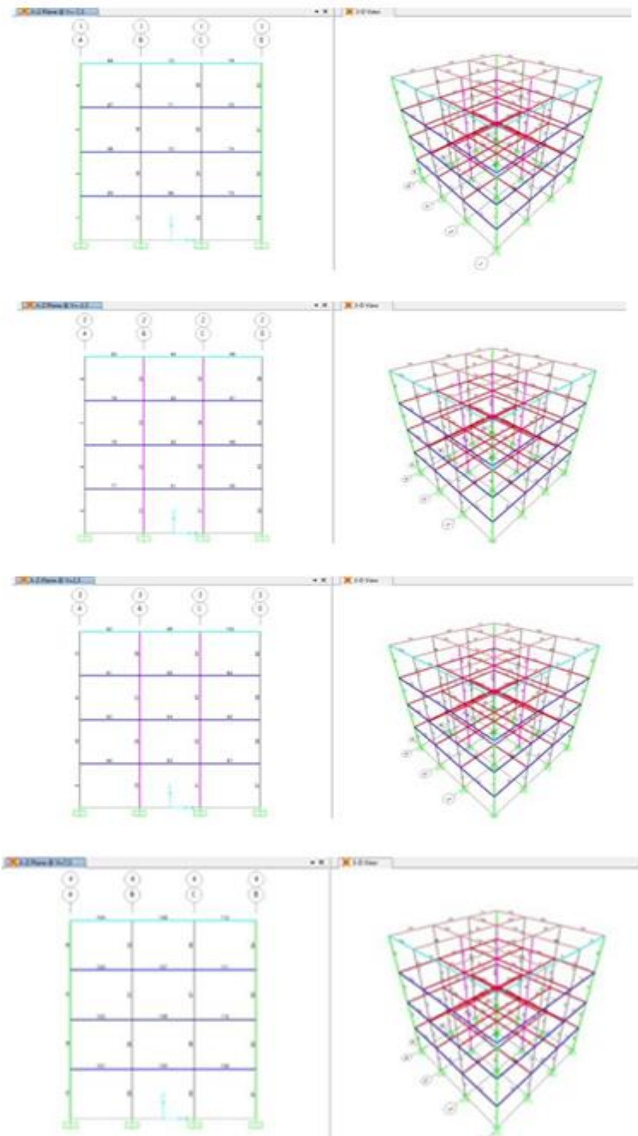

Fig 10 Numbering of Structural Elements

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From the results of calculations on the structure of a four- storey building using the static equivalent method compared to the calculation of dynamic structural analysis with response spectra on soft soils in the city of Semarang. The ratio for the main reinforcement in the column is 0% difference. This is because each analysis obtained a minimum reinforcement of 1%. So that the ratio obtained is 0%. If the column design is minimized, it is possible that you will not get a ratio of 0%.

For shear / stirrup reinforcement in the column ratio obtained is -29.69%. This means that the results of the dynamicdesign of stirrup reinforcement or shear are smaller on averageby 29.69%.

