FINAL PROJECT

STATIC EQUIVALENT VS. RESPONSE SPECTRUM METHODS: A COMPARATIVE STUDY FOR SEISMIC ANALYSIS OF AN RC EDUCATIONAL BUILDING IN YOGYAKARTA

Submitted to Universitas Islam Indonesia Yogyakarta in Fulfillment of the Bachelor's Degree of Civil Engineering



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CIVIL ENGINEERING UNDERGRADUATE PROGRAM
FACULTY OF CIVIL ENGINEERING & PLANNING
UNIVERSITAS ISLAM INDONESIA
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VALIDITY SHEET

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AUTHENTICITY STATEMENT

I hereby state that the Final Project report I made as a requirement for completing the Bachelor's degree in the Civil Engineering Study Program of the Faculty of Civil Engineering and Planning at Universitas Islam Indonesia is an original work I carried out. Separate components of the Final Project report that I took from others have been articulated in the source in a manner that aligns with the general norms, regulations, and ethical considerations applicable to the writing of scientific documents. Suppose it is found in the future that any part of this Final Project report is not my original work, or that there is plagiarism in some sections. In that case, according to applicable legal provisions, I am ready to accept disciplinary action, including cancellation of my academic degree.

Yogyakarta, July 2025

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FOREWORD

Alhamdulillahirabbil'alamin, all praise and gratitude are due to Allah SWT for His boundless blessings and mercy, which enabled the completion of this final project entitled "Static Equivalent vs. Response Spectrum Methods: A Comparative Study for Seismic Analysis of an RC Educational Building in Yogyakarta. This study marks a significant milestone in my undergraduate studies at the Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia Yogyakarta. Throughout this journey, I faced numerous challenges; however, with the unwavering support, guidance, and encouragement from many individuals, I persevered. In this regard, I extend my deepest gratitude to:

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ABSTRACT

This research compares the structural responses of a multi-story reinforced concrete building under the earthquake load using Static Equivalent Analysis (SEA) and Response Spectrum Analysis (RSA) based on SNI 1726:2019. This research aimed to determine the structural response of an eight-story reinforced concrete building when analyzing earthquake loads using Static Equivalent Analysis (SEA) and Response Spectrum Analysis (RSA). The analysis was conducted on an eight-story reinforced concrete building with one basement, used as an educational building in Yogyakarta. The building Structural responses in this research are base shear, story drift, and story shears. The structure was modeled as a special moment resisting frame system (SMRF) in ETABS 22 software. Results of this research showed that the maximum drift using the static equivalent analysis method was 37.053 mm in the x-direction of the third story, while for the same direction in the same story, using the response spectrum analysis method, the drift was 35.689 mm. Maximum drift using the response spectrum analysis method was 36.184 mm in the y-direction of the fourth story, while for the same direction in the same story, using the static equivalent analysis method, the drift was 35.779 mm. Results also showed that the base shear with both methods was almost the same, but the story shears were different in each story due to the difference in the distribution of the base shear along the building height with each method. Findings of this research concluded that the story drift using the static equivalent analysis method was higher than the story drift using the response Spectrum analysis method. Findings of this research also concluded that the distribution of the base shear along the building stories was different in each analysis method.

Keywords: Earthquake, Static Equivalent, Response Spectrum, Story Drift, Story Shear.

CHAPTER I
INTRODUCTION

1.1 Background

Earthquake engineering is one of the most important fields that combines different specializations for the safety of buildings and society. Earthquake engineering means understanding earthquakes, their causes, and how to deal with them to achieve the goal of civil engineering to build strong infrastructure that protects people. To understand this field, it is necessary to have extensive knowledge of the soil, rocks, and the area in which the construction will take place and its seismic history, then work on designing buildings that are resistant to the different types of earthquakes that can occur in them, in addition to developing safety methods in emergencies. Building strong and earthquake-resistant buildings is of utmost importance, as it is related to preserving lives, property, and society. It can also be learned from past lessons to improve construction in the future and reduce the risks of earthquakes. This is especially important in areas that have a lot of earthquakes.

Yogyakarta, where two big plates of earth, the Eurasian and Indo-Australian, meet, means a lot of earthquakes. The serious earthquake in 2006 reminded everyone how important it is to ensure that buildings can withstand earthquakes. According to the National Centers for Environmental Information, more than 5,749 people lost their lives due to this earthquake, over 38,000 individuals sustained injuries, with many suffering from severe trauma, more than 127,000 houses were destroyed, and an additional 451,000 were damaged, rendering them unsafe for habitation (BAPPENAS, 2006). Buildings in Yogyakarta are mostly made of reinforced concrete. This type of building is strong, lasts a long time, and does not cost too much. Looking at the benefits

of both the simple and the tricky ways to study earthquake forces could lead to better and safer buildings in this city, that have a lot of earthquake activity.

The location of the building used in this research is in Yogyakarta, because Yogyakarta is one of the areas in Indonesia that is prone to earthquakes. Designing earthquake-resistant buildings can strongly help the community bounce back after an earthquake. In earthquake science, calculating the forces from an earthquake is complicated. The Static Equivalent method is one method that is used to simplify these forces by analyzing them as though they come from one direction (Kakpure & Mundhada, 2017). This technique makes use of quantitative data regarding the location and material composition of the building to approximate these forces. It offers a faster calculation method, particularly for low-rise buildings, regular buildings, or even those with minor irregularities. However, this method fails to adequately represent the dynamic response characteristics, which are inherent to the actual behavior of structures during seismic events. The progress in advanced computational technology and analytics software has provided researchers with significant ability in the systematic evaluation of the impact on buildings brought about by seismic occurrences. The process makes simulation of seismic events possible, and consequently, there is a better understanding of the resulting responses demonstrated by buildings under the category called dynamic analysis.

Dynamic analysis involves the examination and prediction of structural responses under conditions involving dynamical loads. Dynamic analysis is based not only on empirical observation and gained knowledge but also heavily on logical thinking and the solution of complex mathematical problems (Ghosh et al, 2015). Among the various methods of dynamic analysis, response spectrum analysis stands out as one of the most critical techniques. It is defined as the graphical representation that combines the maximum values of acceleration, velocity, and displacement for single-degree-of-freedom systems in response to a specific ground motion, factoring in a designated damping ratio (Edward, L.W., 2002). This analytical method facilitates

the determination of maximum structural responses, which are essential for calculating lateral forces in the design of earthquake-resistant structures (Bagheriet et al, 2012).

This study is a comparative study focusing on static and dynamic analysis methods. The building used in this study was analyzed using both the static equivalent analysis method and the response spectrum analysis method. This study gives a clear comparison between these two methods of analysis and finds out the most suitable analysis method to be used in Yogyakarta. This research is important because it shows the effect of the analysis methods used. It is necessary to deeply study the analysis methods to know the most suitable methods to be used in an earthquake-prone city like Yogyakarta.

1.2 Problem Formulation

The formulation of problems mentioned in the background is as follows:

1. What are the building structure responses due to earthquake load using the static equivalent analysis method?
2. What are the building structure responses due to earthquake load using the spectrum response analysis method?
3. How does the building structure's response due to earthquake load compare with spectrum response analysis and static equivalent analysis methods?

1.3 Research Objectives

Based on the problem formulation above, the objectives of this research are:

1. To find the building structure responses due to earthquake load using the static equivalent analysis method.
2. To find the building structure responses due to earthquake load using the spectrum response analysis method.
3. To find the comparison of the building structure response due to earthquake load with spectrum response analysis and static equivalent analysis methods.

1.4 Research Benefits

The benefits of this research in architecture and civil engineering are as follows:

1. Giving civil engineers a clear comparison of static equivalent and response spectrum analysis methods, techniques, so they may select the best strategy for various building types.
2. Encouraging the creation of improved building regulations and standards that consider Yogyakarta's seismic conditions to increase the performance and safety of structures during earthquakes.
3. Offering information on flexible and affordable design options for reinforced concrete structures in earthquake-prone areas.
4. Helping to prevent fatalities, lessen financial losses, and lessen structural breakdowns during earthquake disasters.

1.5 Research Limitation

To focus on the research objectives, there are some research limitations for this research, as follows:

1. The research focuses on a reinforced concrete building in Yogyakarta with unique seismic properties because of its closeness to the meeting point of the Indo-Australian and Eurasian plates.
2. This research is limited to the static equivalent and response spectrum analysis methods of an eight-story including one basement reinforced concrete (RC) building with a height of 31.4 m.
3. Building responses in this research are base shear, story displacements, and story shears.
4. This study focuses on the upper structure only. Sloof and foundations are not included.
5. The quality of the concrete in this building is 25 MPa (Source: PDC Pola Data Consultant).

6. The quality of steel in this building is BJTS 40 (fy = 392 MPa, fu = 559 MPa) (Source: PDC Pola Data Consultant).
7. The building was modeled in a 3D open frame using ETABS.
8. Soil type is medium soil (SD) based on the value of Vs30 from USGS.
9. The building codes used in this research:
    a. SNI 1727-2020. Minimum load for the planning of buildings and other structures.
    b. SNI 1726-2019. Procedures for earthquake resistance planning for building and non-building structures.
    c. 2017 Indonesian Earthquake Source and Hazard Map.
    d. SNI 2847-2019. Structural concrete requirements for building.

CHAPTER II
LITERATURE REVIEW

2.1 Previous Research

Previous research related to the topic of this research is as follows:

1. Comparative Study of Internal Force between Dynamic Method and Equivalent Static Methods in Lecture Buildings in Yogyakarta Based on Earthquake Indonesian National Standard (SNI 1726-2019).

   The first research was conducted by Ernawati and Widodo (2021). It covered the subject entitled "Comparative Study of Internal Force between Dynamic Method and Equivalent Static Methods in Lecture Buildings in Yogyakarta Based on Earthquake Indonesian National Standard (SNI 1726-2019)." This research measures the structural effectiveness of a lecture building in Yogyakarta using two different seismic analysis methods, the dynamic response spectrum method and the equivalent static method.

   This research focuses on a building that was built according to the earlier SNI 1726-2012 standards and examines if it meets the seismic resistance requirements set under the new SNI 1726-2019. Its structural modeling uses the SAP2000 program, considering internal forces such as axial force, shear force, and the moment in the important parts of the structure. In addition, the research considers the parameters of the structure, the materials, as well as the seismic force according to the latest national standard.

   The results of this research showed that the internal forces obtained from the response spectrum analysis method are higher than the internal forces obtained

from the equivalent static analysis method. Based on these results, the lecture building does not fully meet SNI 1726-2019.

2. Comparative Study of Static and Response Spectrum Methods for Seismic Analysis of Regular RC Buildings.

   The second research was conducted by Ahmed Yousef Alghuff, Samir Mohammed Shihada, and Bassam A. Tayeh. (2019) titled "Comparative Study of Static and Response Spectrum Methods for Seismic Analysis of Regular RC Buildings." This research compares the discrepancies in seismic analysis using the static versus the dynamic method as applied to reinforced concrete (RC) buildings, and the research compares the conditions under which each method is optimal.

   The research examines two different structural models: a 75-meter-high high-rise structure and a 24-meter-high low-rise structure using ETABS analysis. Both structures are analyzed based on the requirements provided by ASCE7-10 and IBC 2015. The study compares seismic parameters like base shear, bending moment, and displacements using both the equivalent static and the response spectrum methods.

   The results show that for the high-rise building, shear forces from the response spectrum method are 35–60% lower in the X direction and 40–65% lower in the Y direction compared to the equivalent static method. For the low-rise building, the reductions are 25% and 22% in the X and Y directions, respectively. Similar reductions are observed for bending moments and displacements, with dynamic analysis yielding lower values than static analysis.

   These findings indicate that the response spectrum approach provides more efficient and accurate results, particularly for high-rise buildings. This study recommends static analysis when dealing with low-rise buildings because of its simplicity and efficiency in computation. On the other hand, dynamic analysis is preferred in high-rise buildings, since static methods tend to overestimate forces

and moments. The research emphasizes the necessity of selecting the right seismic analysis method, considering the structure's height as well as its characteristics.

3. Comparative Effectiveness of Equivalent Static Analysis & Response Spectrum Analysis in Extreme Seismic Zones.

   Faiz and Kumar (2023), "Comparative Effectiveness of Equivalent Static Analysis & Response Spectrum Analysis in Extreme Seismic Zones," explored the seismic responses displayed by reinforced concrete (RCC) buildings in locations with significant seismic activity. Two different analysis methods have been utilized here: Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA).

   This research includes three different structural layouts with different heights (5-story, 10-story, 15-story) with seismic zones II and V as per the requirements given in IS 1893-2016. Using the ETABS program, the research compares different parameters like the story's maximum displacement, peak drift ratio, base shear, maximum axial force in the columns, the maximum bend of the columns, and the fundamental period.

   Results of this research showed that ESA generally produces higher values for structural responses compared to RSA. In seismic zone IV, ESA results in 36% higher story displacement in the 15-story building, 38% higher in the 10-story building, and 34% higher in the 5-story building. Similar trends for drift ratio and base shear. The fundamental time period remains the same for both methods, but decreases by 9.5% when reducing the building height from 15 to 10 stories and by 29% from 10 to 5 stories. This research ensures that the Response Spectrum Analysis (RSA) provides more realistic results, especially for high-rise buildings in high-seismic areas, while the Equivalent Static Analysis (ESA) is suitable for low-rise structures. This research highlights the importance of selecting appropriate seismic analysis methods to ensure structural safety and cost-effectiveness in earthquake-prone areas.

4. Comparative Study of Static and Dynamic Analysis of Multistoried Buildings in Seismic Zone IV.

Rauniyar and Juneja (2024), "Comparative Study of Static and Dynamic Analysis of Multistoried Buildings in Seismic Zone IV" evaluated the seismic strength of reinforced concrete (RCC) buildings using two analysis methods, Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA). This research analyzed two building structures (G+10) building and (G+25) building using ETABS 2016, focusing on parameters such as story displacement, drift, stiffness, and support reactions under the seismic zone IV scenario.

This research shows that RSA consistently produced lower structural responses than ESA. For the G+25 building, Response Spectrum Analysis (RSA) reduced maximum story displacements by 34.82% in the X-direction and 35.01% in the Y-direction, while for G+10, reductions were 23.02% in the X-direction and 22.91% in the Y-direction. Story drift values from Response Spectrum Analysis (RSA) were up to 32.65% lower than Equivalent Static Analysis (ESA), particularly on higher floors. Static analysis overestimated bending moments at supports by 2.13% in the X-direction and 1.82% in the Y-direction for G+25, and 1.11% in the X-direction and 0.90% in the Y-direction for G+10. Stiffness variations reached 29.67% in the X-direction and 28.55% in the Y-direction in Response Spectrum Analysis (RSA) for taller structures. Economic assessments highlighted Response Spectrum Analysis for cost-effectiveness for high-rise buildings due to reduced material requirements.

The findings of this research show that RSA provides better predictions for multistory buildings in seismically risky areas to enhance the safety and efficiency of operations. Equivalent Static Analysis (ESA) is better for low-rise structures but might lead to overly conservative design strategies.

5. Comparative Study of Linear Static and Linear Dynamic Analysis of Multi-storey RCC Buildings using ETABS.

   Sonawane Dhanashree and Prof. A.R. Kambekar (2020) conducted research titled "Comparative Study of Linear Static and Linear Dynamic Analysis of Multi-storey RCC Buildings using ETABS," which discusses the seismic strength of reinforced

cement concrete (RCC) buildings through the utilization of two different analytical methods: linear static and linear dynamic techniques. The primary objective of this research is to compare and analyze the seismic response of G+5, G+10, and G+15 multi-story RCC frame buildings in seismic Zone V as per Indian standards. As buildings in urban regions are increasing in complexity in nature and height, it is essential to examine the applicability and limitations of different widely used seismic analysis methods. This research highlights the increasing importance of dynamic considerations in the seismic design of tall buildings and attempts to identify which method gives more accurate and safe results for varying building heights.

The authors created three RCC building models: 6-story, 11-story, and 16-story buildings, utilizing the ETABS program. All three models have identical plan dimensions, material characteristics, and load applications. Seismic analysis was conducted according to the Indian Standard IS 1893:2002, in addition to applying both the response spectrum method (linear dynamic analysis) and equivalent static method (linear static analysis). The performance parameters under consideration are lateral displacement, story drift, and base shear.

The findings indicate that linear static analysis will yield high base shear values, whereas linear dynamic analysis provides more realistic displacement and drift predictions, particularly for the case of high-rise buildings. The authors note that the dynamic method more effectively captures the effect of building height, mass distribution, and natural vibration modes and hence is a more precise approximation of true structural responses to seismic loading. Based on the comparative results, the authors conclude that linear dynamic analysis is more appropriate and more reliable for seismic analysis of high-rise RCC buildings. The response spectrum method provides a more realistic estimate of lateral displacements and inter-story drifts in buildings taller than ten stories. However, employing linear static analysis only can be conservative in the estimation of base shear, underestimate the deformation demands, and compromise the structure's

safety and performance. The research stresses the necessity to choose a suitable method of analysis depending on the building height and complexity, justifying the application of dynamic methods in the structural design of multi-story buildings erected in seismically active areas.

2.2 Comparison of Current and Previous Research

The comparison of Current and Previous Research can be seen in Table 2.1.

Table 2.1 The comparison of current and previous studies

Author(s)	Year	Object	Software	Methods	Key Findings	Location	Structural Responses
Abdulrazzaq Abdulrahman Yahaya Al-Khazzan	2025	An eight-story includes one basement educational building,	ETABS	Equivalent Static, Response Spectrum	The comparison of the building responses of the static equivalent analysis method and the dynamic Response Spectrum analysis method.	Yogyakarta, Indonesia	Building Responses in this research are Base Shear, story drift, and story shear.
Alghuff et al.	2019	High-rise (75m) and low-rise (24m) RC	ETABS	Equivalent Static, Response Spectrum	- Response spectrum reduced shear forces by 35–65% (high-rise) and 22–25% (low-rise). - Dynamic analysis preferred for high-rises; static analysis suitable for low-rises.	General (ASCE/IBC codes)	Base shear, bending moment, displacements
Sonawane & Kambekar	2020	G+5, G+10, G+15 RCC buildings	ETABS	Linear Static, Linear Dynamic	- Dynamic analysis captured realistic displacements/drifts for high-rises. - Static analysis overestimated base shear. - Dynamic methods recommended for buildings >10 stories.	Seismic Zone V (India)	Lateral displacement, story drift, base shear
Ernawati & Widodo	2021	Lecture building	SAP2000	Dynamic Response Spectrum,	- Response spectrum yielded higher internal forces than the static method.	Yogyakarta, Indonesia	Axial force, shear force, bending moment

Author(s)	Year	Object	Software	Methods	Key Findings	Location	Structural Responses
				Equivalent Static	- Building failed to meet SNI 1726-2019 standards.		
Faiz & Kumar	2023	5-, 10-, 15-story RCC buildings	ETABS	Equivalent Static, Response Spectrum	- ESA overestimated structural responses (36% higher displacement in the 15-story). - RSA is more realistic for high-rises in extreme seismic zones.	Seismic Zones II & V (India)	Story displacement, drift ratio, base shear, axial force
Rauniyar & Juneja	2024	G+10 and G+25 buildings	ETABS 2016	Equivalent Static, Response Spectrum	- RSA reduced displacements by 23–35% and drifts by 32.65%. - ESA overestimated bending moments (2.13% for G+25). - RSA is more cost-effective for high-rises.	Seismic Zone IV (India)	Story displacement, drift, stiffness, and support reactions

(Alghuff et al., 2019; Ernawati & Widodo, 2021; Faiz & Kumar, 2023; Khan et al., 2022; Rauniyar & Juneja, 2024)

2.3 Research Originality

The Originality of this research is that it focuses on a university building in Yogyakarta city with a specific height of 31.4 m consisting of eight stories, including one basement. This research location is in a high-risk area affected by earthquakes.

CHAPTER III
THEORETICAL BACKGROUND

3.1 General

Determination methods of the earthquake load analysis are specified in SNI 1726-2019. Three primary methods can be used to analyze earthquake loads: Equivalent Static Analysis, Response Spectrum Analysis, and Time History Analysis. The selection of the analysis method depends on several factors, including the seismic design category of the structure, the system of the structure, the dynamic properties of the structure, and the regularity of the structure in terms of its geometry and mass distribution. The permissible analysis procedures for different types of structures can be referenced in Table 16 of SNI 1726-2019. The table of permissible analysis procedures for different types of structures can be seen in Table 3.1 below.

Table 3.1 Permissible analysis procedures

Seismic Design Category	**Structural characteristics**	**Equivalent Lateral Force Analysis**	**Response Spectrum Analysis**	**Seismic Time History Analysis**
B, C	All structures	Permitted	Permitted	Permitted
D, E, F	Buildings with risk category I or II that do not exceed 2 levels above the base	Permitted	Permitted	Permitted
D, E, F	The structure is without structural irregularities, and its height does not exceed 48.8 m	Permitted	Permitted	Permitted

Seismic Design Category	Structural characteristics	Equivalent Lateral Force Analysis	Response Spectrum Analysis	Seismic Time History Analysis
D, E, F	Structure without structural irregularities with a height exceeding 48.8 m and T < 3.5 Ts	Permitted	Permitted	Permitted
D, E, F	Structures with a height not exceeding 48.8 m and having only horizontal irregularities of type 2,3,4, or 5, or vertical irregularities of type 4, 5a, or 5b	Permitted	Permitted	Permitted
D, E, F	All other structures	Not Permitted	Permitted	Permitted

(Source: SNI 1726-2019)

3.2 Risk Category

Based on SNI 1726-2019, buildings and non-building structures can be classified into four categories based on their functions and types. Table 3.2 below shows the classifications of the risk categories.

Table 3.2 Risk Category of Building and Non-Building for Loading Factor

Type of Use	Risk Category
Building and non-building structures that contain low risk and can affect human life in the event of failure include: - Agricultural plantation, livestock, and fisheries facilities - Temporary facilities - Storage warehouse, - Guard houses and other small structures	I

Type of Use	Risk Category
All of the buildings and other structures, except those that include at-risk categories I, III, and IV, but do not have boundaries for: - Housing area - Shop house and office - Market - Office building - Apartment/Flats - Shopping center/mall - Industrial buildings - Manufacturing facilities - Factory	II
Building and non-building structures that have a high risk of human life while the failure occurs, include but are not limited to: - Cinema - Meeting hall - Stadium - Health facilities - Child care facilities - Prison - Nursing home Buildings and not buildings are not included in risk category IV, which has the potential to cause significant economic impacts, major and or mass disruption to community life, daily activities, in the event of failure, including but not limited to: - Power Generation Center - Water handling facilities - Waste handling facilities - Telecommunication center Buildings and non-buildings that are not included in the risk category IV (including manufacturing facilities, or material disposal sites, hazardous fuel) containing toxic or explosive materials in where the amount of ingredients exceeds the limit value required by the competent authority and is sufficient to cause.	III

Type of Use	Risk Category
Buildings and non-buildings designated as important facilities, including, but not limited to: - Monumental buildings - School buildings and educational facilities - Hospitals and health facilities that have bedrooms and an emergency unit (ER) - Fire, ambulance, and police station facilities, as well as garages for emergency vehicles - Shelter against earthquakes, storm winds, and other emergency protection. - Emergency facilities, preparedness communications, operations centers, and facilities for other emergency responses - Energy-generating centers and other required public facilities during an emergency - Additional structures (including telecommunication towers, fuel storage tanks, cooling towers, power station structures, fire-fighting water tanks or house structures, or structures for water or mineral support, or fire-fighting equipment) which required to operate during an emergency. - Buildings and non-buildings are required to maintain the function of the structure - other buildings that fall into the risk category IV	IV

(Source: SNI 1726-2019)

Based on SNI 1726-2019, there is a priority factor (Ie) for each category. The priority factor can be seen in Table 3.3 below.

Table 3.3 Priority Factor

Risk of Category	Priority Factor I e
I or II	1
III	1,25
IV	1,5

(Source: SNI 1726-2019)

3.3 Regular and Irregular Building Structures

Building structures are classified into two different aspects, regular and irregular structures. The classification must be based on the configuration, vertical, and horizontal. The vertical and horizontal configuration based on SNI 1726:2019 can be seen in Tables 3.4 and 3.5 below.

