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INTERPRETATION OF SAP2000 ANALYSIS RESULTS USING THE DESIGN RESPONSE SPECTRUM METHOD IN EARTHQUAKE RESISTANCE IN THE STRUCTURAL PERFORMANCE OF HIGH-STORY BUILDINGS ACCORDING TO SNI 1726:2019

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ABSTRACT
This research investigates earthquake dynamics and their impact on structural responses, focusing on building flexibility and rigidity's influence on seismic performance. Using SAP2000 version 24 software as per 1726:2019 guidelines, the KC BTN Bank office building in Cirebon was evaluated. Seismic load data from RSA PuSGeN Cipta Karya (Desain Spektra Indonesia 2021) assessed the structure's safety against Indonesian seismic standards. The analysis confirms compliance, achieving safety limits and a 90% modal participation mass ratio per Article 7.9.1 of SNI 1726:2019. The building's fundamental periods (T) are 0.562 seconds (Tc) and 0.546 seconds (Ta Min) for each direction. Base reactions reached a 100% scale factor, meeting Article 7.9.1.4.1 requirements. Story displacements in the X and Y directions due to lateral sway are safe, with drifts below the allowable values in Table 20 of SNI 1726:2019. The findings show that the structural design meets earthquake-resistance requirements, ensuring safety and compliance. This research underscores the need for thorough design reviews, confirming that main structural elements align with criteria for multi-story buildings, and provides insights for optimizing designs to enhance resilience and safety in seismically active regions.

Keywords: analysis sap2000; base shear reaction; participating mass ratio; response spectrum; story drift

INTRODUCTION

The tectonic plate situation in Indonesia is quite complex because the region lies directly on the equator (Indriasari et al., 2017; Nugroho, 2019; Pribadi et al., 2021a; Sinaga et al., 2022). Geographically, this area experiences frequent earthquakes due to high seismic activity (Hakim et al., 2022; Sabah & Sil, 2023; Xue et al., 2022). Consequently, natural earthquakes occur, infrastructure is damaged, and there are casualties (Firdha et al., 2021; Hakim et al., 2022; Pelupessy & Silverman, 2024; Pribadi et al., 2021b; Shidik et al., 2024).

Cirebon is a city in West Java, Indonesia, located on the northern coast of Java Island. It serves as a connection between Jakarta and Surabaya via the crossroads of North Java and Central Java. Due to its geographical coordinates, ranging from 108°40′ to 108°48′ E longitude and 6°30′ to 7°00′ S latitude, Cirebon functions as an indirect gateway to West Java (Adistriyono, 2022). Given that its location extends from the northwest to the southeast, some areas of the Cirebon Plain are in lowland regions. The natural environment of Cirebon largely lies along the coast, increasing the likelihood of tectonic activity (Setda Cirebon, 2023).

The response spectrum design is a dynamic analysis method that uses a curve-shaped response spectrum representing the relationship between the structure's vibration period (T) and the maximum spectral response (S_a) (Ahmed & Ghazi, 2022; Calvi & Andreotti, 2022; Freeman, 2007; Fu et al., 2022; Xue et al., 2022). This design is based on a Single Degree of Freedom (SDOF) system with damping ratios of acceleration, displacement, and velocity weighted by specific external forces (earthquake) (Darmawan et al., 2021; Ma et al., 2025; Momeni et al., 2025; Yang & Xie, 2024).

The Indonesian National Standardization Agency (BSN) established the standard SNI 1726:2012 for seismic design procedures applicable to buildings and non-building structures. Subsequently, SNI 1726:2019 was issued on December 17, 2019, to develop this regulation's guidelines further. This standard was prepared following PKBSN number 4 of 2016, which pertains to the drafting guidelines for the Indonesian National Standard (SNI), and it is based on the national earthquake map from 2017. This regulation underwent a public consultation phase from August 30, 2019, to October 29, 2019, and was ultimately approved as an SNI by BSN's General Director, Bambang Prasetia (SNI 1726: 2019). However, the existing literature lacks a comprehensive case research focusing on the practical application and validation of SNI 1726:2019 for high-rise buildings in Cirebon. This research aims to fill that gap.