Table 2 Column Repetition Ratio

Frame	**Design Sect**	**Design Type**	**Ratio**	**Ratio**	**Ratio**
Text	Text	Text	**PMM Area**	**VMaj Rebar**	**VMin Rebar**
1	K3 35X35	Column	0,00%	0,00%	0,00%
2	K3 35X35	Column	0,00%	- 100,00%	- 100,00%
3	K3 35X35	Column	0,00%	- 100,00%	- 100,00%
4	K3 35X35	Column	0,00%	0,00%	0,00%
5	K2 40X40	Column	0,00%	0,00%	-100,00%
6	K2 40X40	Column	0,00%	0,00%	- 100,00%
7	K2 40X40	Column	0,00%	0,00%	0,00%
8	K2 40X40	Column	0,00%	0,00%	0,00%
9	K2 40X40	Column	0,00%	0,00%	0,00%
10	K2 40X40	Column	0,00%	-100,00%	-100,00%
11	K2 40X40	Column	0,00%	0,00%	0,00%
12	K2 40X40	Column	0,00%	0,00%	0,00%
13	K3 35X35	Column	0,00%	0,00%	0,00%
14	K3 35X35	Column	0,00%	-100,00%	-100,00%
15	K3 35X35	Column	0,00%	-100,00%	-100,00%
16	K3 35X35	Column	0,00%	0,00%	0,00%
17	K2 40X40	Column	0,00%	- 100,00%	0,00%
18	K2 40X40	Column	0,00%	-100,00%	0,00%
19	K2 40X40	Column	0,00%	0,00%	0,00%
20	K2 40X40	Column	0,00%	0,00%	0,00%
21	K1 45X45	Column	0,00%	0,00%	0,00%
22	K1 45X45	Column	0,00%	0,00%	0,00%
23	K1 45X45	Column	0,00%	0,00%	0,00%
24	K1 45X45	Column	0,00%	0,00%	0,00%
25	K1 45X45	Column	0,00%	-100,00%	0,00%
26	K1 45X45	Column	0,00%	0,00%	0,00%
27	K1 45X45	Column	0,00%	0,00%	0,00%
28	K1 45X45	Column	0,00%	0,00%	0,00%
29	K2 40X40	Column	0,00%	- 100,00%	0,00%
30	K2 40X40	Column	0,00%	-100,00%	0,00%
31	K2 40X40	Column	0,00%	0,00%	0,00%
32	K2 40X40	Column	0,00%	0,00%	0,00%
33	K2 40X40	Column	0,00%	0,00%	0,00%
34	K2 40X40	Column	0,00%	-100,00%	-100,00%
35	K2 40X40	Column	0,00%	0,00%	0,00%
36	K2 40X40	Column	0,00%	0,00%	0,00%
37	K1 45X45	Column	0,00%	0,00%	-100,00%
38	K1 45X45	Column	0,00%	0,00%	0,00%
39	K1 45X45	Column	0,00%	0,00%	0,00%
40	K1 45X45	Column	0,00%	0,00%	0,00%
41	K1 45X45	Column	0,00%	-100,00%	-100,00%
42	K1 45X45	Column	0,00%	0,00%	0,00%
43	K1 45X45	Column	0,00%	0,00%	0,00%
44	K1 45X45	Column	0,00%	0,00%	0,00%
45	K2 40X40	Column	0,00%	-100,00%	0,00%
46	K2 40X40	Column	0,00%	-100,00%	-100,00%
47	K2 40X40	Column	0,00%	0,00%	0,00%
48	K2 40X40	Column	0,00%	0,00%	0,00%

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49	K3 35X35	Column	0,00%	0,00%	0,00%
50	K3 35X35	Column	0,00%	-100,00%	-100,00%
51	K3 35X35	Column	0,00%	-100,00%	-100,00%
52	K3 35X35	Column	0,00%	0,00%	0,00%
53	K2 40X40	Column	0,00%	0,00%	-100,00%
54	K2 40X40	Column	0,00%	0,00%	-100,00%
55	K2 40X40	Column	0,00%	0,00%	0,00%
56	K2 40X40	Column	0,00%	0,00%	0,00%
57	K2 40X40	Column	0,00%	0,00%	-100,00%
58	K2 40X40	Column	0,00%	-100,00%	-100,00%
59	K2 40X40	Column	0,00%	0,00%	0,00%
60	K2 40X40	Column	0,00%	0,00%	0,00%
61	K3 35X35	Column	0,00%	0,00%	0,00%
62	K3 35X35	Column	0,00%	-100,00%	-100,00%
63	K3 35X35	Column	0,00%	-100,00%	-100,00%
64	K3 35X35	Column	0,00%	0,00%	0,00%
			0,00%	**-29,69%**	**-29,69%**

In static and dynamic design beam reinforcement, the ratio for the top main reinforcement is -18.59%. This means that the dynamic reinforcement is less on average by 18.59% than the reinforcement in the static design. The reinforcement at the bottom of the beam in the dynamic design is smaller on average by 10.74% compared to the static design.

For shear reinforcement in the dynamic design it is also smaller on average by 16.49% compared to the static design. The torsional reinforcement at the edge of the beam for dynamic design is 4.37% smaller than the static design. Also for the stirrup design the stirrups are smaller by 12.28%.