Table 3.4 Horizontal Irregularity

No	**Type and Irregularity explanation**	**The Seismic Design Category**
1a.	Torsion irregularity can be defined if the maximum deviation level includes unpredictable torsion with Ax = 1,0. At one end of the structure, transverse to the axis, is more than 1.2 times the average interlevel deviation at both ends. Torsional irregularity requirements in each chapter will be applied only for the diaphragm rigid or half-rigid structure.	D, E, and F B, C, D, E, and F C, D, E, and F D, E, and F
1b.	Additional Torsion irregularity can be defined if the maximum deviation level includes unpredictable torsion with Ax = 1,0. At one end of the structure, transverse to the axis, is more than 1.4 times the average interlevel deviation at both ends. Torsional irregularity requirements in each chapter will be applied only for the diaphragm rigid or half-rigid structure.	E and F D B, C, and D C And D C and D D B, C, and D
2	Irregularity angle can be defined if both project dimension structural map in inner corner location is higher than 15% of the dimensions of the structure plan when the direction can be considered	D, E, and F D, E, and F
3	A diaphragm discontinuity irregularity is defined if there is a diaphragm that has discontinuity or variation in sudden stiffness, including those with cut areas or open, that get higher than 50% of the gross diaphragm area closed, or a change in effective diaphragm stiffness of more than 50% from one level to the next.	D, E, and F D, E, and F

No	Type and Irregularity explanation	The Seismic Design Category
4	Irregularities resulting from shifts perpendicular to the plane are defined if there is a discontinuity in the resistance path lateral force, such as a shift perpendicular to the plane, and at least one vertical element resists the lateral force.	B, C, D, E, and F D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F
5	The irregularity of a nonparallel system is defined if the elements of the vertical bearing the lateral force are not parallel to the axes main orthogonal seismic force resisting system.	B, C, D, E, and F D, E, and F B, C, D, E, and F F D, E, and F B, C, D, E, and F

(Source: SNI 1726-2019)

Table 3.5 Vertical Irregularity

No	Type and Irregularity explanation	The Seismic Design Category
1a.	Rigid Irregularity soft level defines if there are rigid levels that have less than 70% layer above or less than 80% average rigid level above	D, E, and F
1b.	Excessive Rigid irregularity soft level can be defined if there is a level in lateral rigid that is less than 60% of the lateral rigid of the level above, or less than 70% of the average rigid 3 levels above.	E and F D, E, and F
2	Irregularity mass is defined if the effective mass at any level is more than 150% of the effective mass of a nearby level. A roof that is lighter than the floor below does not need to be reviewed.	D, E, and F
3	Vertical geometry irregularities are defined if the horizontal dimension of the seismic force resisting system at any level is more than 130% of the horizontal dimension of the seismic force resisting system nearby.	D, E, and F

No	Type and Irregularity explanation	The Seismic Design Category
4	Irregularities due to field discontinuities in elements' vertical lateral force resistors are defined if there is a shift in direction field where the element resisting a lateral force is greater than the length of the element, or there is a reduction in the rigid supporting elements at the level below.	B, C, D, E, and F
5a	Weak level irregularities due to discontinuities in strength lateral level is defined if the lateral strength of a story is less than 80% of the lateral strength of the level above. Lateral strength level is the total strength of all seismic bearing elements that share shear force in the considered direction.	E and F D, E, and F
5b	Excessive weak level irregularities result in discontinuity in the lateral force level, defined as the lateral strength of a story being less than 65% of the lateral strength of the story on. The lateral strength of a level is the total strength of all elements of seismic resistors that share shear force in the considered direction.	D, E, and F B and C D, E, and F

(Source: SNI 1726:2019)

3.4 Loading of the structure

3.2.1 Gravity Load

Gravity load or vertical load consists of dead load and live load as follows:

1. Based on SNI 1727:2020, the dead load is the weight of all installed building construction materials, including walls, floors, roofs, ceilings, stairs, fixed partition walls, finishing, building cladding, and other architectural and structural components, as well as other installed service equipment including the weight of faucets. dead load can be seen in Table 3.6.

Table 3.6 Dead Load

No	Material	Unit Weight
1	Reinforced concrete	24 kN/m^3

No	Material	Unit Weight
2	½ brick wall	1700 kg/m^3
3	Ceilings, frames, suspensions	0,2 kN/m^3
4	sand	18 kN/m^3
5	Steel	78,5 kN/m^3
6	Tile roof covering	0,5 kN/m^2
7	Ceramic Weight per 1 cm thick	0,24 kN/m^2
8	Electrical, plumbing, and air conditioning installations	0,2 kN/m^2
9	Specimen weight with a thickness of 2 cm	0,42 kN/m^2

(Source: SNI 1727:2020)

2. Live load is caused by users and occupants of buildings or other structures that do not include construction and environmental loads, such as wind, rain, earthquake, flood, or dead loads (SNI 1727:2020).

3.2.2 Lateral Load

Lateral or horizontal loads generally consist of wind and earthquake loads; loads due to explosions and machine vibrations can be categorized as lateral loads. A wind load is the force exerted on a building or a portion of it by variations in air pressure (strong wind gusts). On the other hand, earthquake loads are all statistically equivalent loads applied to a building or portion of a building that simulate the effects of ground movement brought on by an earthquake. In this research, the focus is on the earthquake force, while the wind force is ignored.

3.2.3 Load Combination

Building structures must be designed using a combination of loads to be as strong as possible to withstand loads. Based on SNI 1726:2019 chapter 5.3.1, the combination and factor load are as follows:

1. 1,4DL
2. 1,2DL + 1,6LL + 0,5(Lr atau R)
3. 1,2DL + 1,6(Lr atau R) + (1,0L atau 0,5W)
4. 1,2DL + 1,0W + 1,0l + 0,5(Lr atau R)
5. 1,2DL + 1,0E + 1,0LL
6. 0,9DL + 1,0W
7. 0,9DL + 1,0E

For numbers 5 and 7 with earthquake loads regulated by SNI 1726-2019 chapter 4.2, the factors and combinations of loads for nominal dead loads, nominal live loads, and nominal earthquake loads are as follows:

1. (1,2 + 0,2 Sds) DL + 1 LL ± 0,3 ρ EX ± 1 ρ EY
2. (1,2 + 0,2 Sds) DL + 1 LL ± 1 ρ EX ± 0,3 ρ EY
3. (0,9 - 0,2 Sds) DL ± 0,3 ρ EX ± 1 ρ EY
4. (0,9 - 0,2 Sds) DL ± 1 ρ EX ± 0,3 ρ EY

Where,

DL = Dead loads, including additional dead loads
LL = Life load
Lr = Roof living load
R = Rain load
W = Wind load
EX = X-directional earthquake load
EY = Y-direction earthquake load
ρ = Redundancy factor
Sds = Parameters of acceleration of the design response spectrum in a short period

3.5 Structural Analysis Methods

Equivalent static and dynamic analyses are two primary approaches in analyzing earthquake loads. Dynamic analysis has many methods of analysis, such as time history and spectral response. In this research, the spectrum response analysis method is the

method used to represent the dynamic analysis. Explanation of both the Equivalent static and spectrum response analysis methods is as follows.

1. Equivalent Static Analysis

   Equivalent static analysis is a method of structural analysis with earthquake vibrations modeled as static horizontal loads acting on the building's mass centers. Buildings with a lot of mass will have many horizontal forces, each acting on the masses. Following the principle of balance, it can be analogized as the existence of a horizontal force acting on the base of the building, which is then called the base shear force, V. This base shear force forms a balance with the horizontal force acting on each building mass (Pawirodikromo, 2001).

   Equivalent static analysis, as defined in SNI 1726:2019, is divided into three stages, including:

   a. Seismic base shear
   b. Calculation of seismic response coefficients
   c. Distribution of vertical earthquake force.

   In the seismic base shear stage, V in the direction specified must correspond to the following equation:

   $$V = Cs.\ W \qquad (1)$$

   where:

   V is the base shear

   Cs is the coefficient of seismic response.

   W is the effective seismic weight/load.

   In the calculation of the seismic response coefficients stage, Cs must be determined by the following equation:

   $$Cs = \frac{SDs}{\frac{R}{Ie}} \qquad (2)$$

where:

SDS = acceleration parameter of the design response spectrum over a short period.

R = response modification factor, and Ie is the earthquake factor.

In the distribution of vertical earthquake force stage, Fx (kN) at all levels must be determined from the equation following:

$$Fx = Cvx.V \quad (3)$$

and

$$Cvx = \frac{W_x h_x^k}{W_i h_i^k} \quad (4)$$

where:

Cvx = Vertical distribution factor

V = Total design lateral force or shear at base of the structure (KN)

Wi & Wx = The total effective seismic weight portion of the structure (W) which is placed or subjected to level i or x

hi & hx = Height from base to level i or x (m)

k = The exponent corresponding to the period of the structure with the following values:

for structures with T ≤ 0,5 second, k = 1

for structures with T ≥ 2,5 second, k = 2

for structures with 0,5 < T < 2,5 seconds, k = 2 or determined by linear interpolation between 1 and 2.

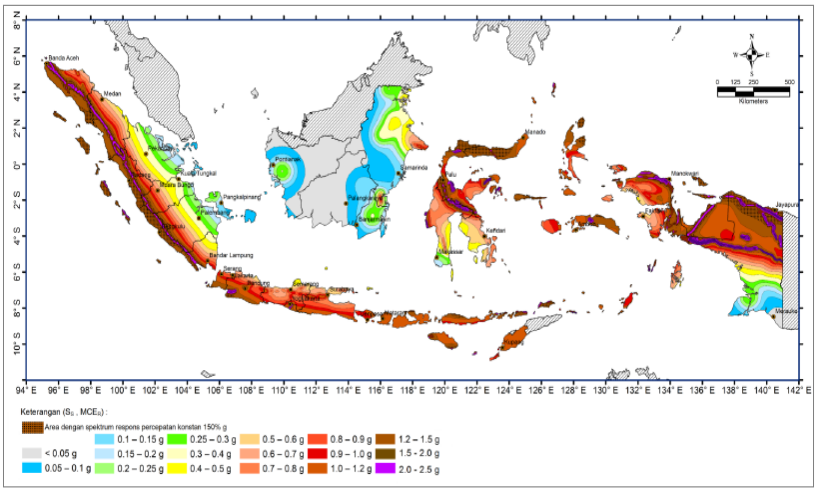
2. Response Spectrum Analysis (RSA)

Response Spectrum Analysis is a spectrum presented in the form of a graph/plot between the vibration period of the structure T, versus the maximum responses based on the damping ratio and a certain earthquake. The maximum responses can be in the form of maximum displacement (spectral displacement, SD), maximum velocity (spectral velocity, SV), or maximum acceleration (spectral acceleration, SA) of the single degree of freedom (SDOF) structure mass (Pawirodikromo, 2012).

The Response Spectrum Analysis method includes several stages as follows:

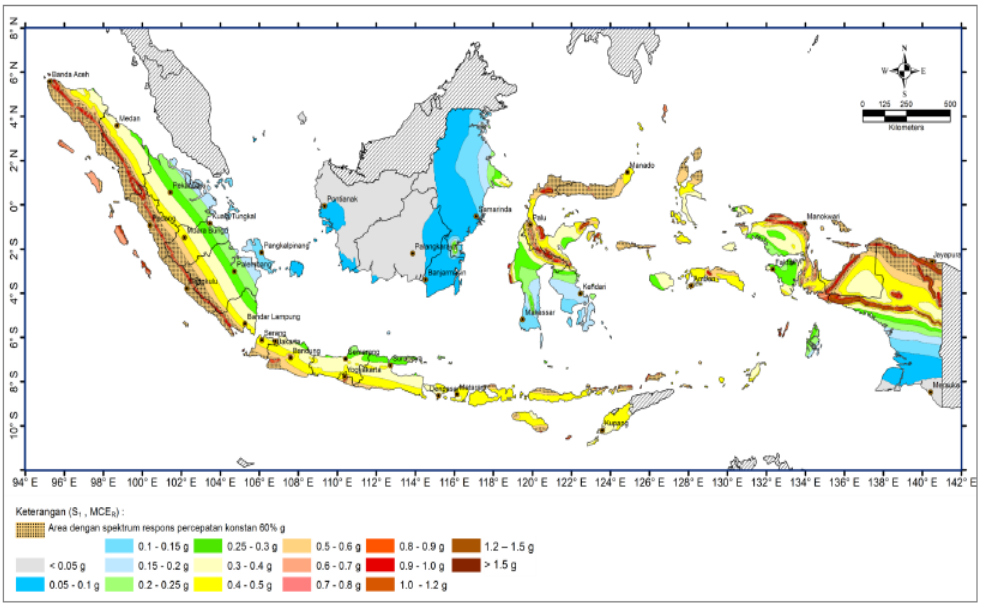
a. Determination of Acceleration Spectra

Based on SNI 1726:2019, the short-period (Ss), 1-second (S1) acceleration spectral responses, and PGA can be determined from the maps presented in Figures 3.1, 3.2, and 3.3.



Gambar 16 – Parameter gerak tanah S_S, gempa maksium yang dipertimbangkan risiko-tertarget (MCE_R) wilayah Indonesia untuk spektrum respons 0,2-detik (redaman kritis 5 %), pada kelas situs BC (S_{BC})

Figure 3.1 Ss, Maximum considered Earthquake risk-targeted (MCER), SB site class
(Source: SNI 1726:2019)



Gambar 17 – Parameter gerak tanah, S_1, gempa maksimum yang dipertimbangkan risiko-tertarget (MCE_R) wilayah Indonesia untuk spektrum respons 0,2- detik (redaman kritis 5 %), pada kelas situs BC (S_{BC})

Figure 3.2 S1, Maximum considered Earthquake risk-targeted (MCER), site class SB

(Source: SNI 1726:2019)

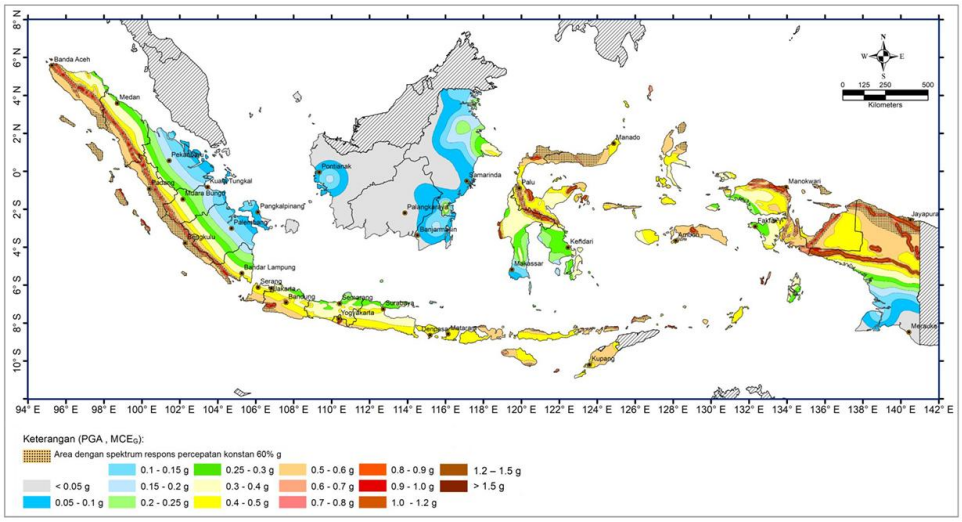


Figure 3.3 PGA. The maximum earthquake considered the geometric mean (MCEG) of the Indonesian region.

b. Site classification refers to SNI 1726:2019.

Site classification according to SNI 1726:2019 can be seen in the following table:

Table 3.7 Site classification

Class Sites	**Vs (m/s)**	**N or Nch**	**Su (kPa)**
SA	≥ 1500	N/A	N/A
SB	750 – 1500	N/A	N/A
SC	350 – 750	≥ 50	≥ 100
SD	175 – 350	15 – 50	50 – 100
SE	< 175	< 15	< 50
	Or any soil profile containing more than 3m of land with the following characteristics: - PI > 20 - W ≥ 40% - Non-flow shear strength Su < 25 kPa		
SF	Each soil layer profile that has one or more of the following characteristics: - Vulnerable and has the potential to fail or collapse as a result of earthquake loads. - Highly organic clay > 3m. - Clay with very high plasticity > 7,5 m (with PI > 75). - Soft/semi-firm clay layer with H > 35 m with Su < 50 kPa.		

(Source: SNI 1726:2019)

c. Determination of site coefficients

The amplification factor of the response parameters of the ground surface acceleration spectrum for short periods (Fa) and 1-second period (Fv) based on SNI 1726:2017 can be seen in the tables below.

Table 3.8 Classification Sites, Fa

Sites Class	Earthquake acceleration spectral response (MCER) parameters mapped on period 1 sec, S1					
	Ss ≤ 0,25	Ss = 0,5	Ss ≤ 0,75	Ss = 1,0	Ss = 1,25	Ss ≤ 1,5
SA	0.8	0.8	0.8	0.8	0.8	0.8
SB	0.9	0.9	0.9	0.9	0.9	0.9
SC	1.3	1.3	1.2	1.2	1.2	1.2
SD	1.6	1.4	1.2	1.1	1	1
SE	2.4	1.7	1.3	1.1	0.9	0.8
SF	Ss					

(Source: SNI 1726:2019)

Table 3.9 Classification Sites, Fv

Sites Class	Earthquake acceleration spectral response (MCER) parameters mapped on a short period, T = 0.2 seconds, Ss					
	Ss ≤ 0,25	Ss = 0,5	Ss ≤ 0,75	Ss = 1,0	Ss = 1,25	Ss ≤ 1,5
SA	0.8	0.8	0.8	0.8	0.8	0.8
SB	0.8	0.8	0.8	0.8	0.8	0.8
SC	1.5	1.5	1.5	1.5	1.5	1.4
SD	2.4	2.2	2	1.9	1.8	1.7
SE	4.2	3.3	2.8	2.4	2.2	2
SF	Ss					

(Source: SNI 1726:2019)

d. Spectral Response Design

Based on SNI 1726:2019, Design spectral acceleration parameters for the short period of 0,2 seconds (SDs) and design spectral acceleration at a period of 1,0 seconds (SD1) using the following equation:

$$\text{Sds} = \frac{2}{3} * Sms \quad (5)$$

$$\text{Sd1} = \frac{2}{3} * Sm1 \quad (6)$$

e. Spectrum Response

Based on SNI 1726:2019, there are 4 elements of the vibration period fundamental structure that occur in the response spectrum graph.

- Periods that are smaller than T0, the response spectrum accelerates design; the equation to determine Sa can be seen as follows.

$$\text{Sa} = \text{Sds}\ (0.4 + 0.6\ \frac{T}{T0}) \quad (7)$$

- Periods that have higher or equal to T0 and less or equal to Ts, design response spectrum Sa equal to SDs.
- Periods that have higher than Ts, the design response spectrum, Sa in the design response spectrum can be defined as this following question.

$$\text{Sa} = \frac{SD1}{T} \quad (8)$$

- Periods that have a value higher than Tl, the design response spectrum, Sa in the design response spectrum can be defined as this following question.

$$Sa = \frac{SD1.Tl}{T^2} \quad (9)$$

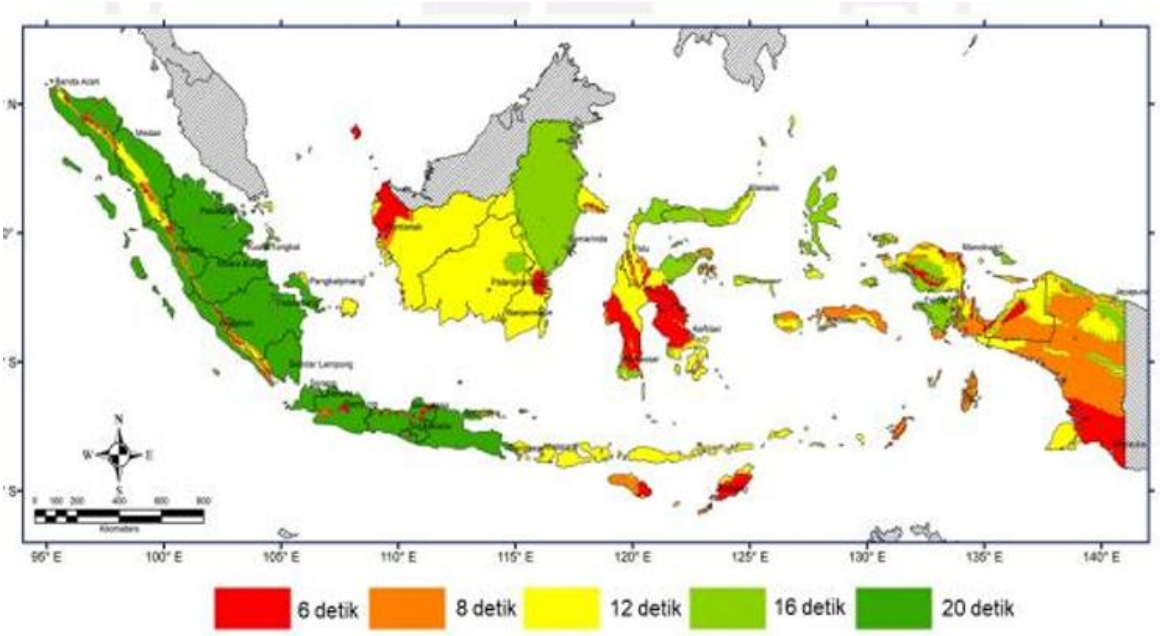
Where:

SD1 = Design spectrum response acceleration parameter with a period of 1,0 seconds

T = Fundamental period of the structure

SDs = Response Spectral Acceleration at Short Periods

Tl = Long period transition map that can be seen as the following figure



(Source: SNI 1726:2019)

Figure 3.4 Indonesian Territory for the Long Term Period, TL

From the equation above, the graphic spectrum response design according to SNI 1726:2019 can be seen in the following figure.

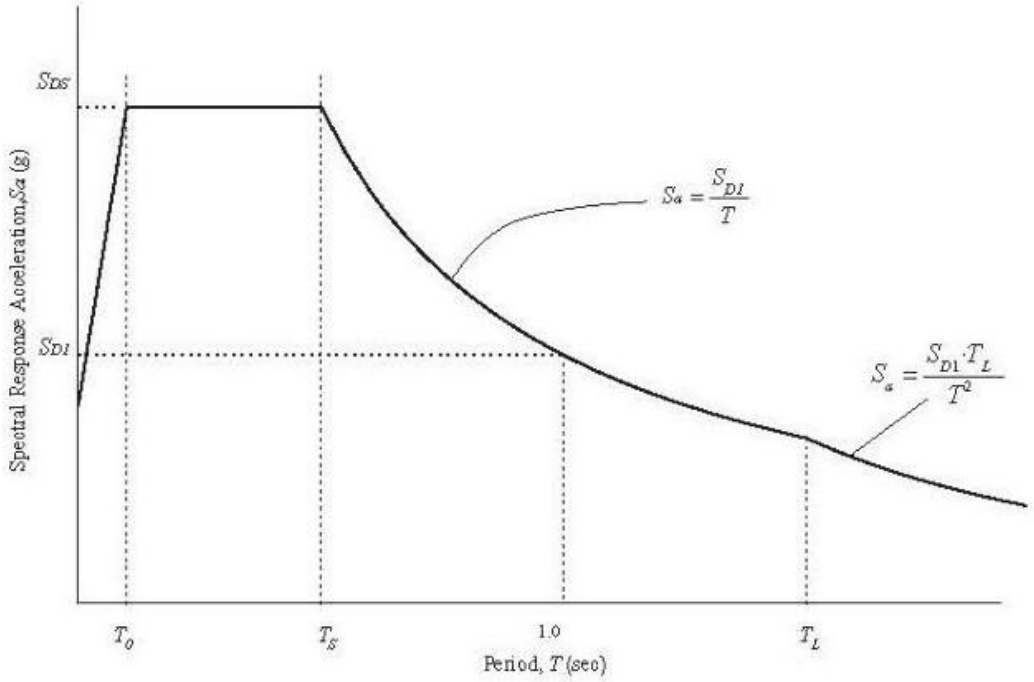


Figure 3.5 Spectral Response Acceleration
(Source: SNI 1726:2019)

3.6 Displacement and Deviations Between Floors

Displacement is one of the important parameters in the planning and design of structural buildings. It measures how far there is a deviation from a reference level, which is established concerning the foundation level of the structure.

The inter-story drift, which is differential displacement between floors, should be determined through an assessment of variations in the position of the centers of mass both above as well as below the considered level. Where vertical alignment of the center of mass is not maintained, computation of the deviation in foundation corresponding to the considered level is considered appropriate, concerning the projection of the upper floor as the reference. More detail on the floors' deviation is shown in the image below.

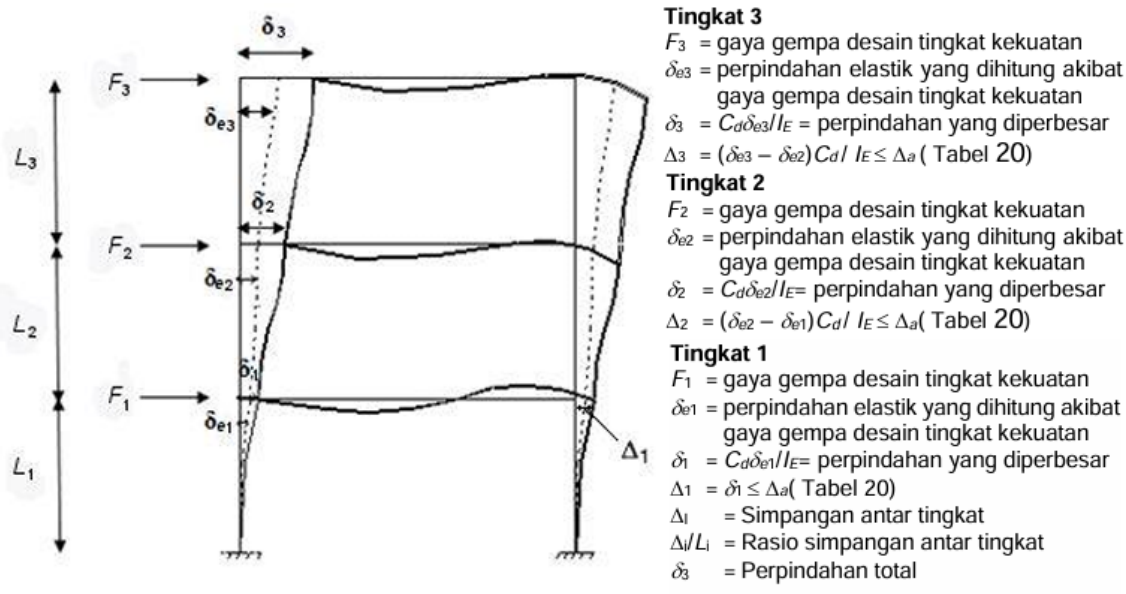


Figure 3.6 Inter-Story Drift
(Source: SNI 1726:2019)

CHAPTER IV

RESEARCH METHODOLOGY

4.1 Type of Research

The research is a comparative study focused on analyzing a multistory reinforced concrete building in Yogyakarta using two different methods: equivalent static analysis, which represents the static analysis of the structure, and response spectrum analysis, which represents the dynamic analysis of the structure. This research aimed to determine how the structure responds if the analysis is carried out using earthquake loads at the reinforced concrete building used as an educational building in Yogyakarta. Structural responses in this research are base shear, story drift, and story shears.