The structure of the building includes structural components such as foundations, columns, slopes, beams, slabs, and shear walls. These components subsequently transfer loads to the ground, which are categorized into dead loads and environmental loads. Consequently, software is required to accurately ensure the durability of the planned load according to SNI standards (Arianto et al., 2024). To support and simplify the structural design of buildings, the advanced software Structural Analysis Program (SAP2000), developed by the American company Computers Structures Incorporated (CSI), is available to assist in performing 2D and 3D structural design analysis. This technology is said to simplify the engineering process of load performance calculations in the structural elements of buildings (Hukama & Erizal, 2023). While SAP2000 is widely utilized, this research offers a detailed analysis of its application in SNI 1726:2019, specifically for a high-rise building in Cirebon, providing insights into potential challenges and solutions.

As the complexity of modern building structural planning rapidly advances, it is crucial to pay special attention to the safety, reliability, and performance aspects of building infrastructure in terms of its ability to withstand seismic loads. SNI 1726:2019 states that the durability and ability of robust structures to withstand earthquakes must be ensured safely and optimally through its standards (D. Marpaung, 2023).

Previous research has explored various aspects of seismic design using SNI 1726:2019. For example, Karunia et al. (2020) investigated the influence of variations in the structural modification response factor reduction on the performance of high-rise reinforced concrete building structures. Furthermore, Arjakoni & Lutfi (2022) focused on evaluating the seismic performance of reinforced concrete building structures with variations in concrete compressive strength. However, this research uniquely contributes by providing a detailed, practical case research focused on the application of SAP2000 version 24 to analyze the seismic performance of a specific high-rise bank building (KC BTN Cirebon) according to SNI 1726:2019, offering a comprehensive evaluation of its structural integrity and compliance in the context of Cirebon's specific seismic conditions. Furthermore, unlike the previous studies, this research validates the design using local seismic data (RSA PuSGeN Cipta Karya) specific to the Cirebon region.

The focus of this research is to present the structural analysis results regarding the seismic performance of high-rise buildings based on the acquisition of the design response spectrum. After that, we modeled using SAP2000 version 24 software and reviewed the land conditions, specifications, and materials used to construct the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon). The focus of the issue is based on the applicable SNI guidelines precisely: (1) SNI 1726:2019 "Seismic planning procedures for buildings and non-building structures", (2) SNI 2847:2019 "Requirements and explanations for structural concrete in buildings", and (3) SNI 1727:2020 "Minimum design loads and related standards for buildings and other structures." While previous studies have explored seismic performance assessments using response spectrum analysis, this research uniquely focuses on the KC BTN Bank office building in Cirebon, providing a detailed case research and offering specific insights into the application of SNI 1726:2019 for buildings in this region. Furthermore, this research thoroughly examines design model reviews, confirming the alignment of primary structural elements and design data with standard criteria for multi-story buildings, which has not been extensively addressed in prior literature.

The reason for conducting the research is based on the following objectives: (1) to obtain the design response spectrum analysis results from structural modeling using SAP2000 version 24 when reviewing the KC BTN Cirebon building, (2) to understand the suitability of structural modeling using SAP2000 version 24 in seismic calculations based on SNI 1726:2019 for the KC BTN Cirebon building, and (3) to find solutions in case of discrepancies in the structural modeling results of the KC BTN Cirebon building's seismic analysis using SAP2000 version 24.

METHOD

This quantitative research used the design response spectrum dynamic analysis method to analyze the structural model of the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon). This method determines the durability of building structures against seismic loads and obtains more accurate evaluation results of the seismic forces acting on high-rise building structures (Fadzilah et al., 2021).

The structural analysis was conducted using the output results from SAP2000 version 24.2.0 Ultimate 64-bit, which were then compared with the calculation results according to the equations in the SNI 1726:2019 guidelines. In addition to the SAP2000 2024 software, auxiliary software such as the RSA PuSGeN Design Spectrum Indonesia 2021 manual application by Cipta Karya (2017 national earthquake map), Microsoft Word 2016, Microsoft Excel 2016, and AutoCAD 2014 were also used to formulate the final research results.