Table 3 Beam Reinforcement Ratio

Frame	**Design Sect**	**Design Type**	**Ratio**	**Ratio**	**Ratio**	**Ratio**	**Ratio**
Text	Text	Text	**FTop Area**	**FBot Area**	**VRebar**	**TLng Area**	**TTrn Rebar**
65	B1 20x45	Beam	-20,94%	-4,64%	-16,12%	0,00%	-21,54%
66	B1 20x45	Beam	-20,91%	-4,57%	-15,33%	0,00%	-21,26%
67	B1 20x45	Beam	-18,01%	-17,62%	0,00%	0,00%	-18,46%
68	B2 20x35	Beam	-6,89%	-15,73%	-100,00%	0,00%	-13,24%
69	B1 20x45	Beam	-19,79%	0,00%	-6,99%	0,00%	-23,80%
70	B1 20x45	Beam	-20,36%	-1,05%	-2,71%	0,00%	-23,91%
71	B1 20x45	Beam	-17,28%	-16,56%	0,00%	0,00%	-21,11%
72	B2 20x35	Beam	-3,18%	-16,87%	-100,00%	-5,02%	-14,29%
73	B1 20x45	Beam	-18,91%	-1,07%	-24,42%	0,00%	-23,25%
74	B1 20x45	Beam	-19,49%	0,00%	-19,14%	0,00%	-23,16%
75	B1 20x45	Beam	-16,28%	-9,99%	0,00%	0,00%	-19,87%
76	B2 20x35	Beam	-10,17%	-15,52%	-100,00%	0,00%	-13,94%
77	B1 20x45	Beam	-22,44%	-6,90%	-34,48%	5,64%	-30,89%
78	B1 20x45	Beam	-22,39%	-5,37%	-34,89%	4,58%	-32,40%
79	B1 20x45	Beam	-18,94%	-7,65%	-15,53%	-100,00%	-100,00%
79	B1 20x45	Beam	-18,69%	-4,13%	-0,28%	-100,00%	-100,00%
80	B2 20x35	Beam	-13,06%	-5,78%	0,00%	0,00%	0,00%
81	B1 20x45	Beam	-22,67%	-4,64%	-68,34%	8,50%	-32,22%
82	B1 20x45	Beam	-23,16%	-1,84%	-67,89%	7,37%	-33,72%
83	B1 20x45	Beam	-19,99%	-13,07%	0,00%	-100,00%	-100,00%
84	B2 20x35	Beam	-14,00%	-10,35%	0,00%	0,00%	0,00%
85	B1 20x45	Beam	-21,48%	-12,07%	-37,86%	8,00%	-32,62%
86	B1 20x45	Beam	-21,95%	-8,82%	-37,67%	7,54%	-33,83%
87	B1 20x45	Beam	-18,64%	-4,13%	0,00%	-100,00%	-100,00%
88	B2 20x35	Beam	-12,71%	0,00%	0,00%	0,00%	0,00%
89	B1 20x45	Beam	-23,15%	-7,71%	-35,38%	5,58%	-30,89%
90	B1 20x45	Beam	-23,05%	-6,15%	-35,71%	4,53%	-32,40%
91	B1 20x45	Beam	-19,48%	-7,65%	-16,51%	-100,00%	-100,00%