4.2 Data Collection

The collected data can be considered assumptions or facts since it has not yet been processed. Once analyzed through research or experiments, data can become more complex, forming a database, information, or even a solution to a specific problem. In this research, the data is from a real building in Yogyakarta used as a university building. Below are more details.

4.2.1 Design Data Collection

Before collecting data, it is necessary to define the research object, the type, and the source of data. According to the English dictionary, the object is the thing or entity being studied. In this research, the object is the "UNY Medicine Faculty Building " in Yogyakarta. This building was designed by PT Pola Data Consultant (PDC) in 2015.

4.2.2 Data Collection Method

Data is a resource that must be controlled and managed to become more beneficial. Research data is divided into two types: primary and secondary. Primary data is directly obtained by the researcher from field studies at or around the research site. Secondary data comes from indirect sources, such as relevant institutions. This research only uses secondary data, specifically structural drawings, and other data of the UNY Medicine Faculty Building.

4.3 Data Used

The data used in this research include:

1. Structural Drawings

   UNY Medicine Faculty Building is an RC building in Yogyakarta with 8 floors. The structural drawings of the building can be seen in Figure 4.1. And the layout of the first floor can be seen in Figure 4.2. The layout of the other floors can be seen in the appendix.

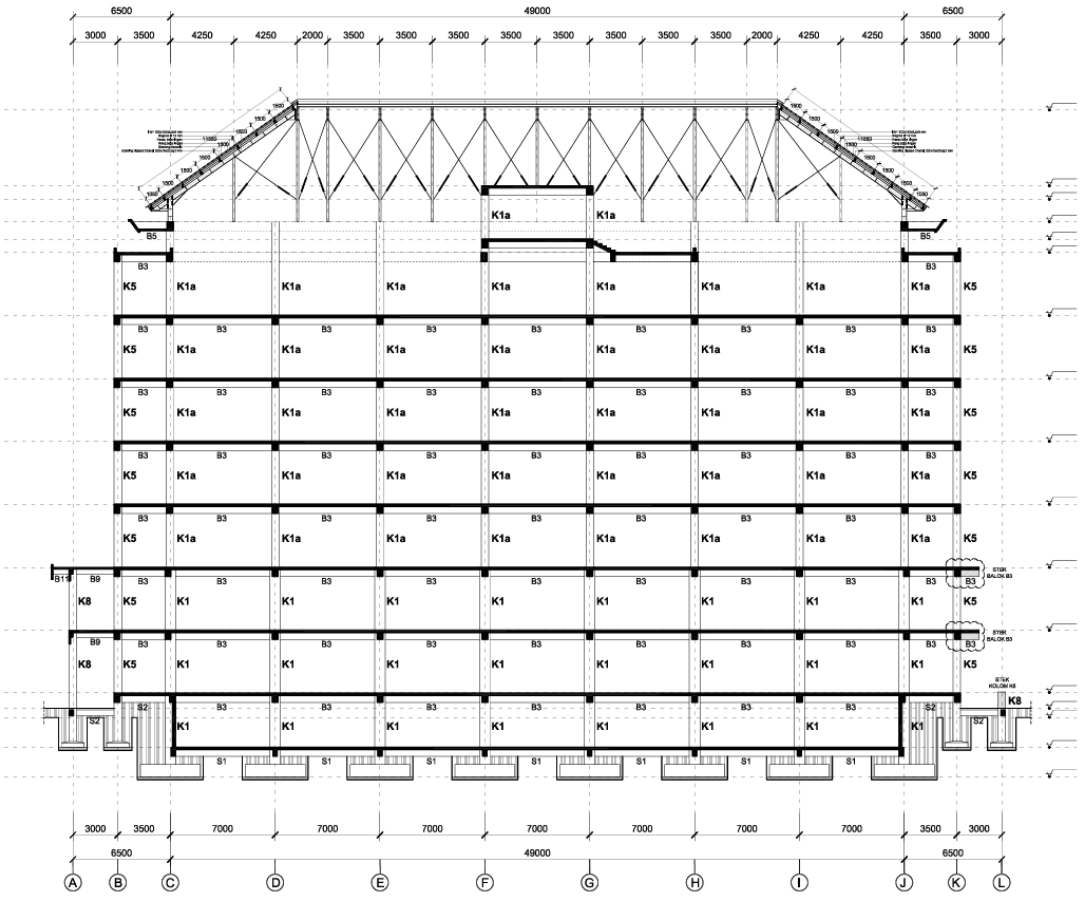


Figure 4.1 Section View

(Source: PT Pola Data Consultant, 2015)

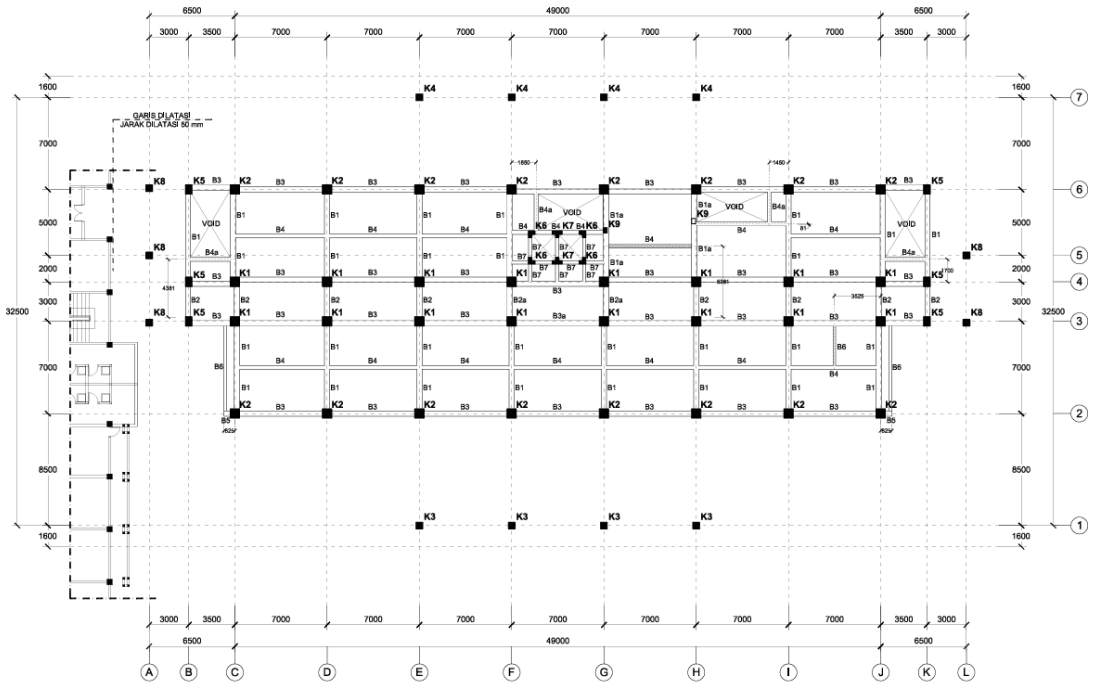


Figure 4.2 The layout of the first floor

2. Materials

   Material quality includes the compressive strength of the concrete (F'c) and the tensile strength of steel (Fy). The compressive strength of the concrete used in this building (F'c) is 25 MPa. The tensile strength of the steel used (Fy) is 392 MPa (BJTS 40) (Source: PT Pola Data Consultant, 2015).

3. Soil Condition

   The type of soil affects the values of the structural responses. The building in this research is designed to be built on a medium type of soil (SD) (Source: USGS). The determination steps of the soil type can be seen in Chapter V.

4.4 Structural Modeling

The ETABS software was used to simulate the building structure. High-rise building structure analysis, including offices, residences, hospitals, and other

structures, is the area of expertise for ETABS software. Steel frame analysis, concrete frame analysis, composite beam analysis, truss steel analysis, and shear wall analysis are the five structural design types that ETABS is specially made to examine. Using this software can result in accurate output and time savings.

4.5 Research Stages

The following research phases were employed to finish this final project.

1. Gathering the required information, such as the structural designs of the building.
2. Using the gathered data to model the plates, beams, and column structures in the ETABS software version 22.
3. Entering the seismic loads into the structural model using both the Equivalent Static Method (ESM) and the Response Spectrum Method (RSM). Input the necessary parameters, such as seismic zone factors, soil conditions, and building importance factors, as per SNI 1726:2019
4. Conduct seismic analysis using both methods to evaluate key structural responses, including Base Shear, Story drifts, and story shears.
5. Compare the results from the Equivalent Static Method and the Response Spectrum Method.
6. Summarize the results and provide recommendations for the most suitable seismic analysis method for RC buildings.

4.6 Research flowcharts

The flowchart of this research activity is presented in the following Figure.

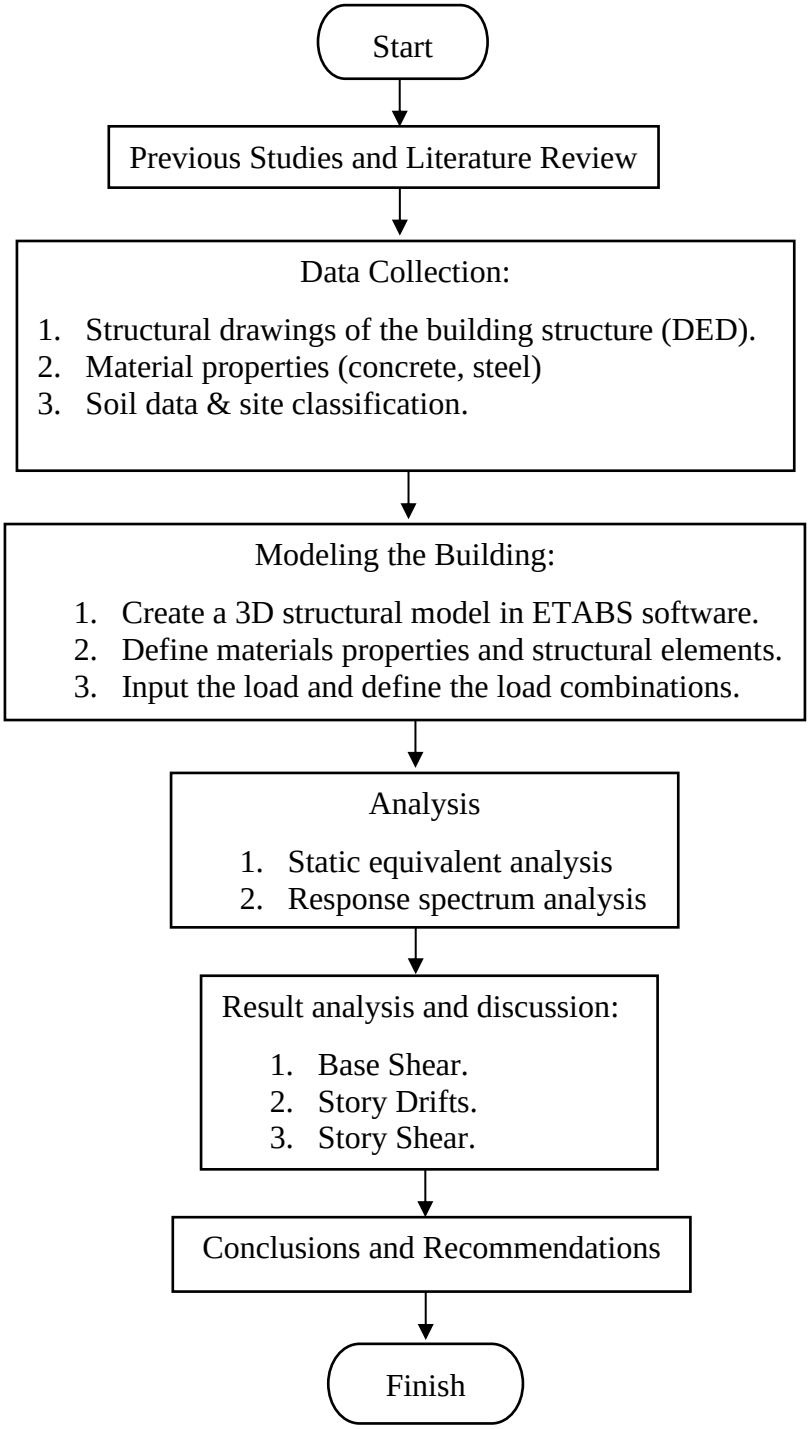


Figure 4.3 Flowchart of the research

CHAPTER V
ANALYSIS AND DISCUSSION

5.1 Building Structure and Gravitational Loading Data

5.1.1 Faculty of medicine of Yogyakarta state University

The structural data of the building given by Pola Data Consultant (PDC) are as follows:

Building function = Lecture Building
Building location = Yogyakarta (-7.775801777255697, 110.38838420282988)
Structural system = Special Moment Resisting Framing Systems
Building height = 31.4m
Number of floors = 8 (Seven stories with one basement)
Floor height = All floors have a height of 4.2 m except the basement, that have a height of 4.15 m.
Seismic design category = Seismic design category D
Risk Category = Risk category of the building is IV
Concrete quality = 25 MPa
Quality of steel reinforcement = BJTS 40 (fy = 392 MPa, fu = 559 MPa)

The building structure model can be seen in Figure 5.1.

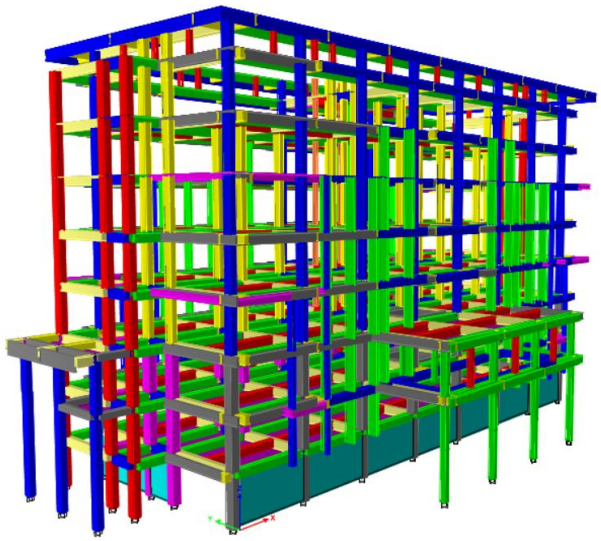


Figure 5.1 The 3D building structure modeled with ETABS.

5.1.2 Description of Building Structure Modeling

The structure was modeled as a special moment resisting frame system (SMRF), because the building is an open frame structure. Based on Table 12 in SNI 1726: 2019, there are three types of moment-resisting frame systems: special, ordinary, and secondary. Based on Table 12 in SNI 1726: 2019, the system used for this building should be a special moment resisting frame system, as it is in seismic design category D. Here are some advantages of choosing the SMRF structure system:

1. High Ductility Under Seismic Loads

   The SMRF system offers high ductility, allowing the structural elements (such as beams, columns, and joints) to undergo significant deformation without collapse. This characteristic enables the building to absorb and dissipate seismic energy, enhancing safety during earthquakes.

2. Effective Dynamic Response

   Given that the structure consists of eight stories, including one basement, it is considered a medium- to high-rise building. Such structures require a lateral force-

resisting system that can respond efficiently to seismic excitation. The SMRF system is well-suited for this purpose.

3. Compliance with SNI 1726:2019

According to the Indonesian seismic code (SNI 1726:2019), buildings located in seismic-prone zones, particularly those classified as Risk Category IV (e.g., educational buildings), are required to use systems with high energy dissipation capacity. SMRF meets this requirement.

This 8-story building, including a basement, was modeled using ETABS 22 software. One model of this structure was made with different earthquake force loading. The earthquake force is based on SNI 1726:2019.

5.1.3 Soil Type at Building Location

Based on the USGS website, the location where the building used in this research has Vs30 equal to 308, and based on Table 3.7, the value of the Vs30 is in the range of the medium soil type. So, the type of soil in the location of the building is medium soil (SD). The value of the Vs30 obtained from USGS can be seen in Figure 5.2.

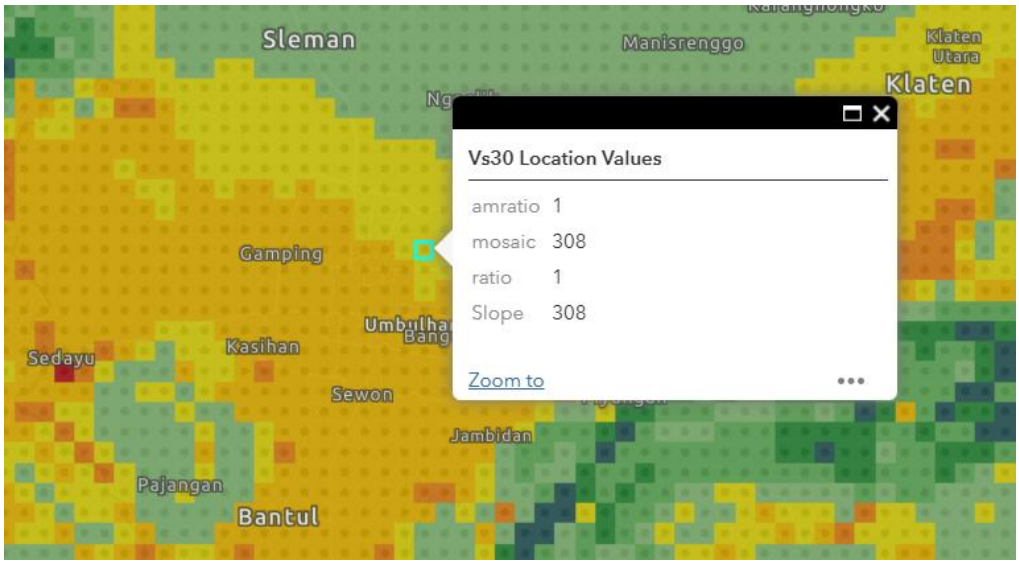


Figure 5.2 The value of Vs30 from USGS

5.1.4 Live Load

Based on SNI 1727:2020, the minimum live load on a floor in a building depends on its use. Based on SNI 1727:2020. The live load is as follows.

Meeting room = 4.79 KN/m^2

Roof = 2.4 KN/m^2

In this building, the live load is 4.79 KN/m^2 for all slabs except roof slabs that have 2.4 KN/m^2.

5.1.5 Additional Dead Load on Slabs

The additional dead load on the floor slab of the building is shown in Table 5.1 below:

Table 5.1 The additional dead load on the floor slab

Type	Thick (m)	Weight per volume KN/m^3	Load per m²	Unit
(1)	(2)	(3)	(4) = (2) * (3)	
Spesi (3 cm)	0.03	2.2	0.66	KN/m^2
Sand	0.01	1.6	0.16	KN/m^2
Ceramic	0.01	2.2	0.22	KN/m^2
Ceiling			0.2	KN/m^2
ME			0.25	KN/m^2
Other			0.5	KN/m^2
Super Dead Load (SDL) =	1.99	KN/m^2		
Rounding			2	KN/m^2

Based on Table 5.1, it is known that the additional dead load on the floor slab is 2 KN/m^2.

5.1.6 Additional Dead Load on Beam Due to Wall

The load on the wall is directly supported by the beam beneath it. Therefore, it is necessary to add more dead load to the beam. The additional dead load from the wall is affected by its thickness, material, and net height. The walls of this building consist of light brick material with a thickness of 15 cm. The height between the floors and beams determines the net height of each floor. The value of the additional dead load on the beam is presented in Table 5.2.

Table 5.2 Dead load of the wall

Wall thickness	T_{wall} =	0.15	m
Story Hight	H =	4.2	m
Thickness of the Beam above the wall	h_{Beam} =	0.6	m
Wall Height Assumption	H_{wall} =	3.6	m
Effective wall area percentage	$\%_{wall}$ =	70%	%
Light Brick	BJ_{wall} =	0.750	T/m^3
q wall = T wall x H wall x % wall X BJ wall =		0.28	T/m
Load used		**2.84**	KN/m

Based on Table 5.2, the additional dead load is 2.84 kN/m. The analysis of this building is assumed to have a uniform wall load of 2.84 kN/m on all floors, including the basement.

5.2 Earthquake Load Analysis Based on SNI 1726:2019

5.2.1 Risk Categories and Building Priority Factors

The risk category for a building is determined by its type of use. According to SNI 1726:2019, this building is classified as risk category IV, because it is used as an

educational building. Based on SNI 1726:2019, buildings in risk category IV have an earthquake priority factor of 1.5.

5.2.2 Peak Ground Acceleration Parameters

According to SNI 1726:2019, short-period site accelerations Ss (0.2 sec) and S1 (1 sec) must refer to the exceedance map indexed at 2 percent in 50 years. The Ss and S1 values were obtained manually and from the response spectrum analysis website, namely PUSKIM. Based on this site, the PGA value is 0.4958 g. Meanwhile, the Ss value is 1.1552 g, and the S1 value is 0.5138 g. The transition period in this building is 6 seconds. The graph and data of the response Spectrum parameters obtained from the PUSKIM website can be seen in Figure 5.3.

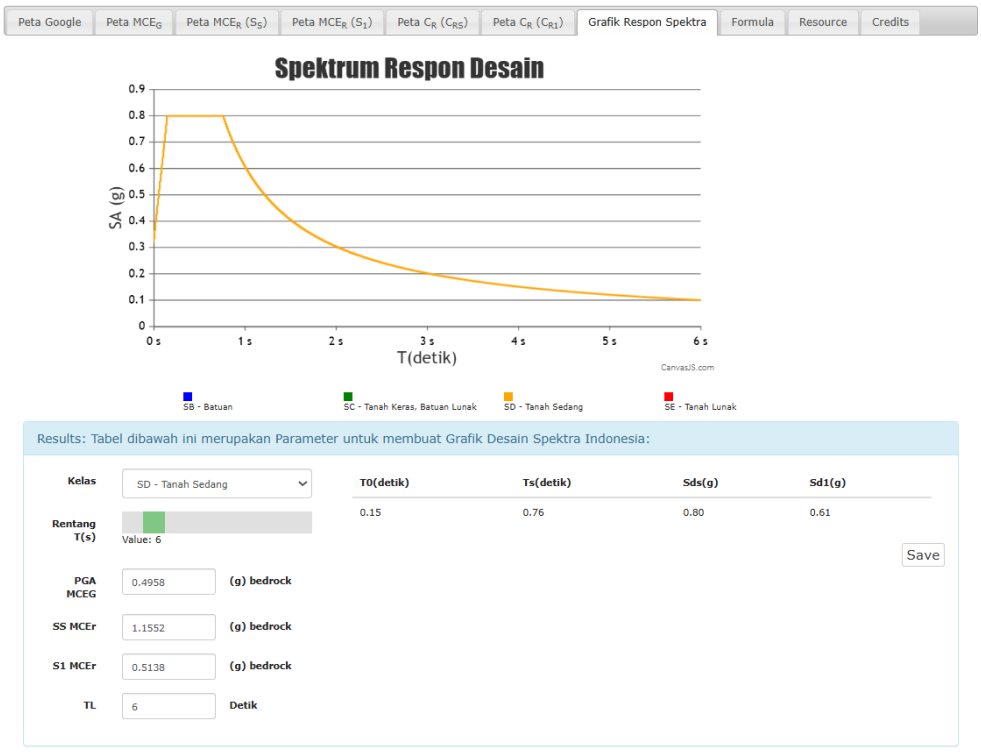


Figure 5.3 The graph and data of the response Spectrum parameters obtained from the PUSKIM website

Manual calculation of the response Spectrum parameters using the 2017 Indonesian Earthquake Source and Hazard Map is as follows:

The short-period site acceleration Ss based on Figure 3.1 is between 1.2 - 1.5 g, and based on Figure 3.2, the short-period site acceleration S1 is between 0.5 - 0.6 g. The Peak Ground Acceleration PGA based on Figure 3.3 is determined to be between 0.5-0.6.

The values obtained from the PUSKIM website were used in the next calculation.

5.2.3 Design Acceleration Parameters

According to SNI 1726:2019, the design acceleration parameters are determined by the site class coefficient.

The site coefficient parameters in SNI 1726 2019 are the Fa value, which is the short-period site coefficient. The Fa value can be seen in Table 3.8. Meanwhile, Fv is the site coefficient for a period of 1 second. The Fv value can be seen in Table 3.9.

Based on Tables 3.8 and 3.9, the value of Fa is 1.038 and the value of Fv is 1.786. So the calculation of SMS, SM1, SDS, and SD1 are as follows:

SMS = 1.1552 * 1.038 = 1.199 g

SM1 = 0.5138 * 1.786 = 0.918 g

SDS = (2/3) * 1.199 = 0.799 g

SD1 = (2/3) * 0.918 = 0.612 g

Based on the calculation above, the Sds value is 0.8 g while Sd1 is 0.61 g. So the spectrum response graph is shown in Figure 5.2.