In the preparation of the research on the structural design of the branch Bank Tabungan Negaraoffice building (KC BTN Bank, Cirebon), primary data was used which was obtained from direct communication and included as-built drawing data as a grid reference, building technical data, building material specifications and land data around the project location. SAP2000 was selected for its advanced finite element analysis capabilities, widespread use in structural engineering for seismic assessments, and ability to accurately model complex structural systems under dynamic loads. The software's compliance with international standards, including those relevant to SNI 1726:2019, further supports its choice for this research. The stages in the research for creating the building structure model include preliminary building design, modeling with SAP2000 v24, creating a response spectrum according to SNI 1726:2019, inputting load patterns according to SNI 1727:2020, reviewing the modal natural mass participating behavior of the structure, checking the base shear force, and checking the story drift (Nur Sholeh, 2022).

The research analyzes the entire structural system of the KC BTN Bank office building, representing a comprehensive sample of its structural elements. This approach is justified by the need to evaluate the building's overall seismic performance according to SNI 1726:2019. The SAP2000 model incorporates detailed data on all structural components, including dimensions, material properties, and connection details.

This research aims to determine and examine the conformity of the structural model created in SAP2000 version 24 software in calculating earthquake-resistant buildings according to SNI 1726:2019. Therefore, a definition of the load pattern in SAP2000 is needed concerning SNI 1726:2019 and SNI 1727:2020.

The SNI 1726:2019 guidelines (adopted from ASCE 7-16) stipulate that structures must be designed to be earthquake-resistant by considering factors such as seismic design category, response spectrum, and earthquake load combinations. By defining the correct earthquake load pattern, the calculation of internal forces due to the earthquake becomes more accurate. In addition, SNI 1727:2020 provides guidelines on minimum loads for various types of structures, including combinations of wind loads, live loads, dead loads, and others. In addition, when creating a load pattern for a structure, meshing must be done on the floor slab and roof slab. This allows for the distribution of internal forces, such as shear forces, and the forces across the plate to be calculated more evenly (Dwiyantoro et al., 2023).

The modeling of the planned structure's drawings will be created in a 3D perspective by incorporating load values such as dead load (D), superimposed dead load (SIDL), live load (L), wind load (W), rain load (R), and earthquake load (E). Furthermore, to determine the parameters of an analysis on the structural performance using the response spectrum dynamic method for the KC BTN Cirebon building, calculations are performed according to the rules in Articles 6.2, 6.3, and 6.4 of the SNI 1726:2019 guidelines. Therefore, the calculations follow Equations (1)-(10).

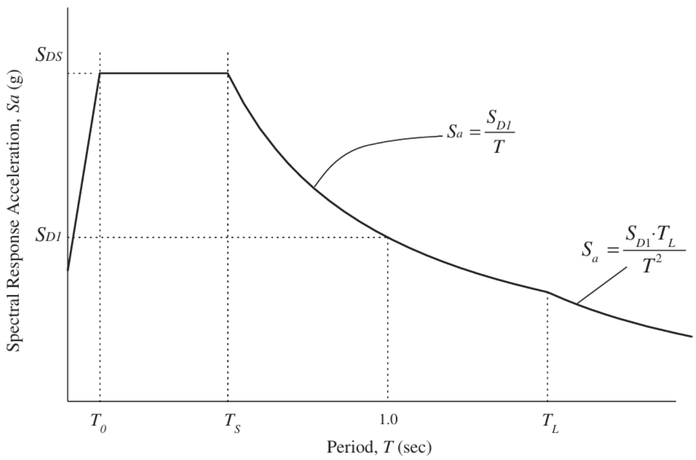


Figure 1. Response Spectrum Curve (ASCE 7-16, Figure 11.4-1)

$S_{MS} = F_a S_s$ (1)

$S_{M1} = F_v S_1$ (2)

$S_{DS} = \frac{2}{3} S_{MS}$ (3)

$S_{D1} = \frac{2}{3} S_{M1}$ (4)

$S_a = S_{DS}\left(0{,}4+0{,}6\ \frac{T}{T_0}\right)$ (5)

$S_a = S_{DS}$ (6)

$S_a = \frac{S_{D1}}{T}$ (7)

$S_a = \frac{S_{D1} T_L}{T^2}$ (8)

$T_0 = 0{,}2\frac{S_{D1}}{S_{DS}}$ (9)