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92	B2 20x35	Beam	-13,43%	-5,78%	0,00%	0,00%	0,00%
93	B1 20x45	Beam	-23,38%	-5,48%	-68,48%	8,47%	-32,47%
94	B1 20x45	Beam	-23,83%	-2,67%	-68,00%	7,35%	-33,72%
95	B1 20x45	Beam	-20,55%	-13,07%	0,00%	-100,00%	-100,00%
96	B2 20x35	Beam	-14,39%	-10,35%	0,00%	0,00%	0,00%
97	B1 20x45	Beam	-22,17%	-12,80%	-38,76%	8,03%	-32,62%
98	B1 20x45	Beam	-22,59%	-9,54%	-38,53%	7,56%	-33,83%
99	B1 20x45	Beam	-19,17%	-4,13%	-1,64%	-100,00%	-100,00%
100	B2 20x35	Beam	-13,08%	0,00%	0,00%	0,00%	0,00%
101	B1 20x45	Beam	-23,09%	-4,64%	-19,87%	0,00%	-21,12%
102	B1 20x45	Beam	-22,91%	-4,57%	-18,96%	0,00%	-20,84%
103	B1 20x45	Beam	-19,66%	-19,23%	0,00%	0,00%	-18,18%
104	B2 20x35	Beam	-8,48%	-17,14%	-100,00%	0,00%	-12,94%
105	B1 20x45	Beam	-21,81%	0,00%	-11,58%	0,00%	-23,80%
106	B1 20x45	Beam	-22,28%	-1,05%	-7,24%	0,00%	-23,91%
107	B1 20x45	Beam	-18,85%	-16,56%	0,00%	0,00%	-21,11%
108	B2 20x35	Beam	-4,92%	-18,33%	-100,00%	-5,01%	-14,29%
109	B1 20x45	Beam	-20,81%	-3,31%	-27,33%	0,00%	-23,44%
110	B1 20x45	Beam	-21,30%	-0,13%	-22,29%	0,00%	-23,54%
111	B1 20x45	Beam	-17,75%	-9,99%	0,00%	0,00%	-20,38%
112	B2 20x35	Beam	-11,60%	-16,83%	-100,00%	0,00%	-14,24%
113	B1 20x45	Beam	-20,94%	-4,64%	-16,12%	0,00%	-21,54%
114	B1 20x45	Beam	-20,91%	-4,57%	-15,33%	0,00%	-21,26%
115	B1 20x45	Beam	-18,01%	-17,62%	0,00%	0,00%	-18,46%
116	B2 20x35	Beam	-6,89%	-15,73%	-100,00%	0,00%	-13,24%
117	B1 20x45	Beam	-19,79%	0,00%	-6,99%	0,00%	-23,80%
118	B1 20x45	Beam	-20,36%	-1,05%	-2,71%	0,00%	-23,91%
119	B120x45	Beam	-17,28%	-16,56%	0,00%	0,00%	-21,11%
120	B2 20x35	Beam	-3,18%	-16,87%	-100,00%	-5,02%	-14,29%
121	B1 20x45	Beam	-18,91%	-1,07%	-24,42%	0,00%	-23,25%
122	B1 20x45	Beam	-19,49%	0,00%	-19,14%	0,00%	-23,16%
123	B1 20x45	Beam	-16,28%	-9,99%	0,00%	0,00%	-19,87%
124	B2 20x35	Beam	-10,17%	-15,52%	-100,00%	0,00%	-13,94%
125	B1 20x45	Beam	-22,44%	-6,90%	-34,48%	5,64%	-30,89%
126	B1 20x45	Beam	-22,39%	-5,37%	-34,89%	4,58%	-32,40%
127	B1 20x45	Beam	-18,94%	-7,65%	-15,53%	-100,00%	-100,00%
128	B2 20x35	Beam	-13,06%	-5,78%	0,00%	0,00%	0,00%
129	B1 20x45	Beam	-22,67%	-4,64%	-68,34%	8,50%	-32,22%
130	B1 20x45	Beam	-23,16%	-1,84%	-67,89%	7,37%	-33,72%
131	B1 20x45	Beam	-19,99%	-13,07%	0,00%	-100,00%	-100,00%
132	B2 20x35	Beam	-14,00%	-10,35%	0,00%	0,00%	0,00%
133	B1 20x45	Beam	-21,48%	-12,07%	-37,86%	8,00%	-32,62%
134	B1 20x45	Beam	-21,95%	-8,82%	-37,67%	7,54%	-33,83%
135	B1 20x45	Beam	-18,64%	-4,13%	0,00%	-100,00%	-100,00%
136	B2 20x35	Beam	-12,71%	0,00%	0,00%	0,00%	0,00%
137	B1 20x45	Beam	-23,15%	-7,71%	-35,38%	5,58%	-30,89%
138	B1 20x45	Beam	-23,05%	-6,15%	-35,71%	4,53%	-32,40%
139	B1 20x45	Beam	-19,48%	-7,65%	-16,51%	-100,00%	-100,00%
140	B2 20x35	Beam	-13,43%	-5,78%	0,00%	0,00%	0,00%
141	B1 20x45	Beam	-23,38%	-5,48%	-68,48%	8,47%	-32,47%
142	B1 20x45	Beam	-23,83%	-2,67%	-68,00%	7,35%	-33,72%
143	B1 20x45	Beam	-20,55%	-13,07%	0,00%	-100,00%	-100,00%
144	B2 20x35	Beam	-14,39%	-10,35%	0,00%	0,00%	0,00%
145	B1 20x45	Beam	-22,17%	-12,80%	-38,76%	8,03%	-32,62%
146	B1 20x45	Beam	-22,59%	-9,54%	-38,53%	7,56%	-33,83%