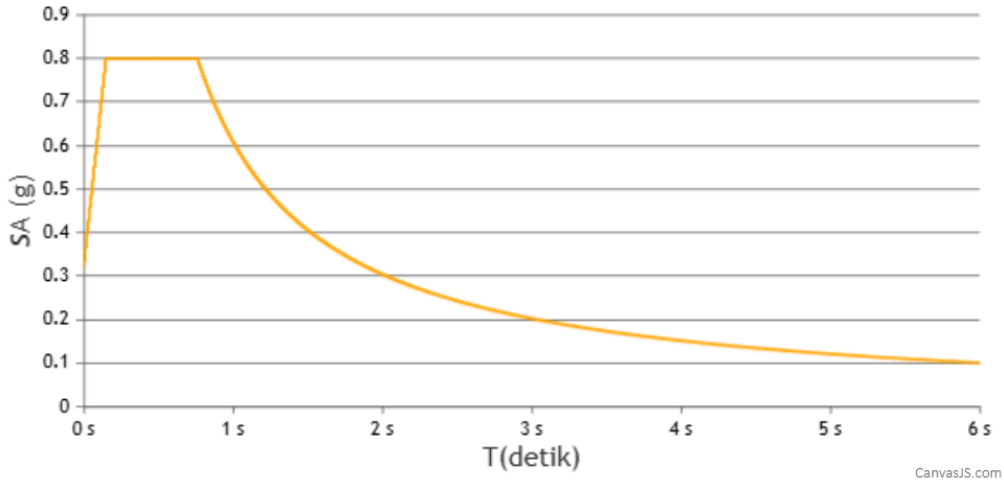


Figure 5.4 The spectrum response graph

Based on Figure 5.4, it is known that the largest Sa value is 0.8 g, while the smallest value at 6 seconds is 0.1 g.

5.2.4 Effective Seismic Weight

Based on SNI 1726:2019, the effective seismic weight of a structure must include all existing dead loads and other loads. The other load is 25% of the floor live load. The effective seismic weight calculated by ETABS version 22 is shown in Table 5.3 below.

Table 5.3 The effective seismic weight

Story	Mass		
	kg	KN	Ton
Top	390022.86	3824.81768	390.02286
Story 7	550542.93	5398.981824	550.54293
Story 6	1122364.51	11006.63592	1122.36451
Story 5	1215476.68	11919.75438	1215.47668
Story 4	1169739.8	11471.22881	1169.7398
Story 3	1205982.12	11826.64456	1205.98212
Story 2	1382214.63	13554.8951	1382.21463
Story 1	1466189.22	14378.40451	1466.18922

Story	Mass		
	kg		kg
Basement	1182398.64	11595.36962	1182.39864
Base	227449.78	2230.520385	227.44978
Sum	9912381.17	97207.2528	9912.38117

Based on Table 5.3, it is known that the effective seismic weight of the building is 97207.2528 kN. The floor with the heaviest seismic weight is located on the 1st floor.

5.2.5 Mass Participation Modal Structure

Based on SNI 1726 2019, the minimum number of variations is 100% of the actual mass in each orthogonal direction. However, there is an exception, namely that the minimum number of variations can be taken as 90% of the actual mass. The mass participation value of the structure is shown in Table 5.4.

Table 5.4 The mass participation value

Mode	Period	UX	UY
	Second		
1	1.826	3.13	63.89
2	1.821	63.33	3.14
3	1.609	0.004823	2.07
4	0.609	11.42	0.003335
5	0.573	0.003416	11.53
6	0.516	0.01	0.21
7	0.358	4.82	0.0006872
8	0.324	0.001702	4.54
9	0.292	0.03	0.05
10	0.241	2.46	0

Mode	Period Second	UX	UY
15	0.134	0.76	0
16	0.13	0.002835	0.0001897
17	0.111	1.32	0
18	0.107	0	1.22
19	0.099	0.003678	0.0006937
20	0.083	0	0.53
21	0.081	0.0009301	0.01
22	0.073	0	0
23	0.066	0	0.0006739
24	0.062	0	0
25	0.057	0	8.43
26	0.035	0	0.0001351
27	0.029	11.42	0
∑		100%	100.0%
If> 90% OK		OK	OK

Based on Table 5.4, it is known that the total participation value for the x direction is 100%. Meanwhile, the y direction is 100%. This value meets the required 100%, so it is following the requirements of SNI 1726:2019.

5.2.6 Fundamental Period of Structure

Based on Table 18 in SNI 1726:2019, this structure's Approximate period parameter (Ct) value is 0.0466, and the Approximate period parameter (x) is 0.9 because the structure system of the building is a moment-resisting concrete frame. The height of this building is 31.4 m. Then there is an upper limit coefficient factor for the calculated period. The coefficient of the upper limit depends on the value of SD1. The

upper limit coefficient value is 1.4 because SD1 is bigger than 0.4. So the calculation of the fundamental period of the structure is as follows:

Ta_{min} = 0.0466 * 31.4 ^ 0.9

= 1.0366 Seconds

Ta_{max} = Cu *Ta_{min}

= 1.4 * 1.0366

= 1.4512

Based on the calculations above, the fundamental period value of the structure is 1.0366 seconds. Then the upper limit value of the fundamental period is 1.4512 seconds.

The fundamental period value needs to be compared with the results of the ETABS analysis. The fundamental period of the structure based on ETABS V.22 is 1.821 for the X-direction and 1.826 for the Y-direction, as can be seen in Table 5.4. It is known that the value of the fundamental period in the x direction exceeds the upper limit value of the fundamental period of SNI 1726:2019. Therefore, the value of the fundamental period in the x direction is taken to be 1.4512 seconds. It is also known that the value of the fundamental period in the y direction exceeds the upper limit value of the fundamental period of SNI 1726:2019. Therefore, the value of the fundamental period in the y direction is taken to be 1.4512 seconds.

5.2.7 Horizontal Irregularities

Based on SNI 1726:2019, horizontal irregularities are divided into 5 types. The following is an analysis of each kind of irregularity.

1. Torsion Irregularities

Torsion irregularities are divided into torsional and excessive irregularities. The classification of torsional irregularities is as follows:

$\delta max < 1.2\ \delta avg$ = There is no torsional imbalance

$1.2\delta avg \leq \delta max \leq 1.4\ \delta avg$ = Torsional irregularity 1a

$\Delta max > 1.4\ \delta avg$ = Torsional irregularity 1b

Checking the torsional irregularities on each floor can be seen in Tables 5.5 and 5.6.

Table 5.5 Torsional and excessive irregularities in X-direction

Story	Output Case	Case Type	Direction	Max Drift	Avg Drift	Ratio	Check	
				mm	mm		1a	1b
Story 7	Ex	LinStatic	X	14.526	14.514	1.001	No	No
Story 6	Ex	LinStatic	X	22.883	22.797	1.004	No	No
Story 5	Ex	LinStatic	X	30.819	30.582	1.008	No	No
Story 4	Ex	LinStatic	X	36.081	35.825	1.007	No	No
Story 3	Ex	LinStatic	X	37.057	37.055	1	No	No
Story 2	Ex	LinStatic	X	27.803	27.167	1.023	No	No
Story 1	Ex	LinStatic	X	17.331	17.231	1.006	No	No
Basement	Ex	LinStatic	X	0.338	0.32	1.057	No	No

Table 5.6 Torsional and excessive irregularities in Y-direction

Story	Output Case	Case Type	Direction	Max Drift	Avg Drift	Ratio	Check	
				mm	mm		1a	1b
Story 7	Ey	LinStatic	Y	17.188	15.766	1.09	No	No
Story 6	Ey	LinStatic	Y	24.947	22.171	1.125	No	No
Story 5	Ey	LinStatic	Y	31.807	28.234	1.127	No	No
Story 4	Ey	LinStatic	Y	35.78	32.151	1.113	No	No
Story 3	Ey	LinStatic	Y	35.496	33.402	1.063	No	No
Story 2	Ey	LinStatic	Y	29.575	29.551	1.001	No	No
Story 1	Ey	LinStatic	Y	20.649	20.553	1.005	No	No
Basement	Ey	LinStatic	Y	1.688	1.655	1.02	No	No

Based on Tables 5.5 and 5.6, it is known that the ratio between the maximum and average deviation does not exceed 1.2. So it can be ensured that there are no torque irregularities in this building.

2. Internal Corner Irregularities

Internal angle irregularities occur when Py > 0.15 Ly or Px > 0.15 Lx. These parameters require reviewing the building plan. The building plan is shown in Figure 5.3.

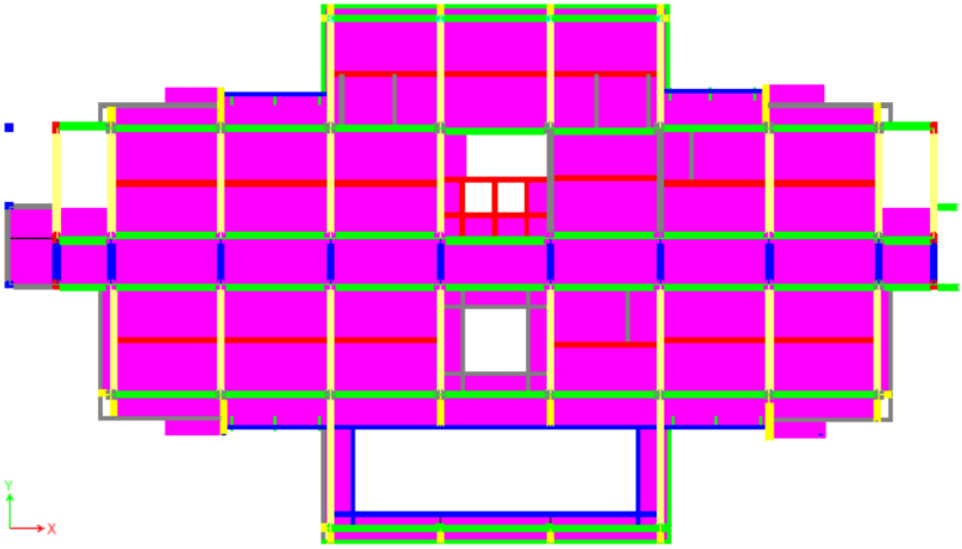


Figure 5.5 The building plan of the 1st story

Based on Figure 5.5, it is known that the plan has inner corners located in the left, right, upper, and bottom corners. Check internal corner irregularities as follows:

Location	= Top right corner
Px	= 17.5 m
Lx	= 56 m
Px / Lx	= 0.3125 m
Check	= Internal corner irregularities occur
Py	= 5.7 m

Ly = 34 m

Py/Ly = 0.168 m

Check = Internal corner irregularities occur

Based on the calculations above, it can be concluded that there is an internal angle irregularity in the x and y directions in the first and second stories.

3. Diaphragm Discontinuity Irregularities

This irregularity is defined if there is an opening of 50% of the gross area on the lower floor. Based on Figure 5.5, it can be seen that there is no change in openings that exceeds 50%. Therefore, in this structure, there is no irregularity in the diaphragm discontinuity.

4. The Irregularity of Transverse Story Drift Against the Plane

This irregularity occurs when there is a discontinuity in the path of the lateral support element, such as a transverse shift in the vertical plane. The plan of the building section is shown in Figure 5.6.

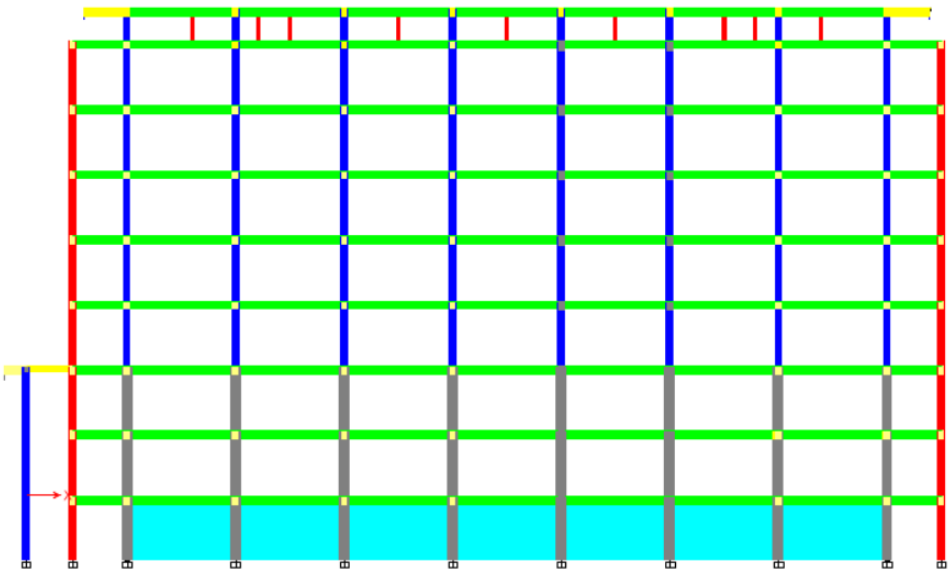


Figure 5.6 The plan of the building section

Based on Figure 5.6, this building does not experience irregular transverse shifts in the plane.

5. Irregularities of Nonparallel Systems

This irregularity arises when the vertical lateral resisting elements are not parallel or symmetrical to the main orthogonal axis of the seismic resisting system. Based on Figure 5.5, it is understood that the lateral force resisting element is parallel to the main orthogonal axis. Therefore, in this building, there are no irregularities in the non-parallel system.

Based on the analysis of the horizontal irregularities above, it is known that this building has only one type of horizontal irregularity, which is the Internal Corner Irregularities. Based on SNI 1726:2019, for structures located in Seismic Design Categories D that exhibit horizontal irregularities of Type 2, the design seismic forces shall be increased by 25% for critical structural elements, including the connections between diaphragms and vertical seismic force-resisting elements or collectors, and the collector elements and their connections, to ensure adequate strength and reliability in transferring lateral forces under irregular seismic behavior.

5.2.8 Vertical Irregularities

Based on SNI 1726:2019, vertical irregularities are divided into 5. The following is an analysis of each irregularity:

1. Soft Level Stiffness Irregularities

Soft grade stiffness irregularities are categorized into soft grade and excessive stiffness irregularities. Soft story irregularities occur when a story has lateral stiffness of less than 70% of the lateral stiffness of the story above it, or less than 80% of the average stiffness of the three stories above it. In contrast, excessive soft level irregularities occur when a level has less than 60% of the lateral stiffness of the level above, or less than 70% of the average stiffness of the three levels above. check the soft level irregularities on each floor can be seen in Tables 5.7, 5.8, 5.9, and 5.10.

Table 5.7 Soft Level Stiffness Irregularities check, 70% and 80% in the x-direction

Story	Load Case	Stiffness kN/m	Check 70%	Check 80%
Story 7	EX	177275.093	No	
Story 6	EX	215701.186	No	No
Story 5	EX	224209.41	No	No
Story 4	EX	228886.464	No	No
Story 3	EX	245726.688	No	No
Story 2	EX	356458.099	No	No
Story 1	EX	574199.353	No	No
Basement	EX	30961377.75	No	No

Table 5.8 Soft Level Stiffness Irregularities check, 60% and 70 % in the x-direction

Story	Load Case	Stiffness kN/m	Check 60%	Check 70%
Story 7	EX	177275.093	No	
Story 6	EX	215701.186	No	No
Story 5	EX	224209.41	No	No
Story 4	EX	228886.464	No	No
Story 3	EX	245726.688	No	No
Story 2	EX	356458.099	No	No
Story 1	EX	574199.353	No	No
Basement	EX	30961377.75	No	No

Table 5.9 Soft Level Stiffness Irregularities check, 70% and 80% in the y-direction

Story	Load Case	Stiffness kN/m	Check 70%	Check 80%
Story 7	Ey	163199.957	No	
Story 6	Ey	221779.302	No	No
Story 5	Ey	242849.384	No	No
Story 4	Ey	255040.76	No	No
Story 3	Ey	272600.603	No	No
Story 2	Ey	327443.907	No	No
Story 1	Ey	481396	No	No
Basement	Ey	5979006.095	No	No

Table 5.10 Soft Level Stiffness Irregularities check, 60% and 70% in the y-direction

Story	Load Case	Stiffness kN/m	Check 60%	Check 70%
Story 7	Ey	163199.957	No	
Story 6	Ey	221779.302	No	No
Story 5	Ey	242849.384	No	No
Story 4	Ey	255040.76	No	No
Story 3	Ey	272600.603	No	No
Story 2	Ey	327443.907	No	No
Story 1	Ey	481396	No	No
Basement	Ey	5979006.095	No	No

Based on the Tables above, it is known that there are no irregularities in soft level stiffness and excessive soft level. So, there are no vertical irregularities, types 1a and 1b in this building.

2. Weight Irregularities (Mass)

This irregularity occurs when the effective weight of all stories exceeds 150% of the effective weight of adjacent stories. In such cases, roofs that are lighter than the floor below can be disregarded during the checking process. The mass on each floor is derived from the ETABS output as shown in the following table.

Table 5.11 Weight Irregularities Check (Mass)

Story	Mass kg	Compared to 1,5 times the story mass above	Compared to 1,5 times the story mass below
Story 6	1122364.51	NO	No
Story 5	1215476.68	No	No
Story 4	1169739.8	No	No
Story 3	1205982.12	No	No
Story 2	1382214.63	No	No
Story 1	1466189.22	No	No
Basement	1182398.64	No	NO

Based on Table 5.10, it is known that there is no mass irregularity in this building.

3. Vertical Geometry Irregularities

This irregularity occurs when the dimensions of the lateral resisting elements at any level are more than 130% of the horizontal dimensions of the adjacent lateral force resisting system. The irregularities in vertical geometry can be checked in the following tables.

Table 5.12 Vertical geometry in the x-direction

story	di (m)	1.3*di	check
Story 7	56	72.8	regular
Story 6	56	72.8	regular
Story 5	56	72.8	regular
Story 4	56	72.8	regular
Story 3	56	72.8	regular
Story 2	59	72.8	regular
Story 1	56	76.7	regular
Basement	56	72.8	regular

Table 5.13 Vertical geometry in the y-direction

story	di (m)	1.3*di	check
Story 7	21.15	28.795	regular
Story 6	22.15	27.495	regular
Story 5	21.85	28.795	regular
Story 4	21.85	28.405	regular
Story 3	21.85	28.405	regular
Story 2	26.1	28.405	regular
Story 1	33	33.93	regular
Basement	33	42.9	regular

Based on the tables above, the vertical geometry irregularities do not exist in this building.

4. Plane Direction Discontinuity in Irregularities of Vertical Lateral Force Resisting Elements

This irregularity occurs when there is a shift in the direction of the lateral force resisting plane that is greater than the length of the element, or there is a reduction in the stiffness of the lateral force resisting element at the lower level. Based on Figure 5.6, it is known that all the columns at the bottom level up to the roof have no plane shift, so it can be concluded that there is no plane direction discontinuity in the irregularity of the elements resisting vertical lateral forces.

5. Discontinuities in Strong Lateral Level Irregularities

Level lateral strength stiffness irregularities are divided into level and excessive lateral strength irregularities. Irregularities in the lateral strength of a story occur when the lateral force of a story is less than 80% of the lateral force of the story above. Then, for excessive level strength irregularities, namely irregularities that occur when the lateral force of the level is less than 65% of the lateral force of the level above. Chucking of the lateral strength irregularities can be seen in the following tables.

Table 5.14 Chucking of the lateral strength irregularities, 80%

Story	Load Case/Combo	Vx	Vy	Check 80% X direction	Check 80% Y direction
		kN	kN		
Story 7	RSX & RSY	2890.3869	2870.1284	No	No
Story 6	RSX & RSY	4853.9248	4742.7619	No	No
Story 5	RSX & RSY	6253.5738	6103.5116	No	No
Story 4	RSX & RSY	7282.1689	7101.9429	No	No
Story 3	RSX & RSY	8285.8821	8070.2673	No	No
Story 2	RSX & RSY	9337.528	9148.2101	No	No
Story 1	RSX & RSY	10062.2638	9975.3153	No	No
Basement	RSX & RSY	10274.8456	10210.2538	No	No

Table 5.15 Chucking of the lateral strength irregularities, 65%

Story	Load Case/Combo	Vx	Vy	Check 65% X-direction	Check 65% Y-direction
		kN	kN		
Story 7	RSX & RSY	2890.3869	2870.1284	No	No
Story 6	RSX & RSY	4853.9248	4742.7619	No	No
Story 5	RSX & RSY	6253.5738	6103.5116	No	No
Story 4	RSX & RSY	7282.1689	7101.9429	No	No
Story 3	RSX & RSY	8285.8821	8070.2673	No	No
Story 2	RSX & RSY	9337.528	9148.2101	No	No
Story 1	RSX & RSY	10062.2638	9975.3153	No	No
Basement	RSX & RSY	10274.8456	10210.2538	No	No

Based on the tables above, it is known that there are no discontinuities in Strong Lateral Level Irregularities in this building. Based on the analysis of the vertical irregularities above, it is known that this building does not have any type of vertical irregularities.

5.2.9 Static Equivalent Analysis

Calculating the equivalent static earthquake analysis is relatively straightforward, specifically by multiplying the seismic response coefficient (Cs) by the gravity load. The formula for the seismic response coefficient is divided into three categories: Cs, minimum Cs, and maximum Cs. Consequently, the calculation for the seismic response coefficient value in the x direction is as follows:

Cs = 0.799 / (8/1.5)
= 0.150 g

Cs max = 0.612 / (1.451*(8/1.5))
= 0.079 g

Cs min = 0.044*0.799*1.5
= 0.053 g

Based on the calculations above, it can be concluded that the Cs value exceeds the maximum Cs value. So the seismic response coefficient used for the x direction is 0.079 g. Since the value of the fundamental period in the x direction and the y direction is the same, the seismic response coefficient used for the y direction is 0.079 g as well.

The next step is to perform an analysis of the structure's weight. According to Table 5.3, the effective seismic structure weight is determined to be 97207.2528 kN. Thus, the calculation of the equivalent static earthquake load of SNI 1726 2019 is as follows:

Vx = 0.079* 97207.2528

= 7679.372971 KN

Vy = 0.079* 97207.2528

= 7679.372971 KN

According to the calculation above, the base shear force value in the x direction and the y direction are the same, which is equal to 7679.372971 KN.

5.2.10 Dynamic Response Spectrum Analysis.

Dynamic earthquake analysis uses spectrum response analysis. The spectrum response analysis used is unscaled (RSY and RSX) and scaled (RSY and RSX) spectrum responses. Earthquake scaling based on SNI 1726 2019 is 100% of the basic static earthquake shear force.

The input value in one direction of the earthquake response spectrum must represent 100% in the same direction and 30% in the perpendicular direction. The spectrum response factor formula for input to the ETABS program is shown below.

Unscaled RSX = 9810 * (Ie / R) mm/ second

Then, the spectrum response factor formula, which has been scaled with the static base earthquake force for input to the ETABS program, is shown below.

RSX = 9810 * (Ie / R) * (1 *(V static / Unscaled RSX) mm/ second

Based on the formula above, The Unscaled RSX value is a dynamic earthquake factor that has not been scaled to the equivalent static earthquake. Calculation of the earthquake scale for the unscaled spectrum response factor (Rsu) is as follows:

Factor Unscaled RSX = 9810 * (1.5 / 8)
= 1839.38
0.3 * Unscaled RSX = 551,814
Factor Unscaled RSY = 9810 * (1.5 / 8)
= 1839.38
0.3 * Unscaled RSY = 551,814

Based on the calculations above, it is known that the Unscaled RSX and RSY earthquake scale values are the same in both directions. The scale value is 1839.38. Meanwhile, the value of 30% from the perpendicular direction is 551.814. Then, using ETABS software, the base shear force value of the analysis spectrum response is shown in Table 5.15.

Table 5.16 Spectrum Response Results Not yet scaled

Type	Dir-X	Dir-Y
	kN	kN
Unscaled RSX	4307.7895	1760.2057
Unscaled RSY	1757.8426	4318.4865

Based on Table 5.16, it is known that the value of the base shear force unscaled RSX in the x direction is 4307.7895 kN, while the y direction is 1760.2057 kN. Then the value of the base shear force unscaled RSY in the x direction is 1775.8426 kN, while the y direction is 4318.4865 kN. Then, the calculation of the dynamic versus static earthquake force scaling is as follows:

x direction

Factor Unscaled RSX = 1839.38

The base shear force	= 4307.7895 KN
Unscaled RSX in the same di rection	
The base shear force	= 1760.2057 KN
Unscaled RSX in the perpendicular direction	
100% of the Vstatic in the x direction	= 9893.9053 KN
30% of the Vstatic in the x direction	= 2968.17159 KN
Factor-scaled RSX is in the same direction	=1839.38*(9893.9053/4307.7895)
	= 4225
Factor-scaled RSX is in the	=551,814*(2963.9053/1760.2057)
perpendicular direction	= 931
Y direction	
Factor Unscaled RSY	= 1839.38
The base shear force	= 4318.4865 kN
Unscaled RSY in the same direction	
The base shear force	= 1757.8426 kN
Unscaled RSY in the perpendicular direction	
100% of the Vstatic in the y direction	= 9893.9053 kN
30% of the Vstatic in the y direction	= 2968.17159 kN
Factor-scaled RSY is in the same direction	=1839.38*(9893.9053/ 4318.4865)
	= 4214
Factor-scaled RSY is in the	=551,814*(2968.17159/1757.8426)
perpendicular direction	= 932

Based on the calculation above, the scale value for RSX in the same direction is 4225. Meanwhile, the perpendicular direction is 931. Then the scale value for RSY in the same direction is 4214. Meanwhile, for the perpendicular direction, it is 932. The scale value is then input into the ETABS software. The results of the calculations are then checked. This check is useful to ensure that the dynamic earthquake base shear force is equal to 100% of the static base shear force. The results of the dynamic base shear force, which have been scaled, can be seen in Table 5.16.

Table 5.17 Check the Static and Dynamic base shear forces

Seismic Type		FX	FY	Seismic scale	
		KN	KN	X	Y
Static	EX	9893.905	2968.172		
	EY	2968.172	9893.905		
Dynamic	RSX	9881.056	3506.109	99.9 %	118.1 %
	RSY	3498.579	9880.018	117.9 %	99.9 %

Based on Table 5.17, it is known that the dynamic base shear force value after rounding up the values is greater than or equal to 100% of the static earthquake force in each direction x and y. Therefore, it is following the requirements of SNI 1726:2019.

5.2.11 Story Drift

The x and y deviation data were obtained from the ETABS results. An example of calculating the acceptance deviation in the x direction with an earthquake load static equivalent is as follows:

ΔX = (Cd * deviation) / 1.5

(5.5 * deviation) / 1.5

deviation in the x direction of the Roof floor = 188.689 mm

deviation in the x direction of the 7th floor = 185.64 mm

ΔX = (5.5 * (188.698 – 185.64)) / 1.5

= 11.1797 mm

ΔX permission = 4200*0.01

= 42 mm

Check = ΔX < ΔX permission (Safe)

Story Drift of the building using Static and dynamic loads in both x and y directions is as follows:

1. The building's story Drift using the static equivalent analysis method can be seen in Table 5.18.

Table 5.18 The building's story Drift using the static equivalent analysis method

Story	story Displacements		EX Story Drift	EY Story Drift	Story Hight	Drift Limit
	δe_X	δe_Y	δe_X	δe_Y		
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
8	188.689	201.872	3.049	4.976	4200	42.000
7	185.64	196.896	14.498	17.188	4200	42.000
6	171.142	179.708	22.762	24.947	4200	42.000
5	148.38	154.761	30.344	31.807	4200	42.000
4	118.036	122.954	35.569	35.779	4200	42.000
3	82.467	87.175	37.053	35.326	4200	42.000
2	45.414	51.849	27.777	29.575	4200	42.000
1	17.637	22.274	17.299	20.586	4200	42.000
0	0.338	1.688	0.338	1.688	4150	41.500

Based on Table 5.18, the maximum drift is 37.053 mm in the x direction of the third story due to the accumulation of lateral displacements from the base upward and the dynamic characteristics of the structure. Story drift is defined as the relative lateral displacement between two consecutive floors under seismic loading, and it reflects the building’s flexibility and stiffness distribution. In this case, the third story exhibits the greatest drift primarily because it lies within the mid-height zone of the building, where lateral flexibility tends to be more pronounced due to lower stiffness in comparison to the base and upper stories. Additionally, the concentration of lateral deformations in this region can be attributed to the modal shape of the structure under seismic

excitation, where maximum curvature typically appears near the building's mid-height. The reduction in stiffness or abrupt changes in mass distribution around this level may also contribute to the increased drift. Although the drift value is the highest at this level, it remains within the permissible limit of 42 mm as prescribed by the relevant design code, indicating that the structure maintains compliance with safety requirements under the static equivalent analysis. The graph of the Story drift of the building with the static equivalent analysis method can be seen in Figure 5.7.

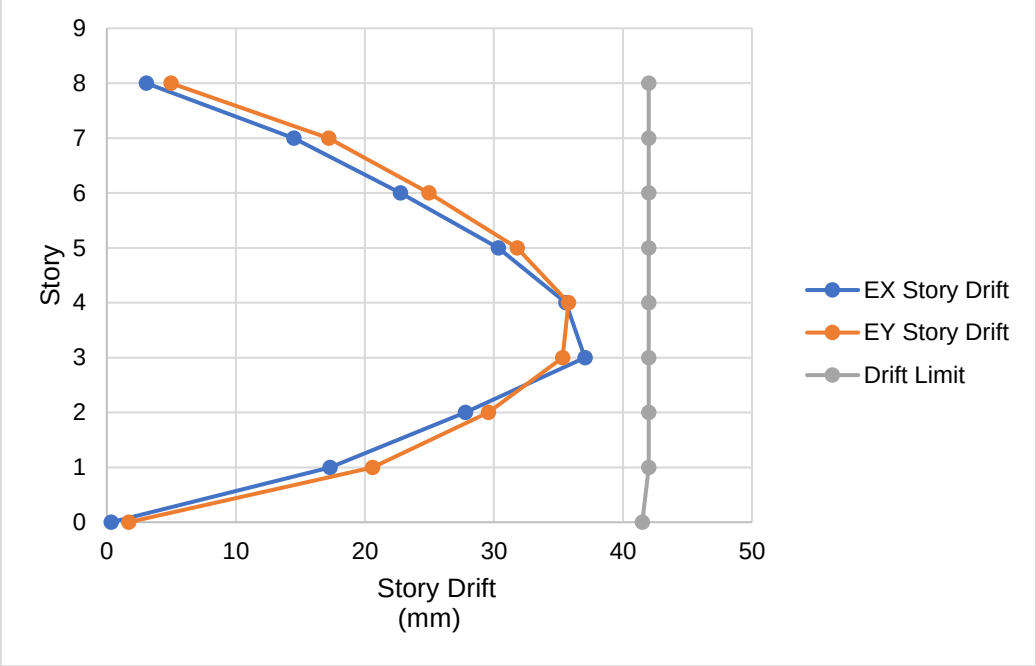


Figure 5.7 Graph of the Story drift of the building with the static equivalent analysis method.

2. The story drift of the building, determined using the dynamic response spectrum analysis method (RSX&RSY), is shown in Table 5.19.

Table 5.19 The building's story Drift using the dynamic response spectrum analysis method (RSX&RSY)

Story	story Displacements		RSX Story Drift	RSY Story Drift	Story Hight	Drift Limit
	δe_X	δe_Y	δe_X	δe_Y		
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
8	165.618	207.769	2.746	3.654	4200	42.000
7	162.872	204.115	11.540	16.541	4200	42.000
6	151.332	187.574	18.298	24.193	4200	42.000
5	133.034	163.381	25.077	31.371	4200	42.000
4	107.957	132.01	30.465	36.184	4200	42.000
3	77.492	95.826	33.464	35.689	4200	42.000
2	44.028	60.137	26.430	34.145	4200	42.000
1	17.598	25.992	17.270	24.167	4200	42.000
0	0.328	1.825	0.328	1.825	4150	41.500

Based on Table 5.19, the maximum drift is 36.184 mm in the y-direction of the fourth story, resulting from the dynamic interaction of multiple vibration modes during seismic excitation. In response spectrum analysis, this level often coincides with a transition zone where modal shapes cause amplified relative displacement. The fourth story may also represent a point of reduced lateral stiffness or mass discontinuity, contributing to increased drift. Additionally, directional stiffness variation in the y-axis can intensify movement at this level. Although this drift is the highest recorded, it remains within the allowable limit of 42 mm, indicating structurally acceptable performance under seismic loading.. The following figure shows the graph of the building’s story drift using the dynamic response spectrum analysis method (RSX and RSY).

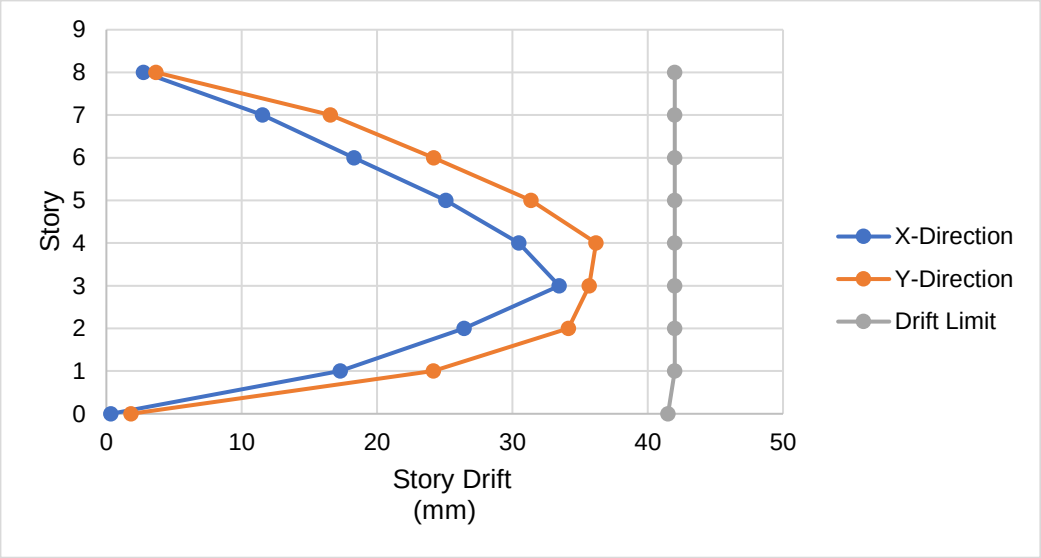


Figure 5.8 Graph of the Story drift of the building using the dynamic response spectrum analysis method (RSX&RSY)

Based on Tables 5.18 and 5.19, and Figures 5.7 and 5.8, it is known that the maximum story drift obtained from the static equivalent analysis method (EX and EY) was greater than the story drift obtained from the dynamic response spectrum analysis method (RSX and RSY). Figures 5.9 and 5.10 show the comparison of the story drift in each direction x and y for both static equivalent and response spectrum analysis methods.

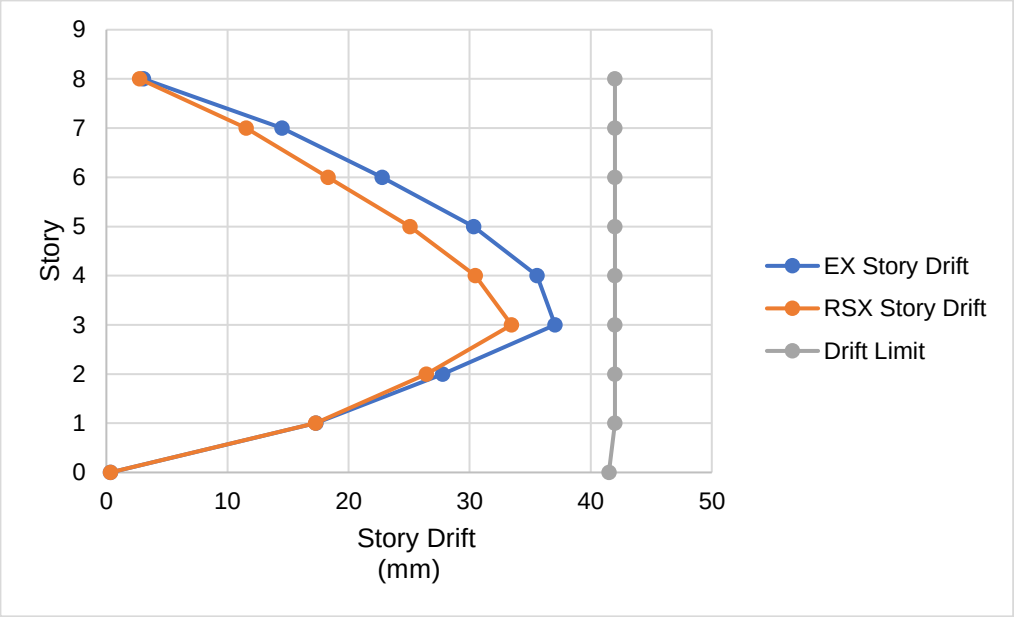


Figure 5.9 The comparison of the story drift in the X-direction for both static equivalent and response spectrum analysis methods.

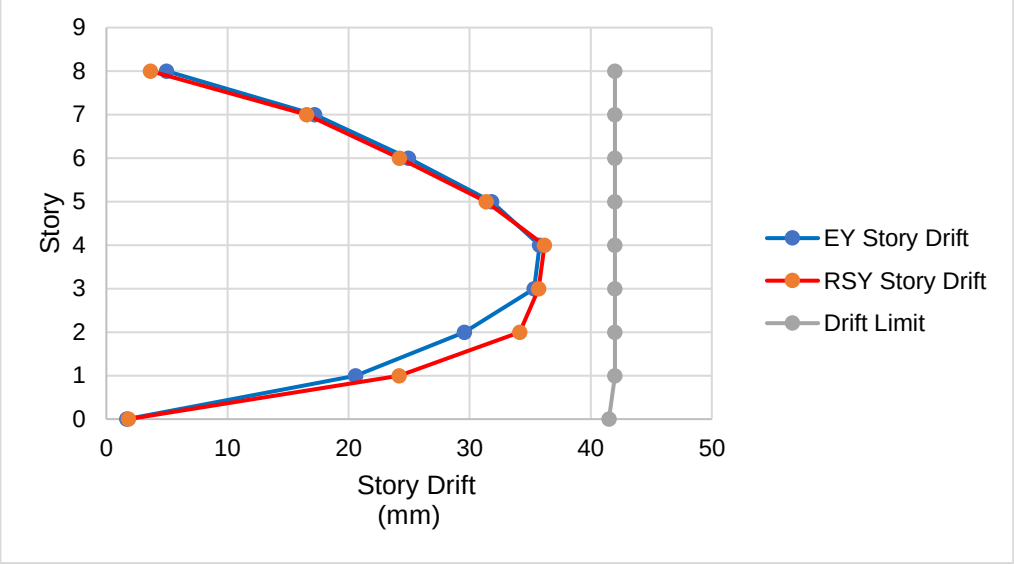


Figure 5.10 The comparison of the story drift in the Y-direction for both static equivalent and response spectrum analysis methods.

5.2.12 Story Shears

3. Story shear of the building with Ex can be seen in Table 5.20.

Table 5.20 Story shear of the building with Ex

Story	X-Direction KN	Y-Direction KN
Roof Story	-1129.51	0
Story7	-2572.95	0
Story6	-4916.98	0
Story5	-6856.71	0
Story4	-8199.77	0
Story3	-9105.5	0
Story2	-9676.21	0
Story1	-9893.91	0
Basement	-9893.91	0

The diagram of the Story shear of the building with Ex can be seen in Figure 5.11.

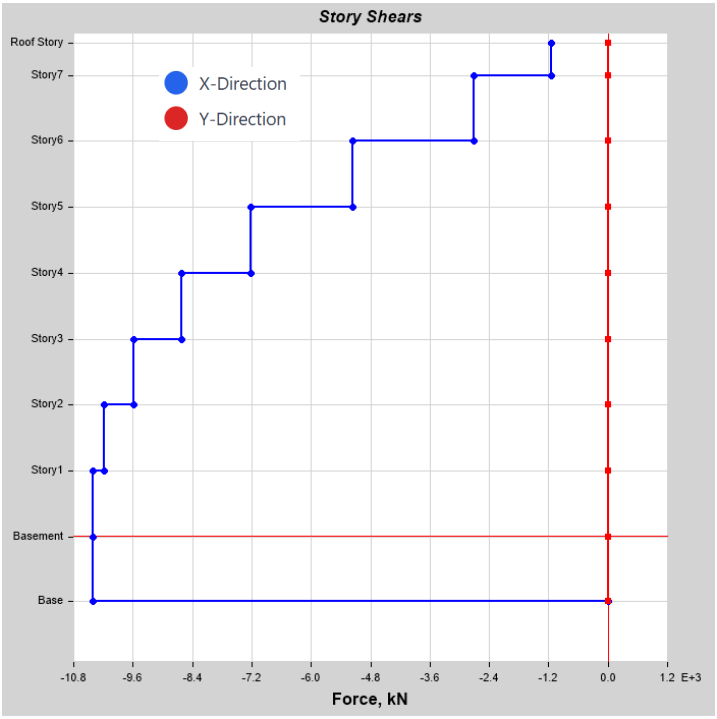


Figure 5.11 The diagram of the Story shear of the building with Ex

2. Story shear of the building with Ey can be seen in Table 5.21.

Table 5.21 Story shear of the building with Ey

Story	X-Direction KN	Y-Direction KN
Roof Story	0	-1129.51
Story7	0	-2572.95
Story6	0	-4916.98
Story5	0	-6856.71
Story4	0	-8199.77
Story3	0	-9105.5
Story2	0	-9676.21

Story	X-Direction KN	Y-Direction KN
Story1	0	-9893.91
Basement	0	-9893.91

The diagram of the Story shear of the building with Ey can be seen in Figure 5.12.

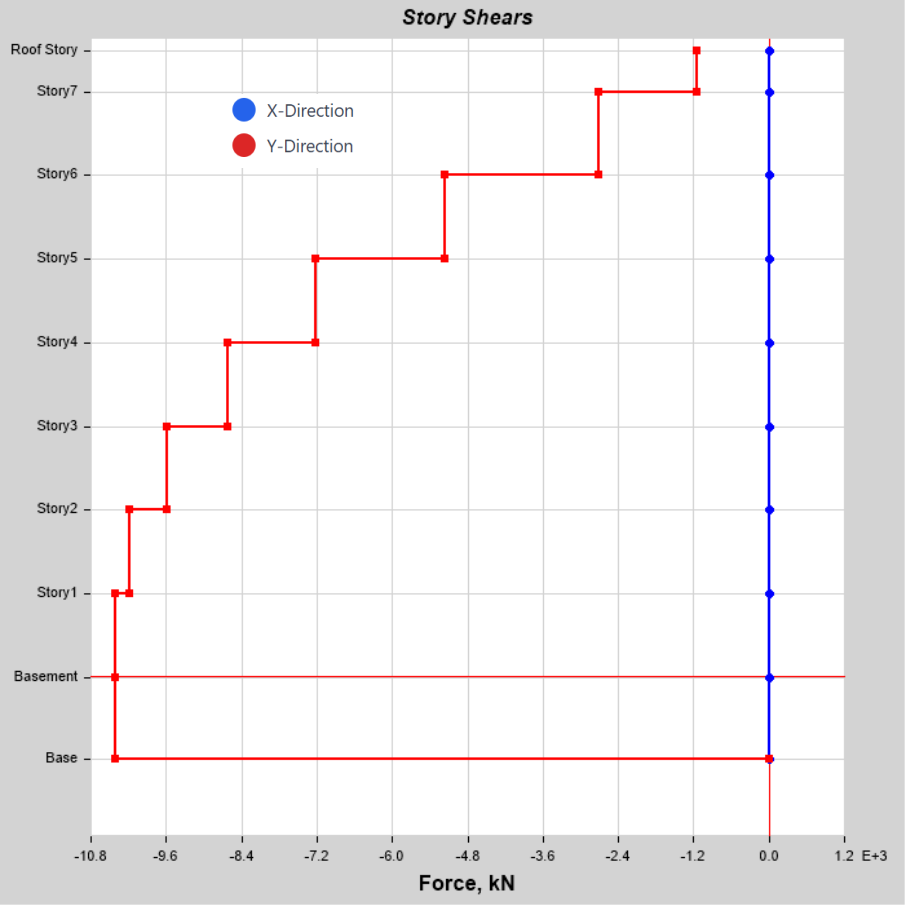


Figure 5.12 The diagram of the Story shear of the building with Ey

4. Story shear of the building with RSX can be seen in Table 5.22.

Table 5.22 Story shear of the building with RSX

Story	X-Direction KN	Y-Direction KN
Roof Story	1248.1849	365.9463
Story7	2779.021	807.305
Story6	4667.4412	1495.6958
Story5	6013.9895	2099.9626
Story4	7003.6734	2570.8095
Story3	7969.0756	2955.6682
Story2	8980.1686	3278.3096
Story1	9676.7888	3469.9696
Basement	9881.0564	3506.1085

The diagram of the Story shear of the building with RSX can be seen in Figure 5.13.

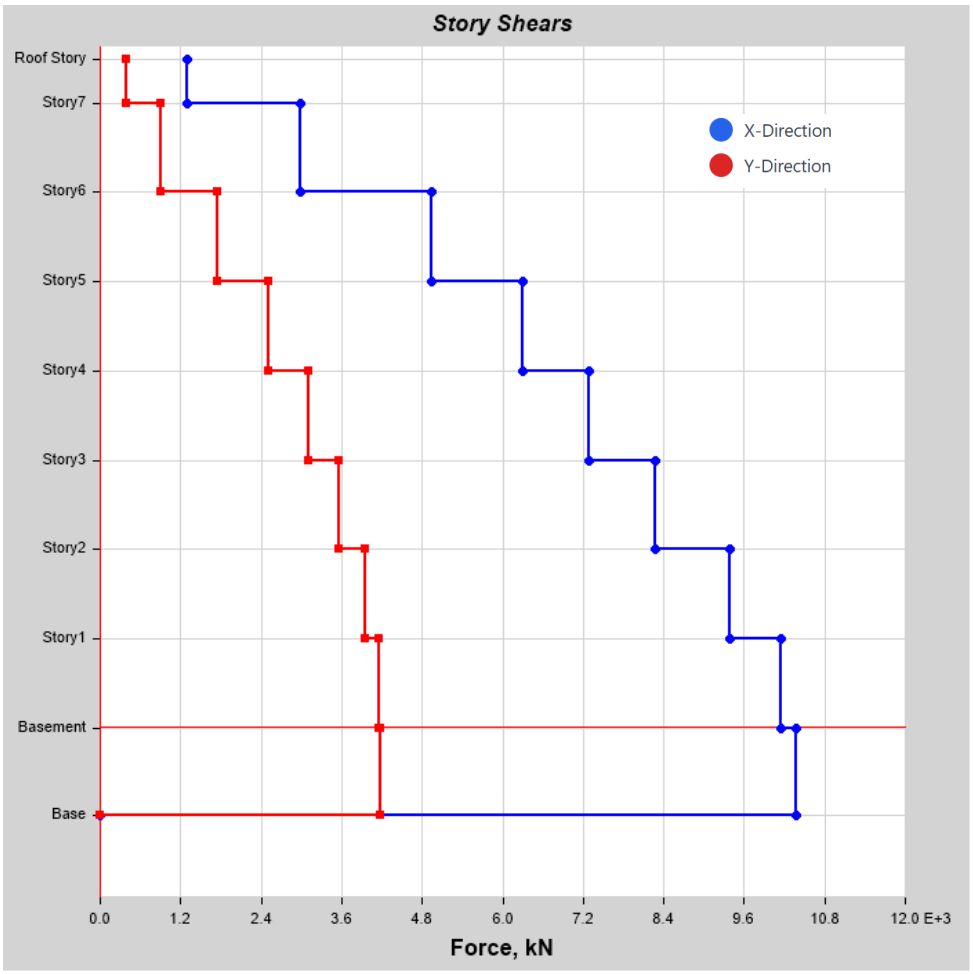


Figure 5.13 The diagram of the Story shear of the building with RSX

4. Story shear of the building with RSY can be seen in Table 5.23.

Table 5.23 Story shear of the building with RSY

Story	X-Direction KN	Y-Direction KN
Roof Story	356.6878	1316.028
Story7	814.9378	2776.719
Story6	1529.091	4588.909

Story	X-Direction KN	Y-Direction KN
Story5	2152.123	5906.117
Story4	2631.563	6872.725
Story3	3012.628	7809.926
Story2	3309.551	8852.824
Story1	3469.684	9652.838
Basement	3498.579	9880.018

The diagram of the Story shear of the building with RSY can be seen in Figure 5.14.

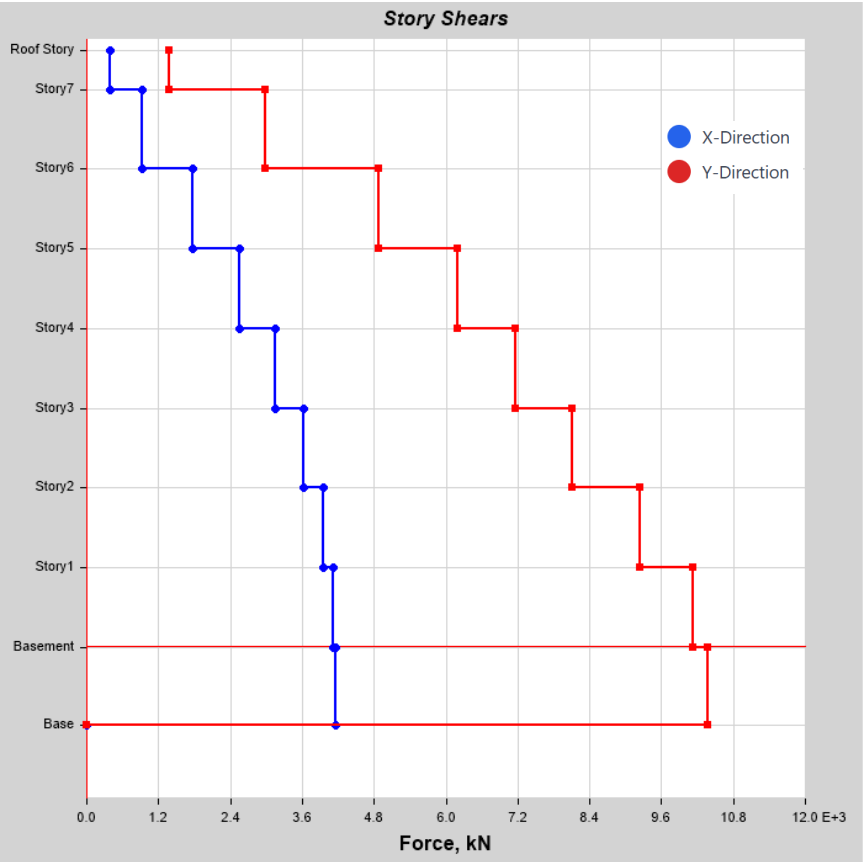


Figure 5.14 The diagram of the Story shear of the building with RSY

Based on Tables 5.20 – 5.23 and Figures 5.11- 5.14, it's clear that the story shear differences are 2.36% with using the static equivalent analysis method and with using the dynamic response spectrum analysis method.