147	B1 20x45	Beam	-19,17%	-4,13%	-1,64%	-100,00%	-100,00%
148	B2 20x35	Beam	-13,08%	0,00%	0,00%	0,00%	0,00%
149	B1 20x45	Beam	-23,09%	-4,64%	-19,87%	0,00%	-21,12%
150	B1 20x45	Beam	-22,91%	-4,57%	-18,96%	0,00%	-20,84%
151	B1 20x45	Beam	-19,66%	-19,23%	0,00%	0,00%	-18,18%
152	B2 20x35	Beam	-8,48%	-17,14%	-100,00%	0,00%	-12,94%
153	B1 20x45	Beam	-21,81%	0,00%	-11,58%	0,00%	-23,80%
154	B1 20x45	Beam	-22,84%	-1,05%	-8,65%	0,00%	-23,91%
155	B1 20x45	Beam	-18,85%	-16,56%	0,00%	0,00%	-21,11%
156	B2 20x35	Beam	-4,92%	-18,33%	-100,00%	-5,01%	-14,29%
157	B1 20x45	Beam	-20,81%	-3,31%	-27,33%	0,00%	-23,44%
158	B1 20x45	Beam	-21,30%	-0,13%	-22,29%	0,00%	-23,54%
159	B1 20x45	Beam	-17,75%	-9,99%	0,00%	0,00%	-20,38%
160	B2 20x35	Beam	-11,60%	-16,83%	-100,00%	0,00%	-14,24%
			-18,59%	**-10,74%**	**-16,49%**	**-4,37%**	**-12,28%**

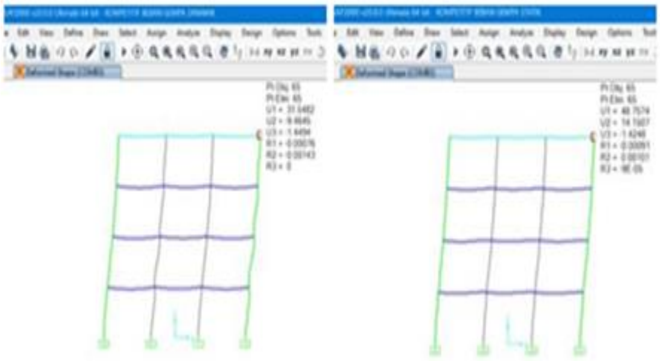

Fig 11 Static and Dynamic Design Deformation

Figure 11 explains that the deformation that occurs in a static design is greater than in a dynamic design, so it can be concluded that the reinforcement requirements in a static design are greater than in a dynamic design. The difference in deformation is 17.21 mm. The difference ratio in the dynamic design is smaller at 35.29%.

V. CONCLUSION

Based on the discussion of the research results, the following conclusions can be drawn:

Column reinforcement in the dynamic and static design hasa ratio of 0.00%, meaning that the reinforcement gets the same result. The shear reinforcement is smaller in the dynamic design by 29.69%. The beam reinforcement for the top reinforcement in the dynamic design is smaller by 18.59%. for the bottom reinforcement it is smaller by 10.74%, for the shearreinforcement it is smaller by 16.49%. As for the reinforcement, the torsion of the side beams and the torsion of the stirrups are smaller, respectively, by 4.37% and 12.28%. The difference in deformation is 17.21 mm. The difference ratio in the dynamic design is smaller at 35.29%.

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