In this study, it was observed that SEA resulted in higher displacement values compared to Response Spectrum Analysis (RSA). This outcome can be attributed to the fact that in low-rise, regular buildings, the structural response is largely governed by the first mode of vibration, and the influence of higher modes, which RSA is designed to capture, becomes negligible. SEA, as prescribed by SNI 1726:2019, calculates seismic forces using conservative code-based parameters, such as the design spectral acceleration and the response modification factor (R). This often leads to an overestimation of base shear and lateral displacements.

The story shear values remain relatively similar between the two methods. This is because both approaches are calibrated to produce equivalent total base shear forces in accordance with seismic design codes. The main difference lies in the distribution of these forces along the building height. While SEA assumes a predefined distribution based on height and mass, RSA distributes shear according to modal participation.

The findings of this research align with the findings of some previous research, as in many studies, the displacements from using the static equivalent analysis method are higher than the displacements from using the dynamic response spectrum analysis method.

CHAPTER VI

CONCLUSION

6.1 Conclusion

The conclusions of this research are as follows:

1. The seismic response analysis of the building was conducted by the static equivalent analysis method with a focus on base shear, story shears, and story drift. The base shear force (V) was 9893.9053 kN in both X and Y directions. The maximum story drift achieved was 37.053 mm in the X-direction at the third story level. For the story shears, values were provided for every level, with, for example, Story 1 in the X-direction with a shear of -9676.2066 kN.
2. The seismic response analysis of the building was also conducted by the dynamic response spectrum analysis method. The base shear forces before scaling were 4307.7895 kN (X-direction) and 4318.8465 kN (Y-direction), which, upon scaling to meet SNI 1726:2019 requirements, were 9881.0564 kN (RSX) and 9880.0178 kN (RSY), respectively. The maximum story drift obtained was 36.184 mm in the Y-direction on the fourth story. The story shear values were also provided, e.g., Story 1 in the X-direction with RSX as 9676.7888 kN.
3. In the comparison of the two methods, the Response Spectrum Analysis (RSA) dynamic base shear could satisfy the 100% Equivalent Static Analysis (ESA) requirement based on SNI 1726:2019, with the value matching in 0.3% without additional adjustments. However, a considerable difference was observed in story drift: the static equivalent analysis method always yielded larger maximum story drift values compared to the dynamic response spectrum method, which indicates that RSA provides more accurate results, whereas ESA overestimates story drift. In contrast, the story shears computed using both approaches were determined to be "nearly identical." Sources and associated content.

6.2 Recommendation

At the end of this research, there are some recommendations as follows:

1. To focus more on the nonlinear methods, such as the nonlinear static pushover analysis method and the nonlinear time history analysis method.
2. To use several software analysis programs, such as SAP2000 and other software.
3. To use more complex buildings that can show a significant difference between static and dynamic analysis methods.

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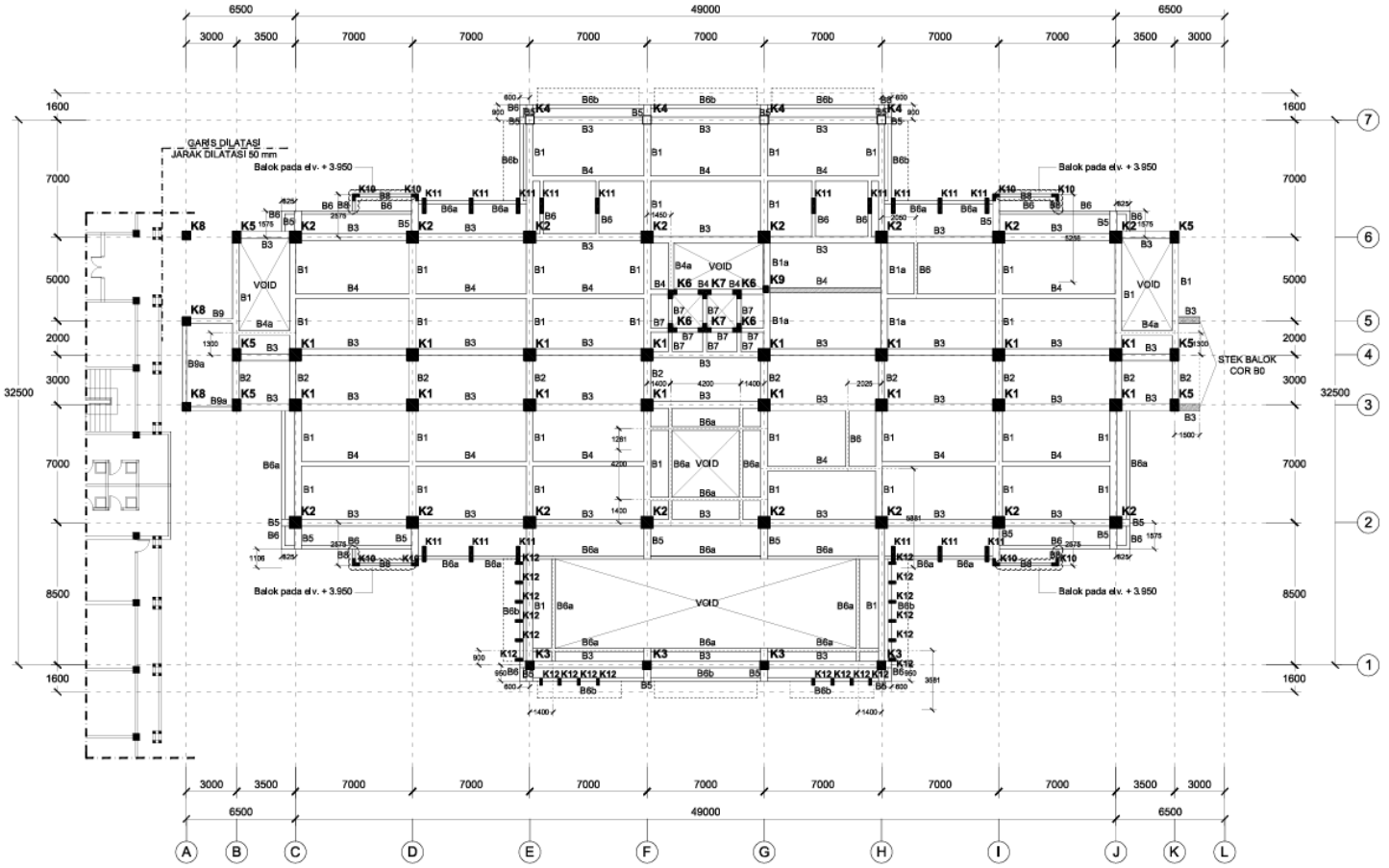
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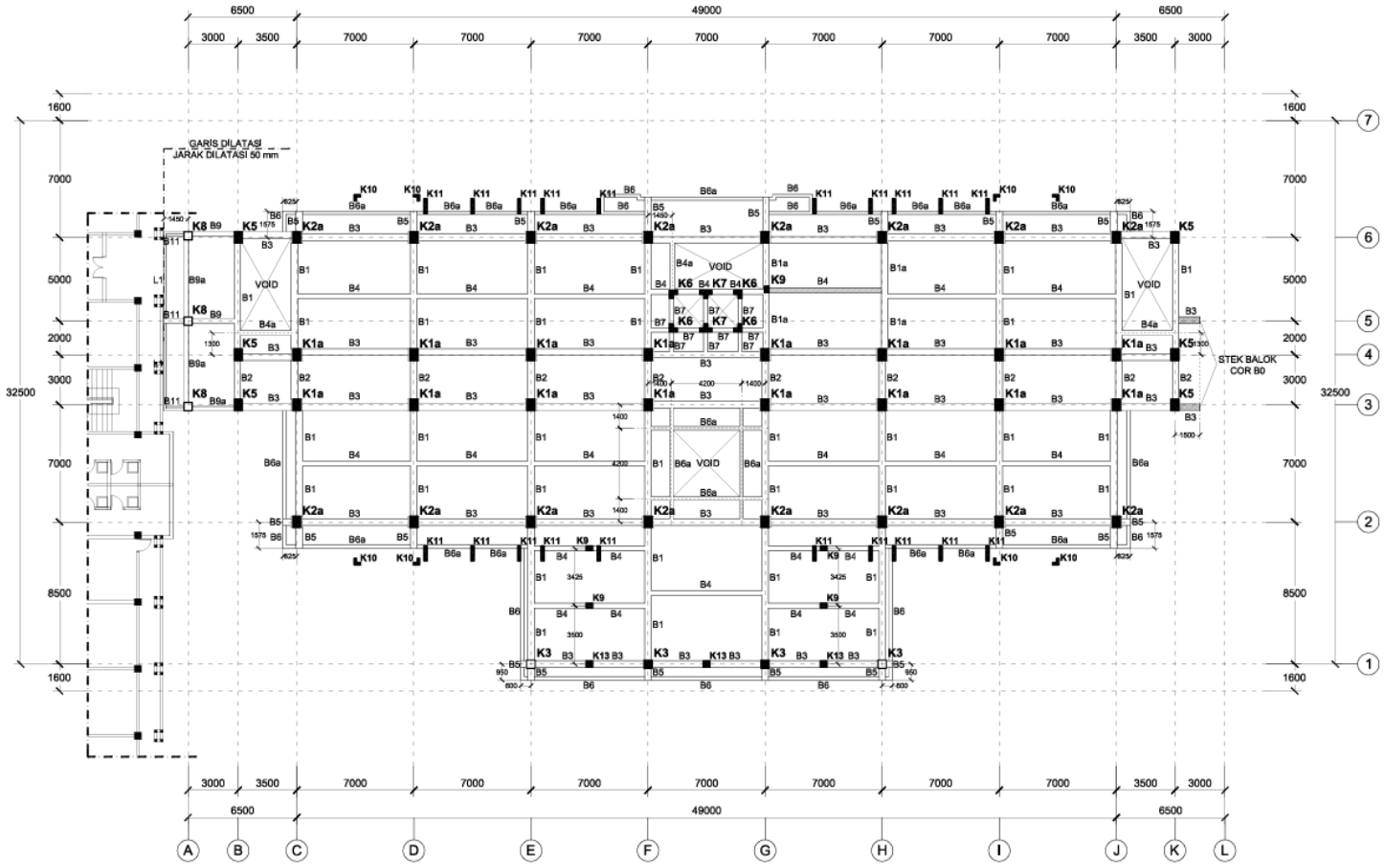
APPENDIX

Appendix 1 Beams Plan of Elevation +4.15



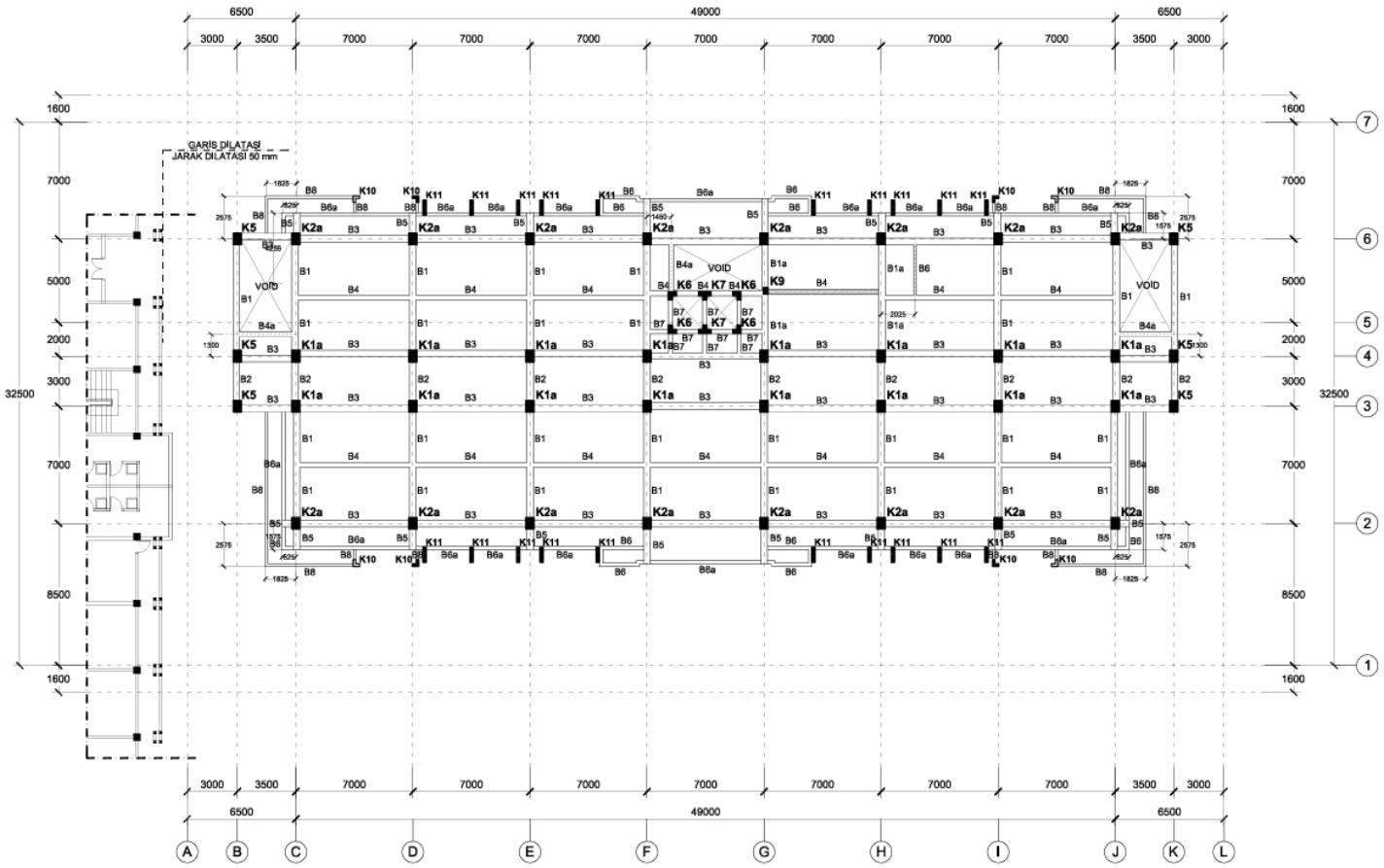
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Appendix 2 Beams Plan of Elevation +8.35



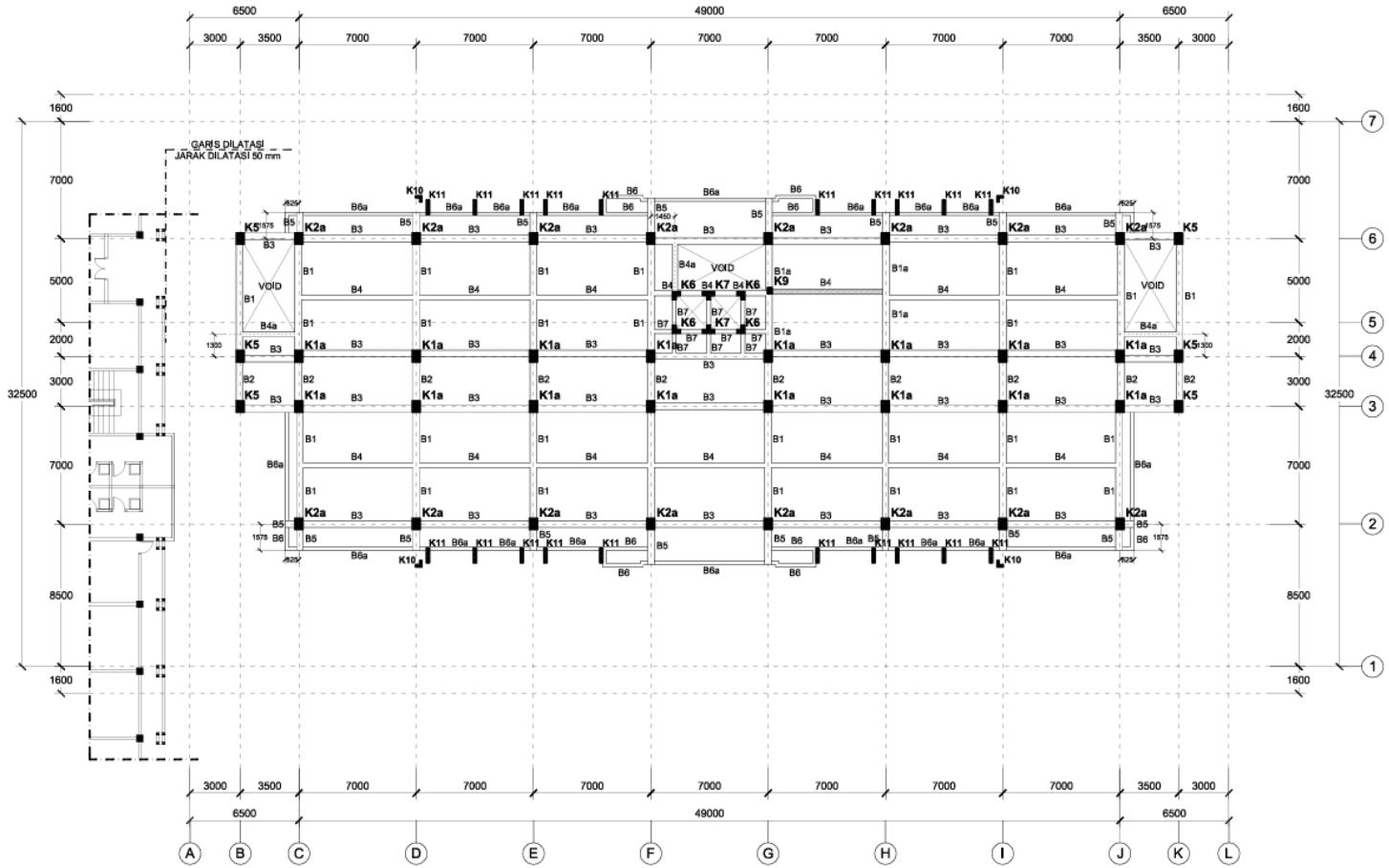
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Appendix 3 Beams Plan of Elevation +12.55



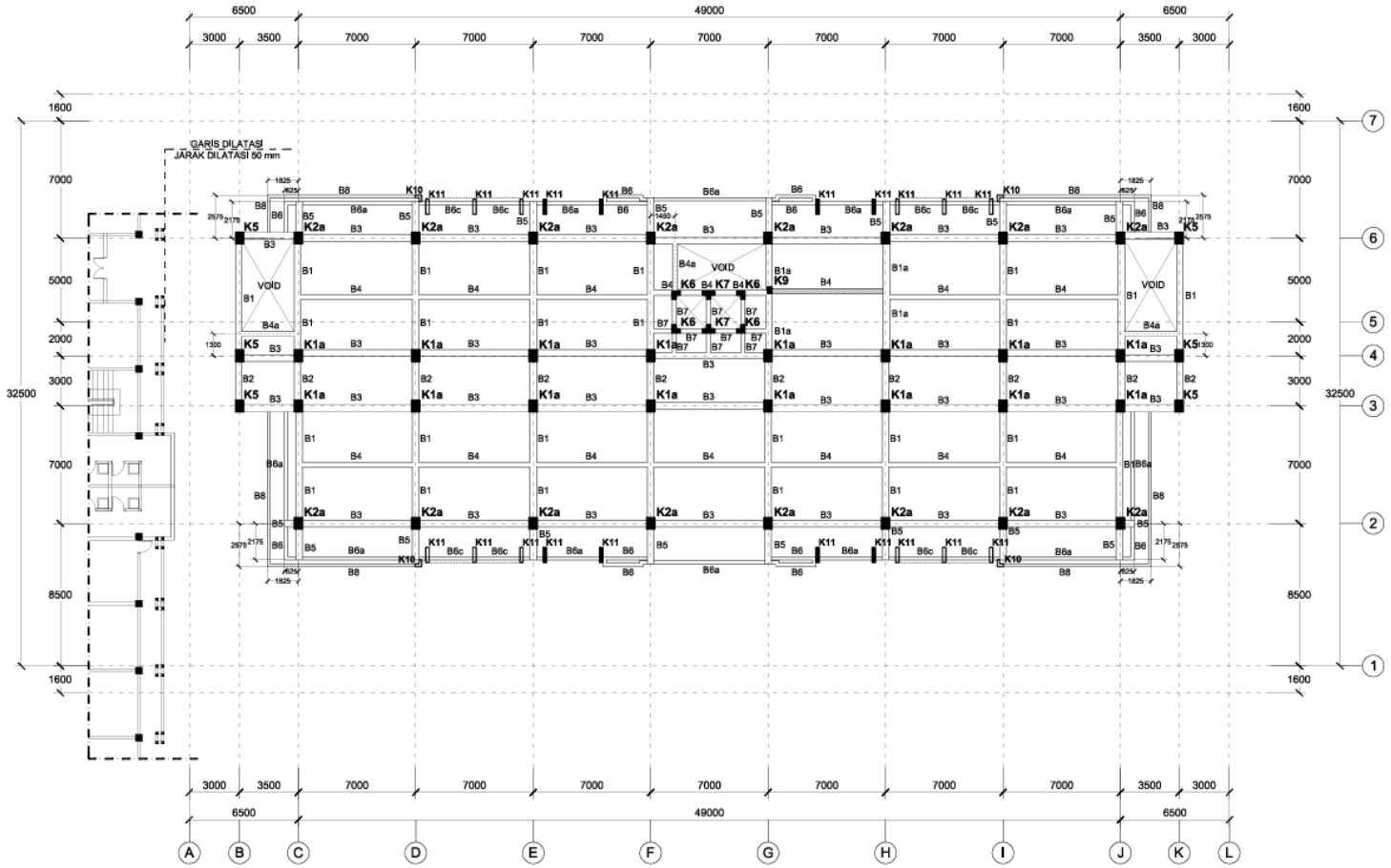
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Appendix 4 Beams Plan of Elevation +16.75



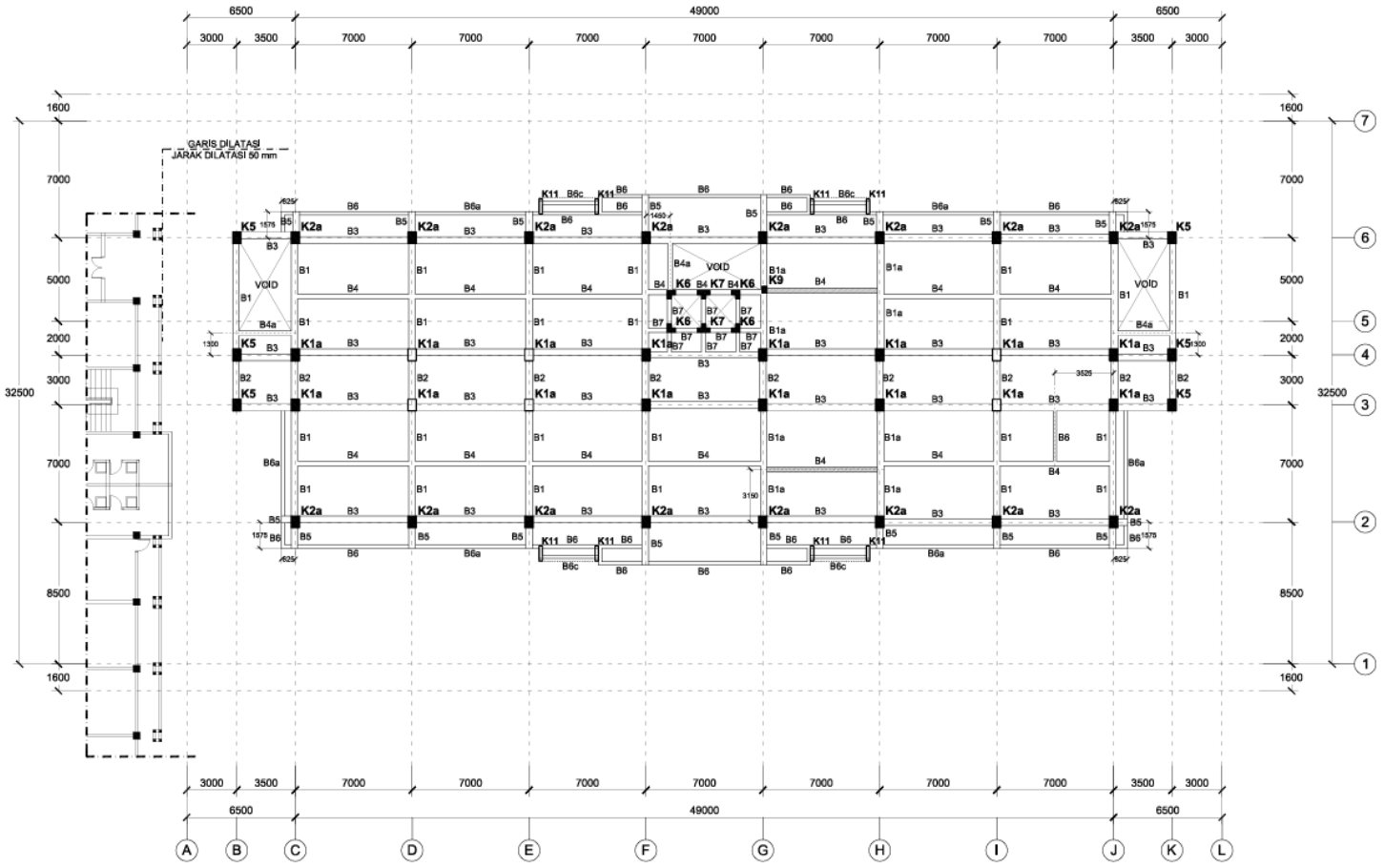
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Appendix 5 Beams Plan of Elevation +20.95



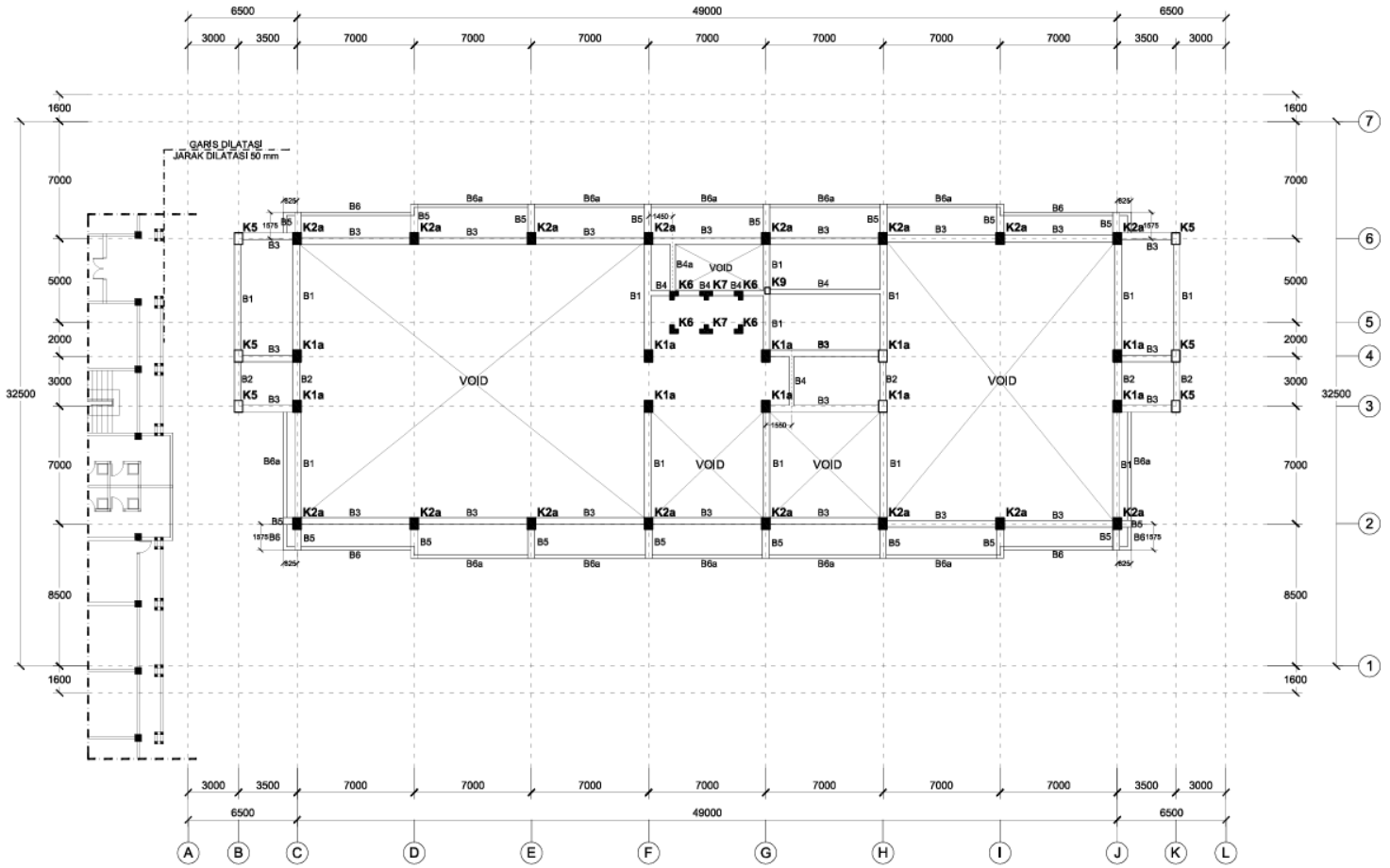
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Appendix 6 Beams Plan of Elevation +25.15



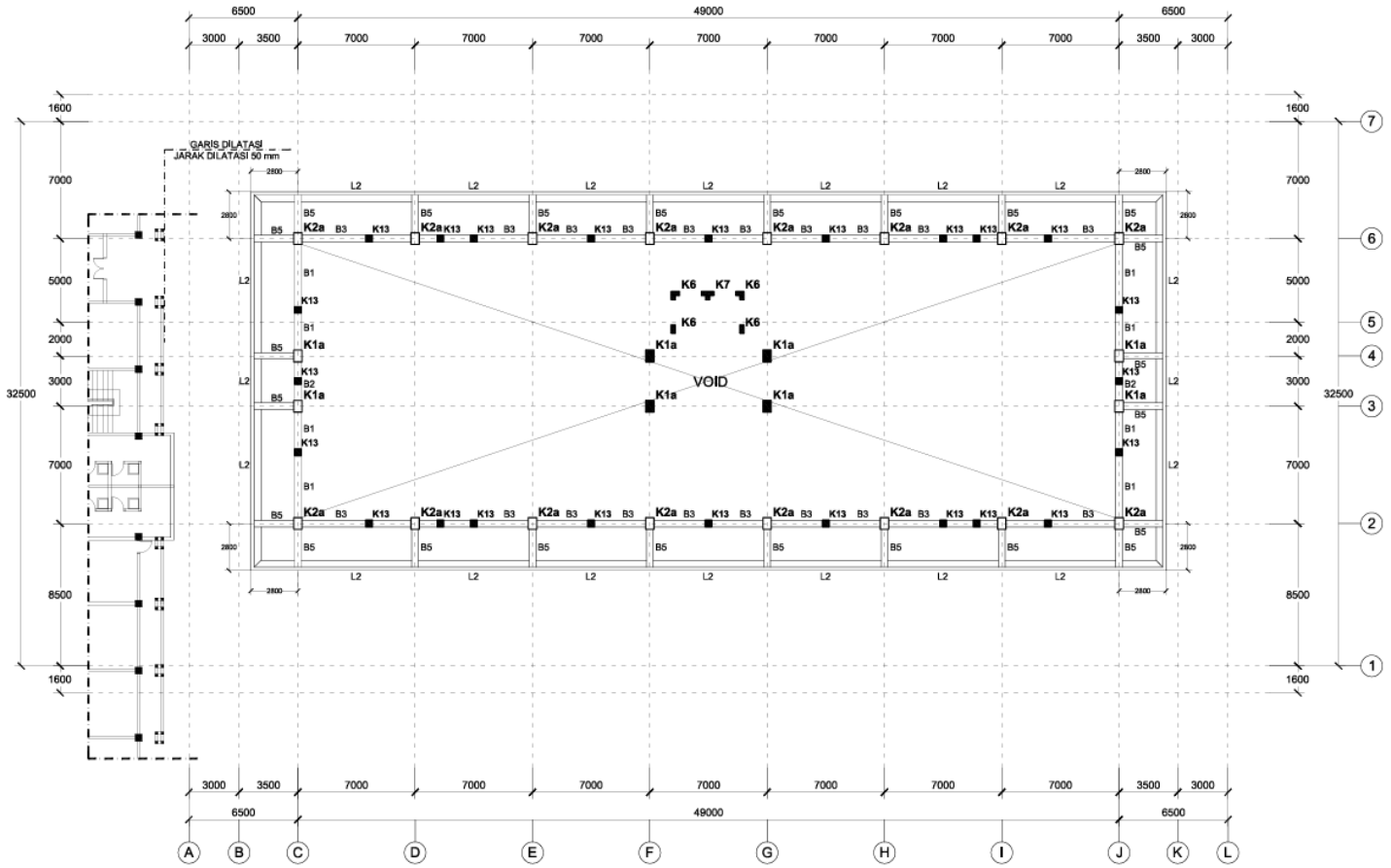
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Appendix 7 Beams Plan of Elevation +29.35



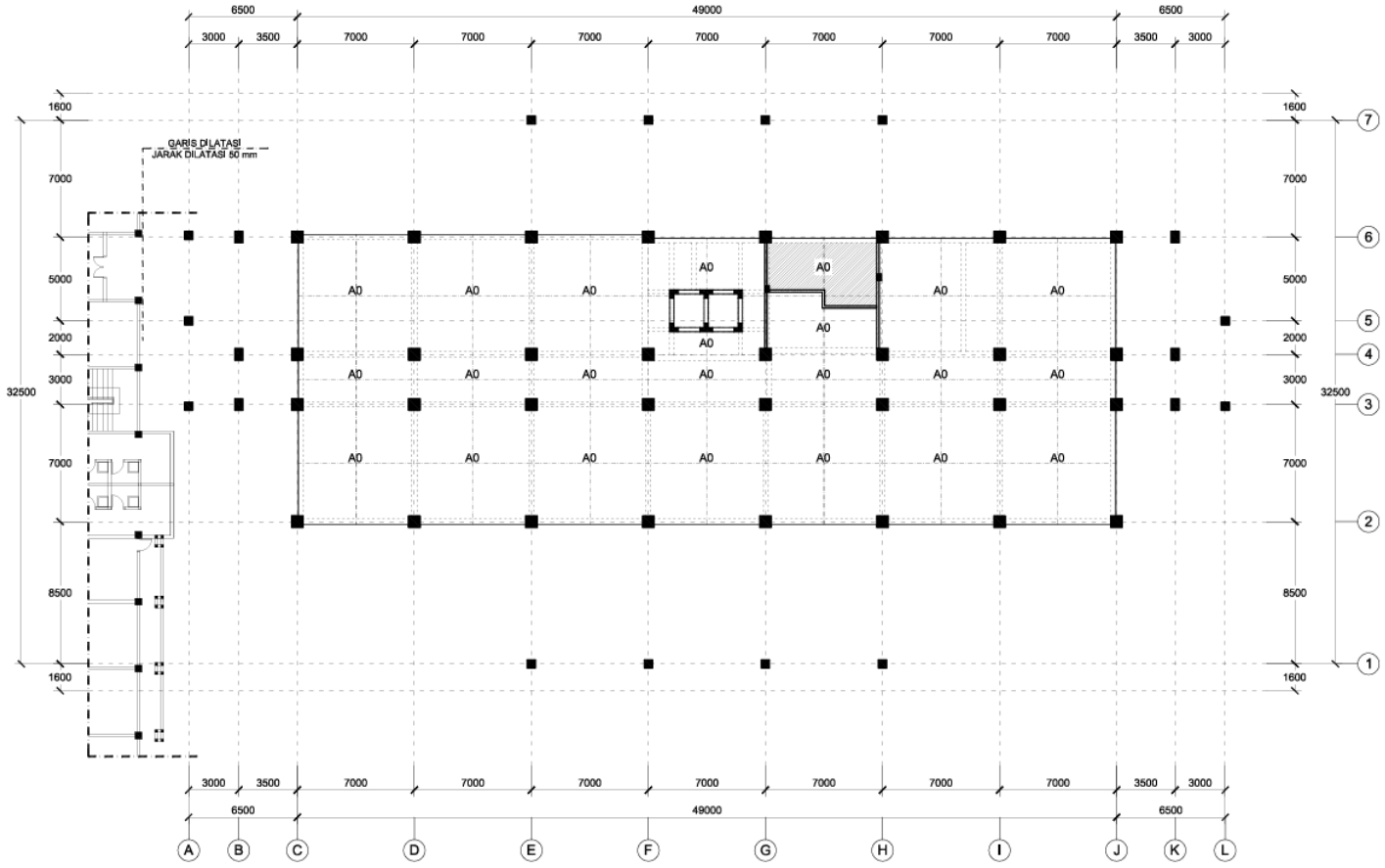
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Appendix 8 Beams Plan of Elevation +31.4



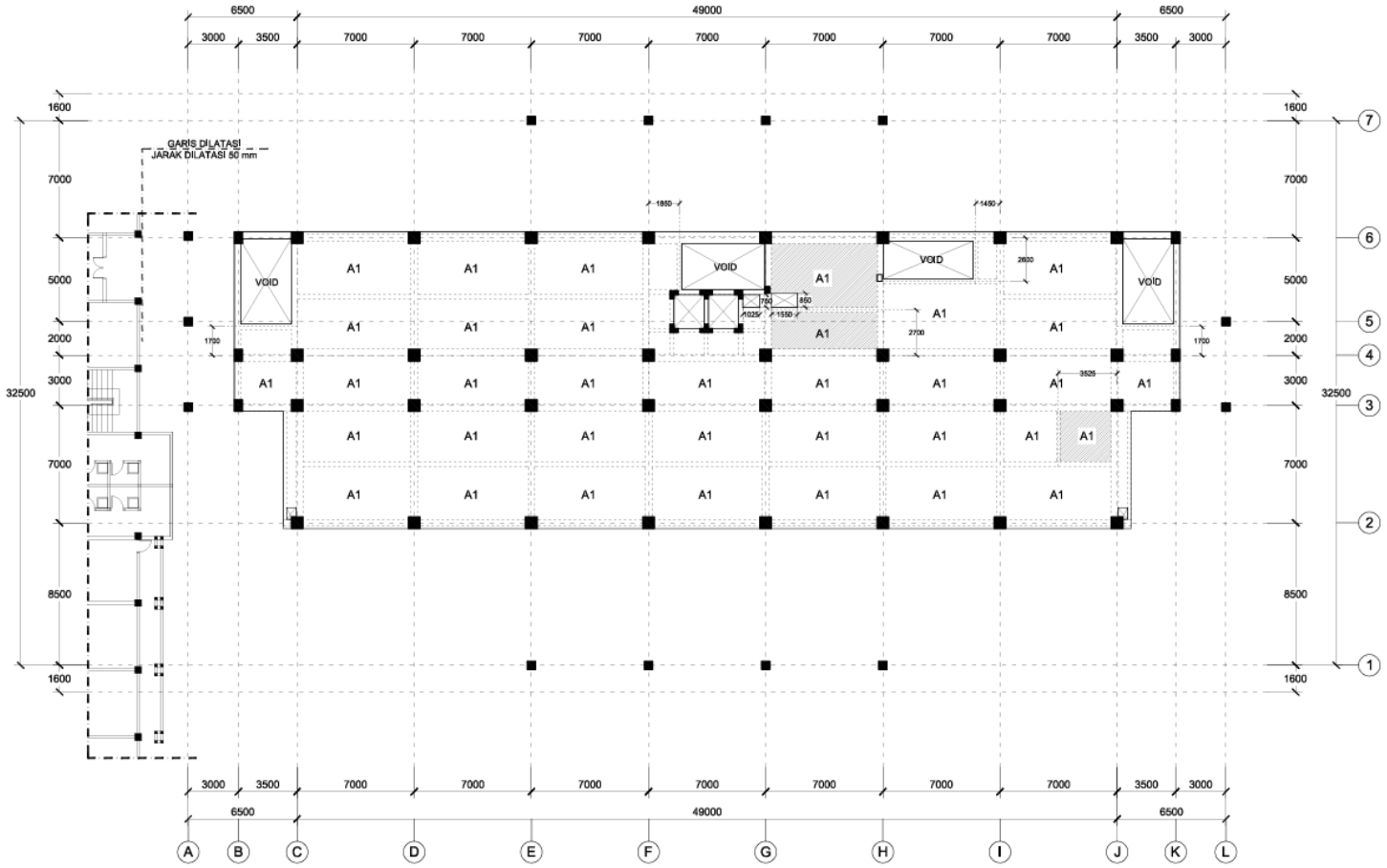
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Appendix 9 Slab Plan of Elevation -3.65



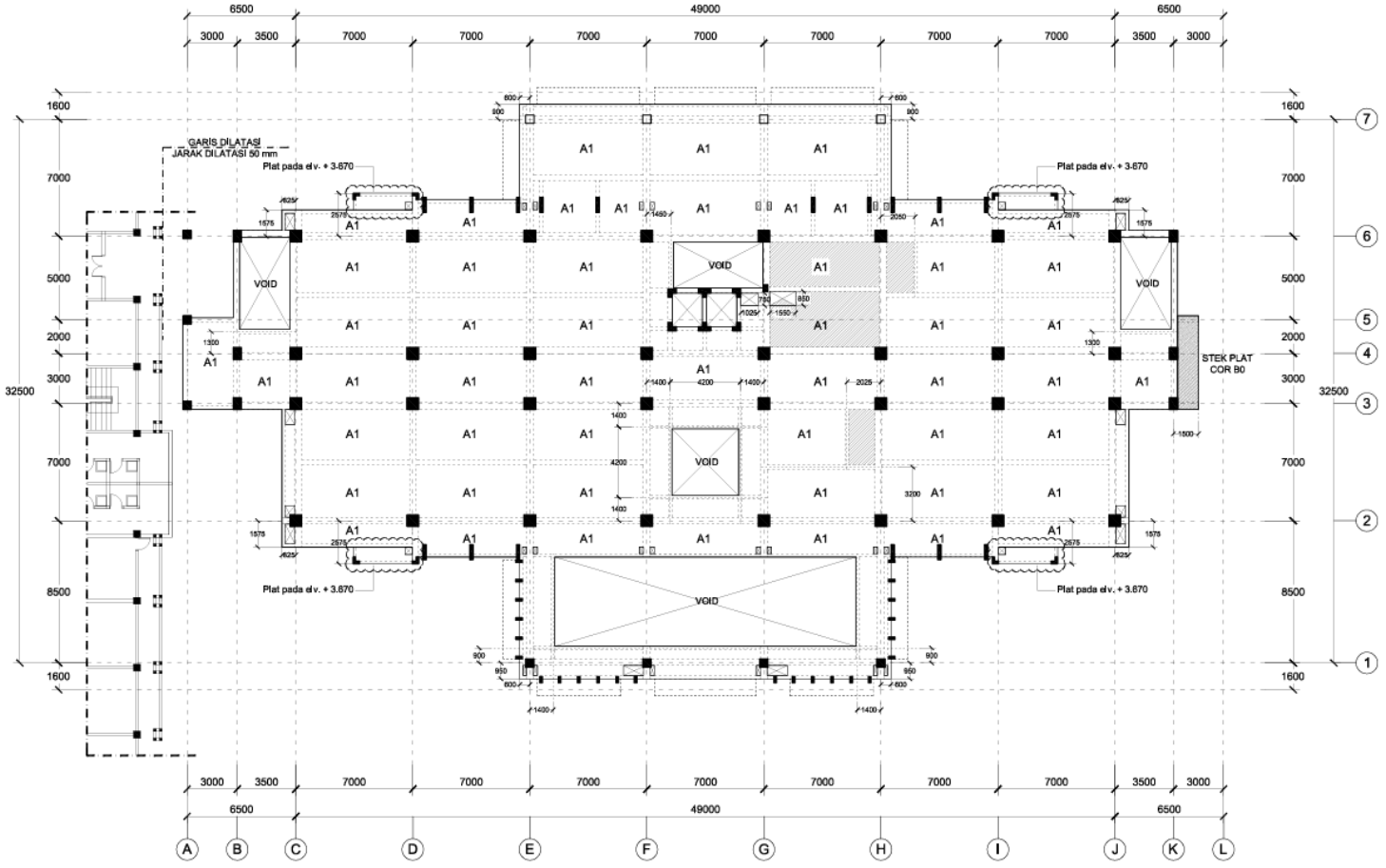
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Appendix 10 Slab Plan of Elevation -0.05



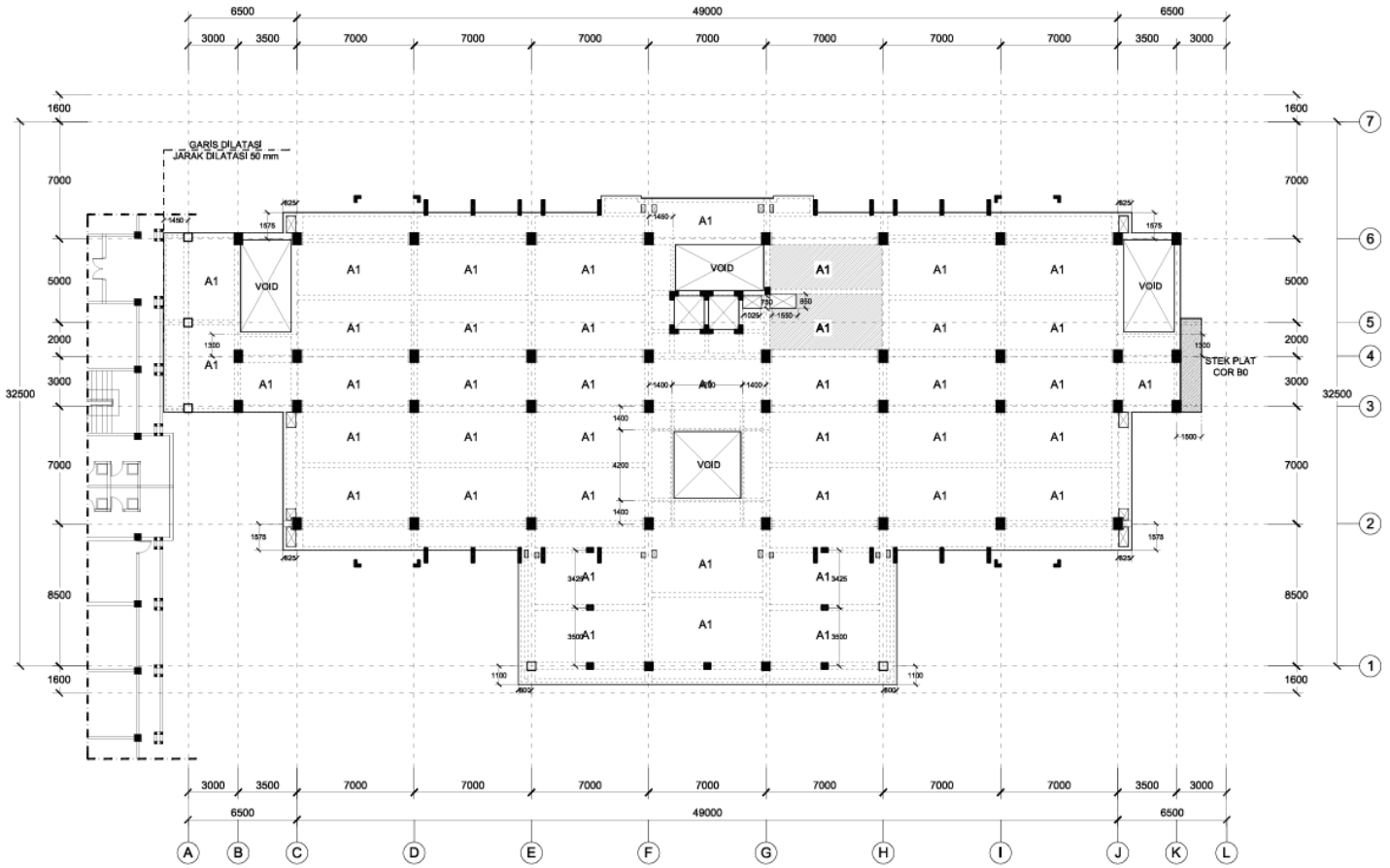
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Appendix 11 Slab Plan of Elevation



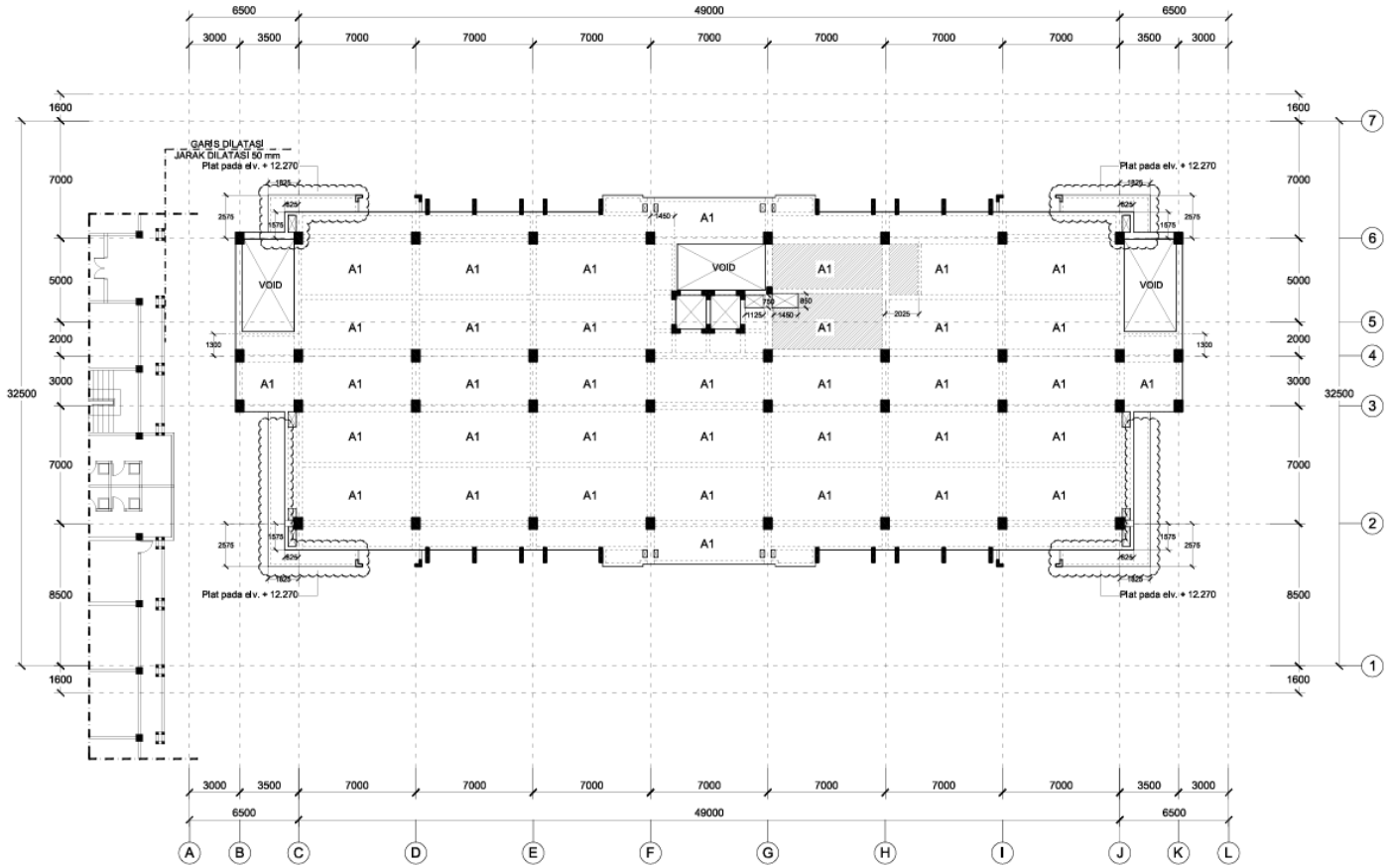
(Source: PT Pola Data Consultant, 2015)

Appendix 12 Slab Plan of Elevation + 8.35



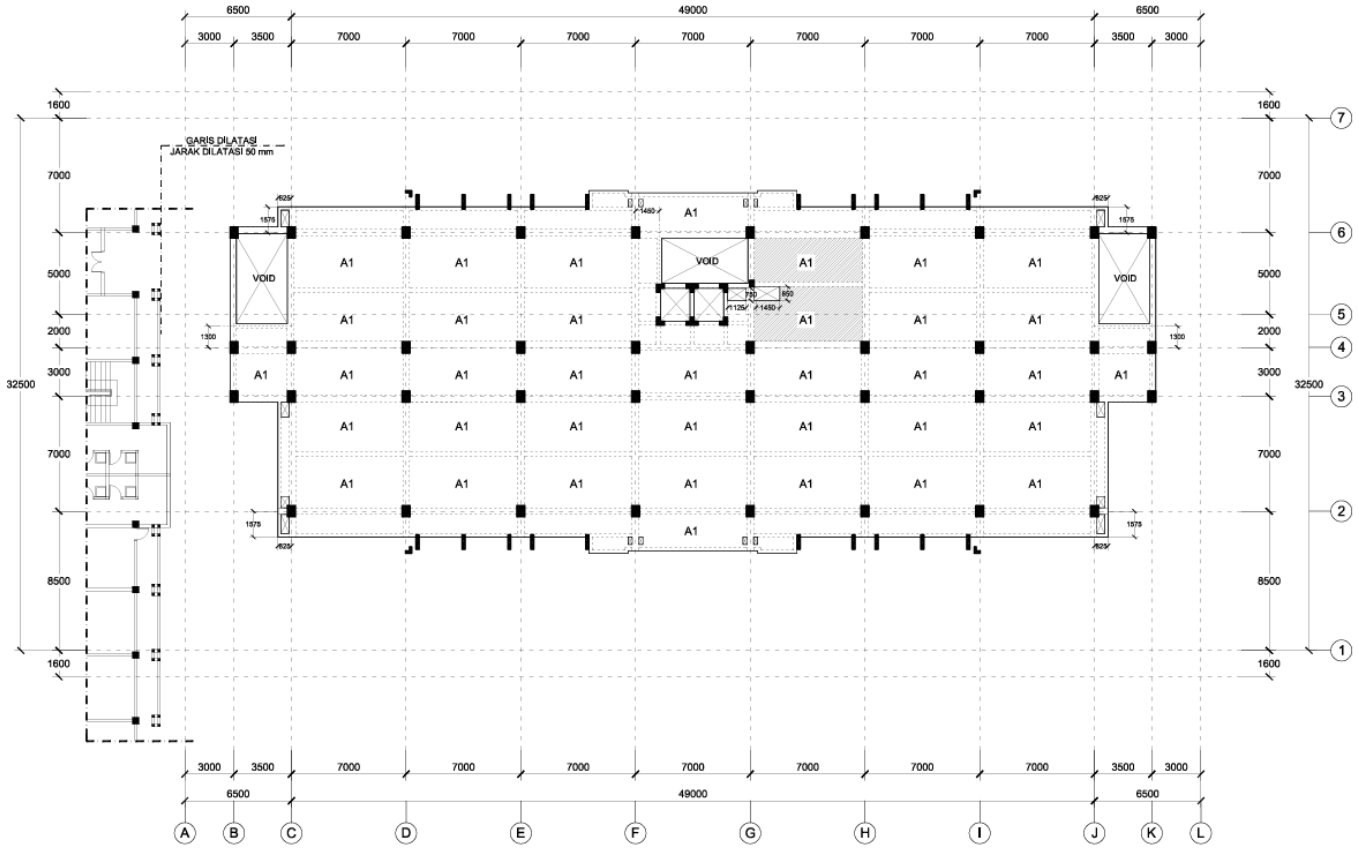
(Source: PT Pola Data Consultant, 2015)

Appendix 13 Slab Plan of Elevation + 12.55



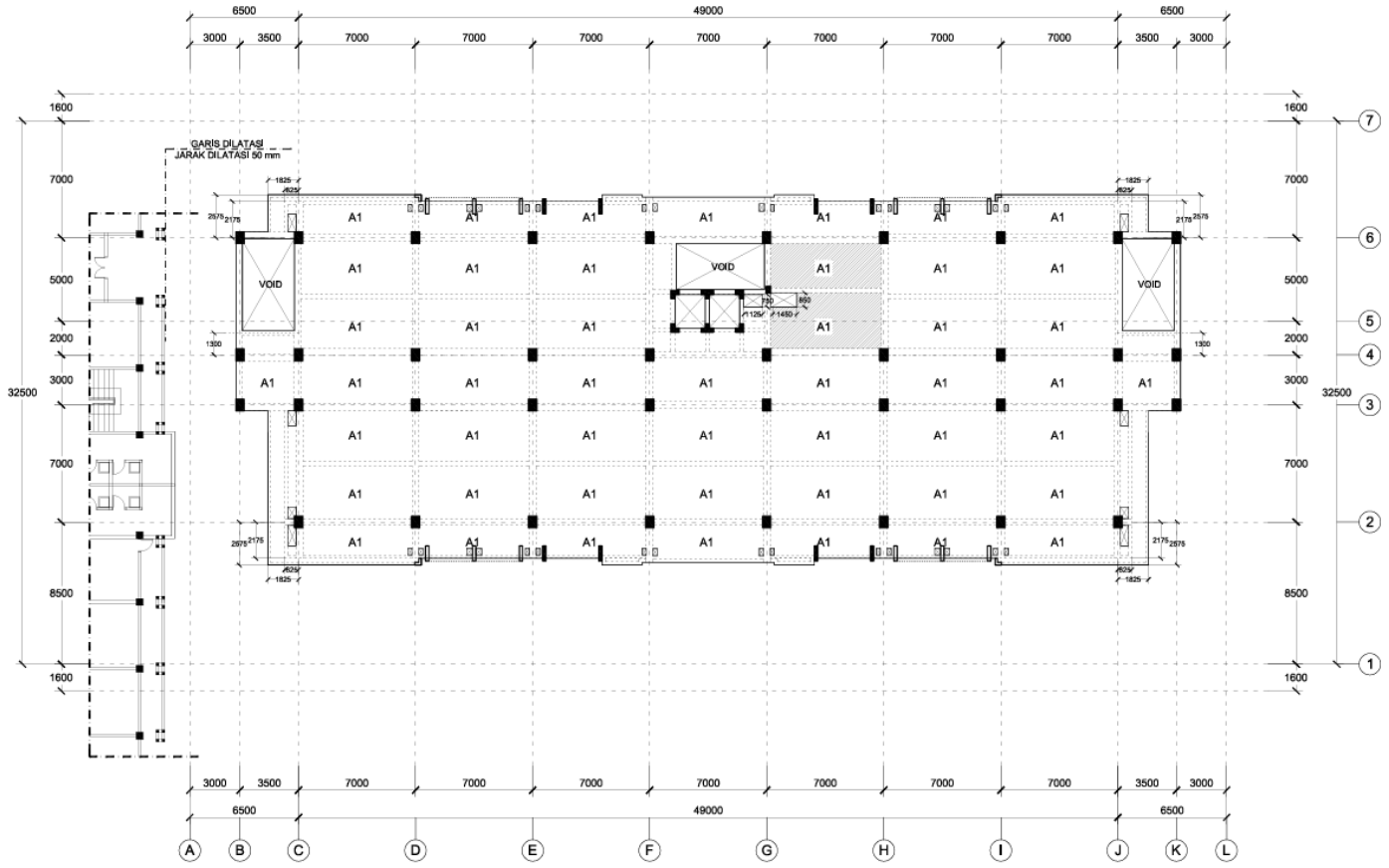
(Source: PT Pola Data Consultant, 2015)

Appendix 14 Slab Plan of Elevation + 16.75



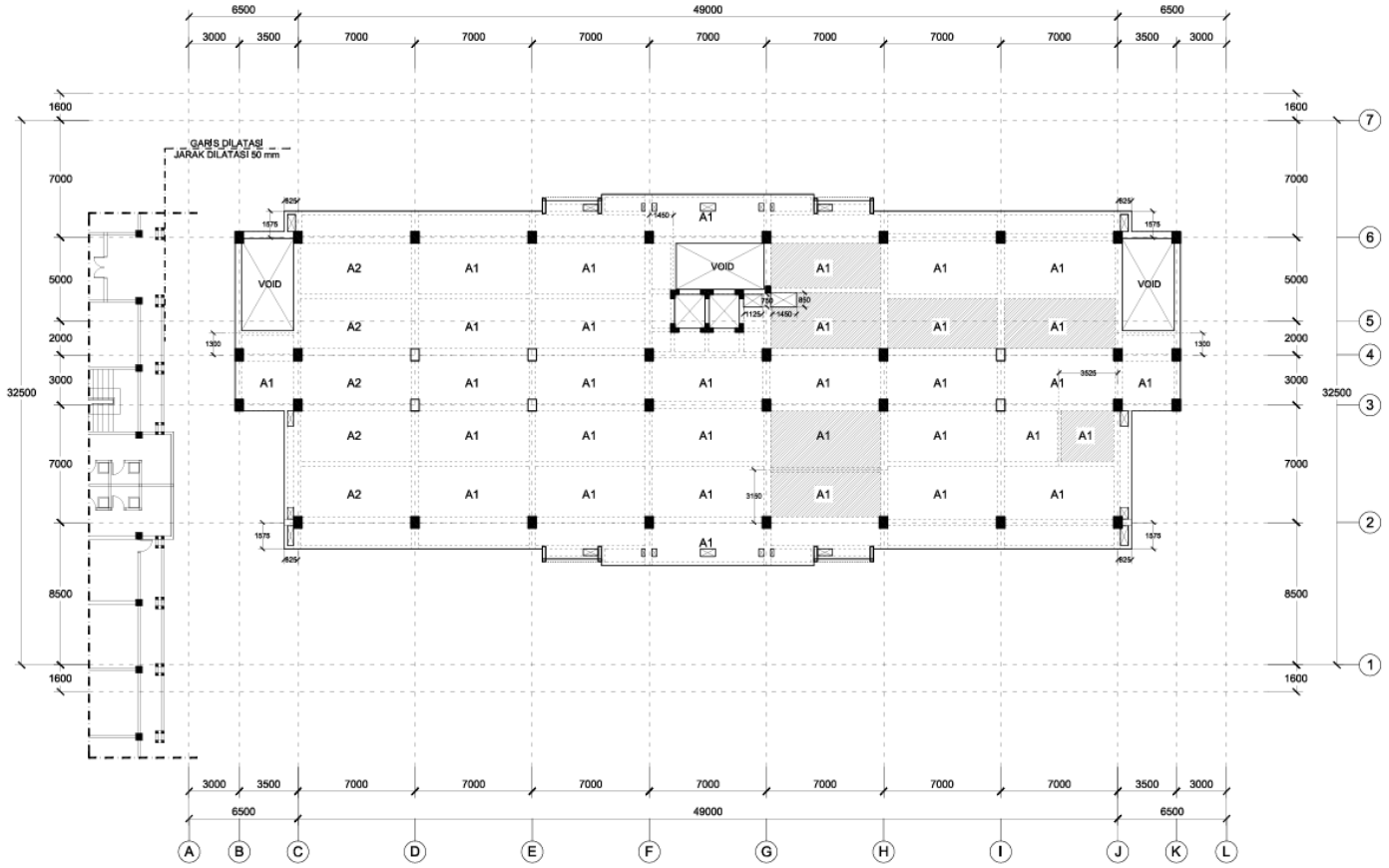
(Source: PT Pola Data Consultant, 2015)

Appendix 15 Slab Plan of Elevation +20.95



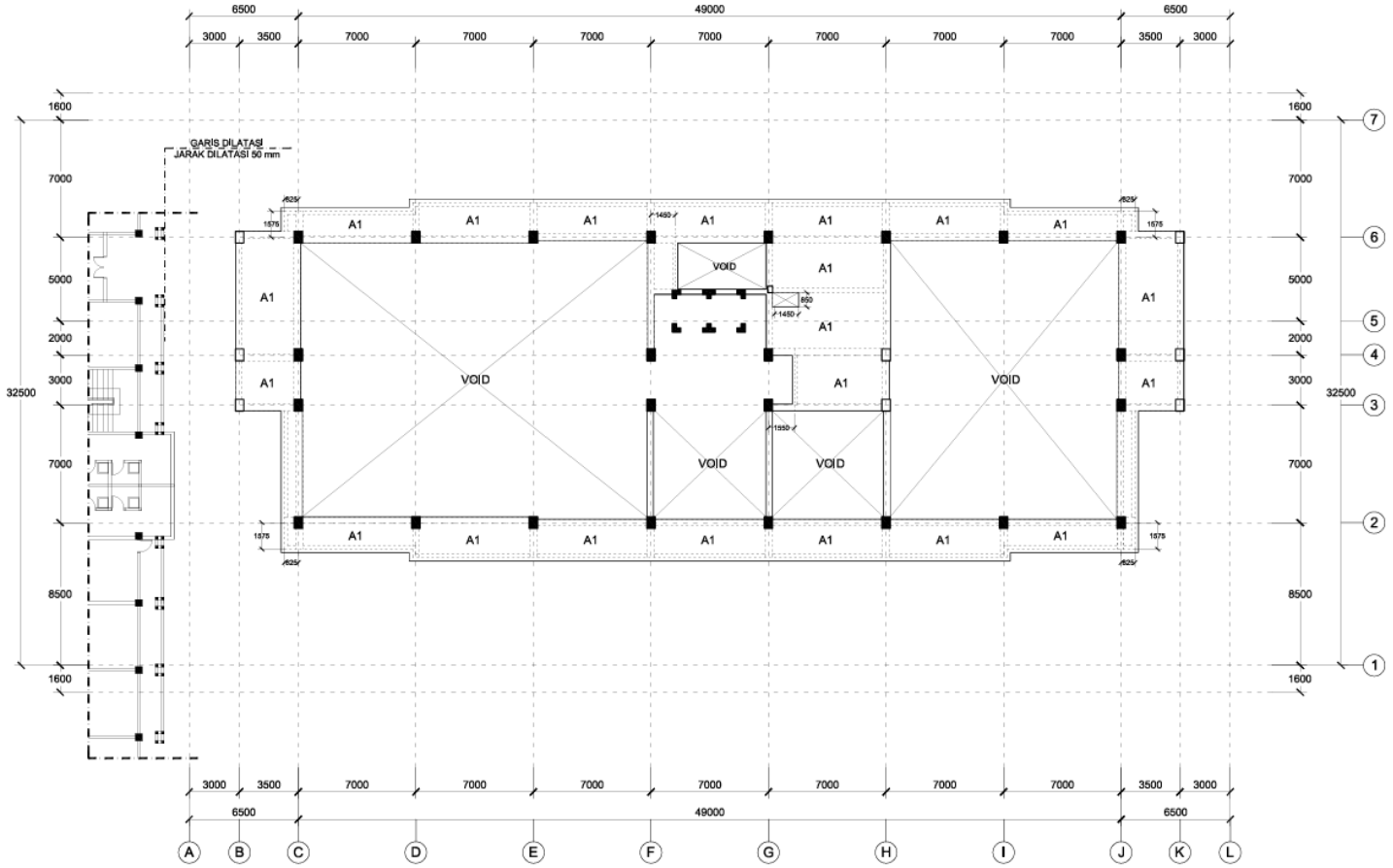
(Source: PT Pola Data Consultant, 2015)

Appendix 16 Slab Plan of Elevation + 25.15



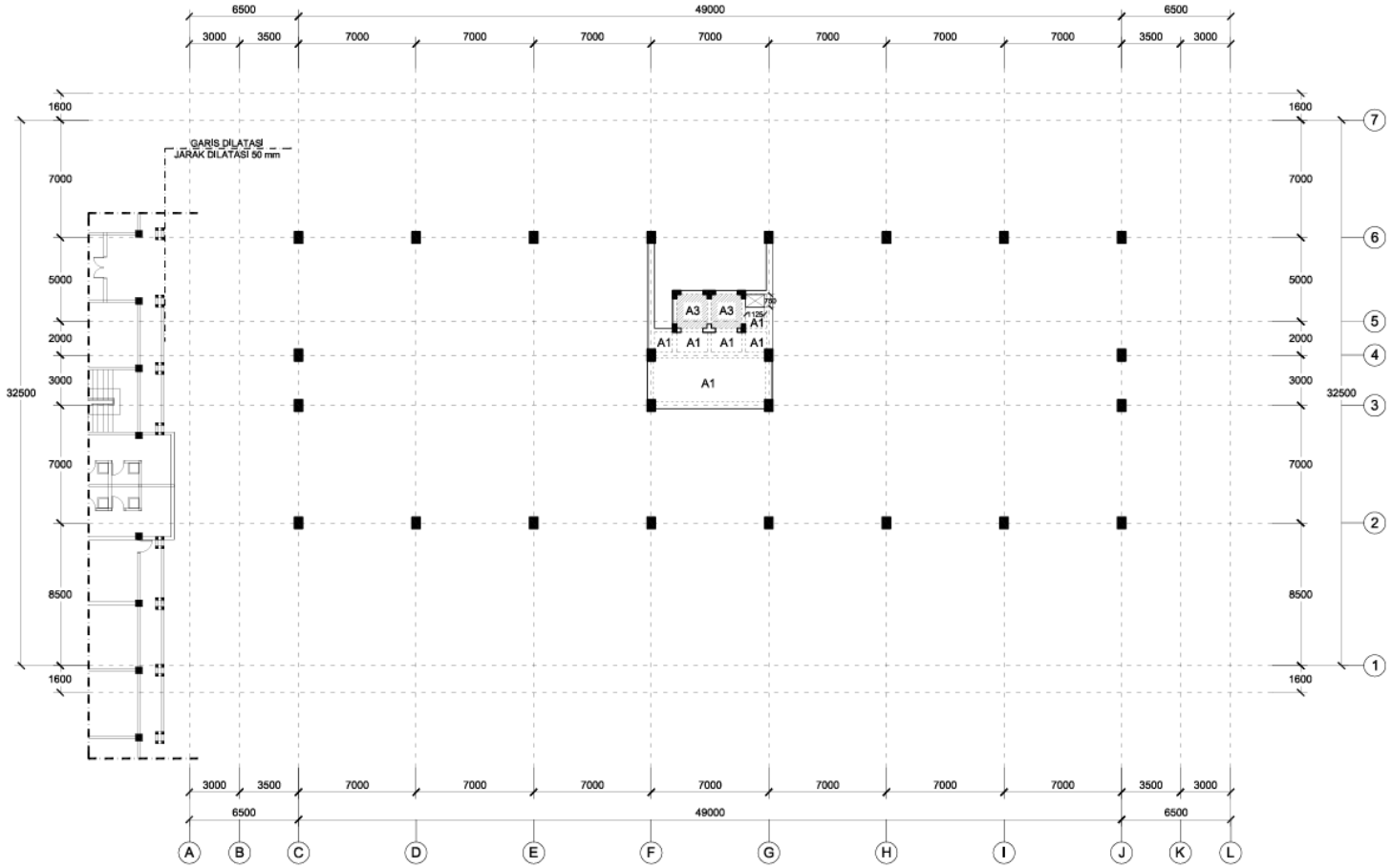
(Source: PT Pola Data Consultant, 2015)

Appendix 17 Slab Plan of Elevation + 29.35



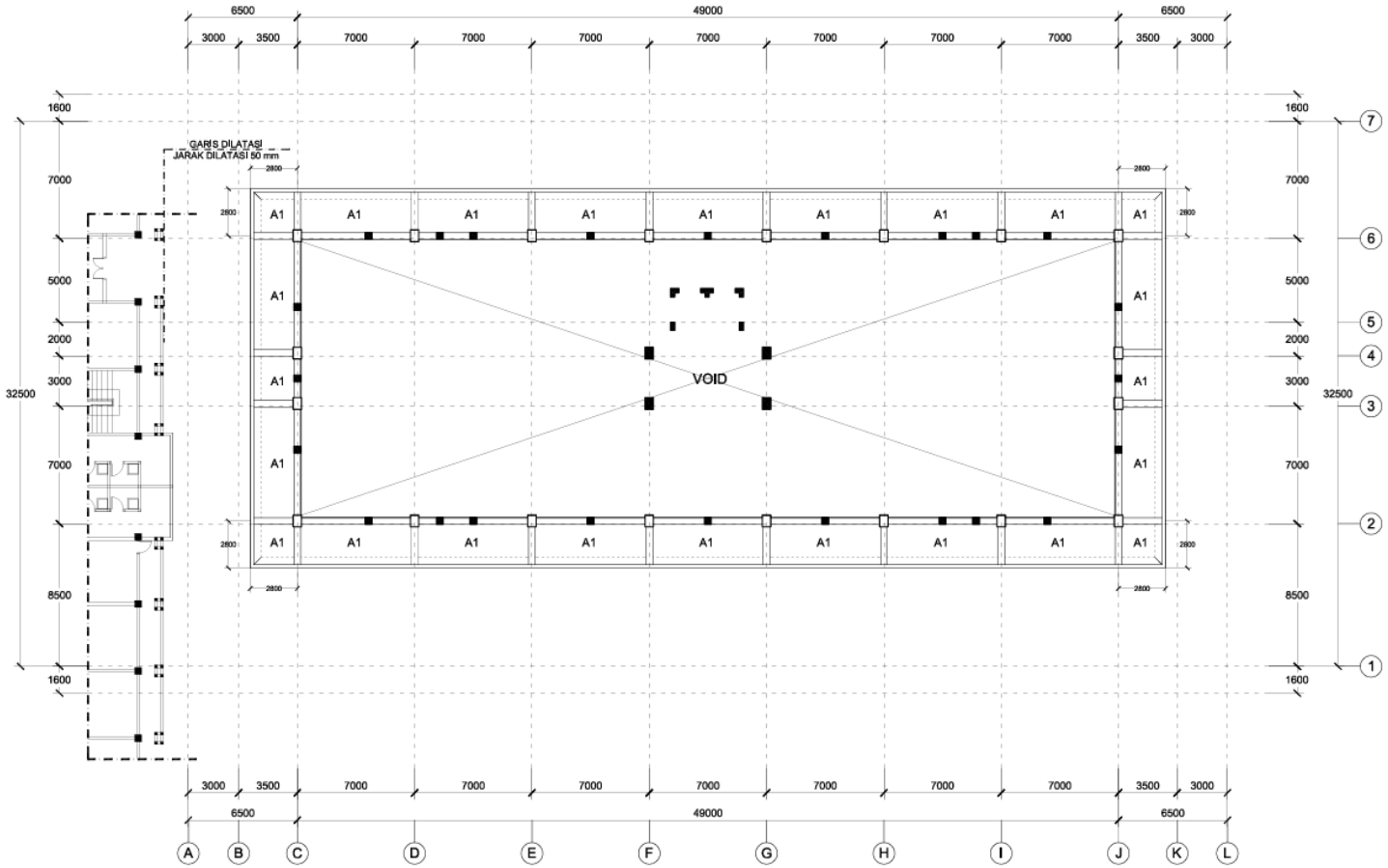
(Source: PT Pola Data Consultant, 2015)

Appendix 18 Slab Plan of Elevation + 30.25



(Source: PT Pola Data Consultant, 2015)

Appendix 19 Slab Plan of Elevation + 30.92



(Source: PT Pola Data Consultant, 2015)