$T_s = \frac{S_{D1}}{S_{DS}}$ (10)

Explanation:

S_{MS} = response spectrum acceleration parameters for a short period
S_{M1} = response spectrum acceleration parameters for a 1 second period
F_a = coefficient for short period 0,2 seconds
F_v = coefficient for long period 1 seconds
S_s = response spectrum acceleration parameters short period MCE, attenuation 5%
S_1 = response spectrum acceleration parameters 1 second period MCE, attenuation 5%
S_{DS} = response spectrum acceleration parameters short period, attenuation 5%
S_{D1} = response spectrum acceleration parameters 1 second period, attenuation 5%
S_a = response spectrum acceleration
T_0 = the first time a building responds to vibration
T_s = travel time for short periods, attenuation 5%
T = fundamental period of building structure
T_L = long period transition map Figure 20 SNI 1726:2019

Every structure has a vibration period when disturbed by forces such as wind load or earthquakes. In the dynamic response spectrum analysis, the vibration period is represented by the type of mode shape. That period must be controlled to avoid the occurrence of a structure that is too flexible or too rigid (over stress). Therefore, a suitability analysis can be conducted on this building structure. The obtained results will later be evaluated by SNI 1726:2019 with output data in the form of mass participation tables, base shear, and story drift (Fauzan et al., 2024).

According to the provisions of Article 7.9.1 SNI 1726:2019, the participating mass ratio explains that analysis is allowed with a minimum tolerance alternative of 90% to achieve combined modal mass participation of 100% of the building's mass. Before calculating that value, it is necessary first to obtain the fundamental period value of the structural approach (T_a) used to estimate the natural vibration period of a building structure. Then, the calculation results from the minimum and maximum T_a equations will serve as the final reference for the output value obtained in the SAP2000 analysis (T_c), which is taken from the first and second modes in the Modal Participating Mass Ratios (MPMR) Table with the final result determined in Equation (13)-(15). Meanwhile, the value of T_a is calculated in Equation (11) or see Table 17 and (12) or 36 in Article 7.8.2 and 7.8.2.1 of SNI 1726:2019.

$$\text{Ta Min} = C_t(h_n)X \quad (11)$$
$$\text{Ta Max} = C_u T_{a\,Min} \quad (12)$$
$$\text{if Tc} > \text{Ta Max, T} = \text{Ta Max} \quad (13)$$
$$\text{if Ta Min} < \text{Tc} < \text{Ta Max, T} = \text{Tc} \quad (14)$$
$$\text{if Tc} < \text{Ta Min, T} = \text{Ta Min} \quad (15)$$

Explanation:
$T_{a\,Min}$ = minimum limit of the fundamental period of the structure approach (sec)
$T_{a\,Max}$ = maximum limit of the fundamental period of the structure approach (sec)
C_t = fundamental period parameters approach (SNI 1726:2019, Table 18)
X = fundamental period parameters approach (SNI 1726:2019, Table 18)
h_n = height of the building structure (m)
C_u = coefficient for the upper limit in the calculated period

Seismic base shear (V), according to the provisions of Article 3.20 and Article 7.9.1.4.1 in the SNI 1726:2019 guidelines, explains that the value of dynamic base shear must not be less than 100% of the product of the static base shear. Meanwhile, SNI 1726:2019 requires that if the minimum dynamic base shear value is not met at 100%, a design scale factor value is required as the following Equation (16).

$$\text{Scale Factor} = \frac{100\%\ V_{static}}{V_{dinamic}} \quad (16)$$

After that, the story drift (Δ) was also checked. Referring to SNI 1726:2019 in Article 7.8.6, the determination of story drift in the design requires calculations that consider the difference in drift at the center of mass above and below the level being reviewed. If the center of mass of the building is not in a straight vertical line, it is permissible to calculate the deflection at the base of the level based on the vertical projection of the center of mass above it. The formula to calculate Δ is as in Equation (17) or 44 in SNI 1726:2019 as below.

$$\Delta_x = \frac{C_d . \delta xe}{I_e} < \Delta_a \qquad (17)$$

Explanation:

C_d = deflection magnification factor (SNI 1726:2019, Article 7.2.2)
δ_{xe} = deviation at x-level according to the requirements of elastic analysis
I_e = major factors in earthquakes (SNI 1726:2019, Article 4.1.2)
Δ_a = story drift permission (SNI 1726:2019, Table 20)

RESULTS AND DISCUSSION

The specifications for the materials used in the structural elements of this branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon) are K-300 grade reinforced concrete (f’c = 25 MPa) with an elastic modulus (E_c) of 23,500 MPa. Next, we will use BjTS 420 B (fy = 420, fu = 525 MPa) as the reinforcing rebar for concrete, as well as BjTS 280 and BjTP 280 for the beugel rebar; each value is (fy = 280, fu = 585 MPa). On the other hand, the elastic modulus of steel (E_s) is 200,000 Mpa, according to the design data (Structure Design Report for the Construction of the New Branch Bank BTN Office Building, Cirebon, 2022).

The type of cross-section used in constructing the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon) is similar to general building infrastructure, which is built on core structural components such as slopes, columns, beams, floor slabs, roof slabs, and shear walls. The type of foundation itself is deep and shallow, using spun piles modeled in SAP2000 version 24 as fixed supports. Next, the structural elements of columns, slopes, and beams are used with detailed dimensions.

Table 1. Specification Sections on the Building Structural KC BTN Cirebon

Section Type	Specification	Dimension (cm)
Column 1	BjTS 420 B	50 × 50
Column 2	BjTS 420 B	20 × 13
Column 3	BjTS 420 B	13 × 50
Slope 1	BjTS 420 B	30 × 50
Slope 2	BjTS 420 B	25 × 40
Beam 1	BjTS 420 B	30 × 50
Beam 2	BjTS 420 B	20 × 30
Beam Ring	BjTS 420 B	20 × 35
Floor Slab	BjTS 420 B	Thick 15
Roof Slab	BjTS 420 B	Thick 12

Shear Wall	BjTS 420 B	Thick 20

Source: KC BTN Cirebon Building Design Data (SNI 2052:, 2017) (SNI 2847:, 2019)

Modeling in the case research of structural performance analysis in the research of the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon) is done by modeling the portal frame, which includes columns, beams, and slopes as a frame. Then, the floor slab and roof slab are modeled as shells. Similarly, the shear wall is modeled as a shell. The steel truss roof structure is not modeled because it is made of a material different from the main building structure. In addition, the base column support to the foundation is modeled as fixed, with 3D frame models. The application of the necessary components in the building is shown in Figure 2 in the SAP2000.

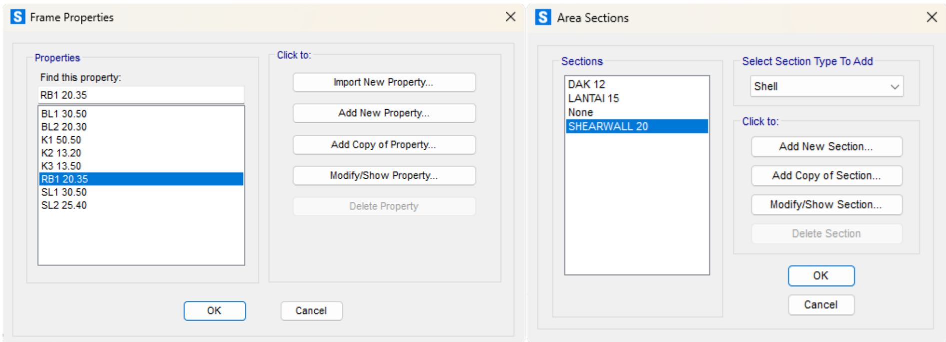


Figure 2. SAP2000 V24 Properties and Section KC BTN Cirebon Building

The definition of the geometric structure model in SAP2000 version 24 is categorized into two types: templates (Quick Start Lines) and manual coordinate determination. The type of geometry template is usually used if all the distances along the X and Z axes are the same. Meanwhile, the manual ordinate is used when the distance between the X and Z axes is not the same. The distances between the X, Y, and Z axes are different in this research of the Bank Tabungan Negara (BTN) branch office building (KC Bank BTN, Cirebon). Thus, a custom grid system is used to create a reference for the images or lines of those elements.

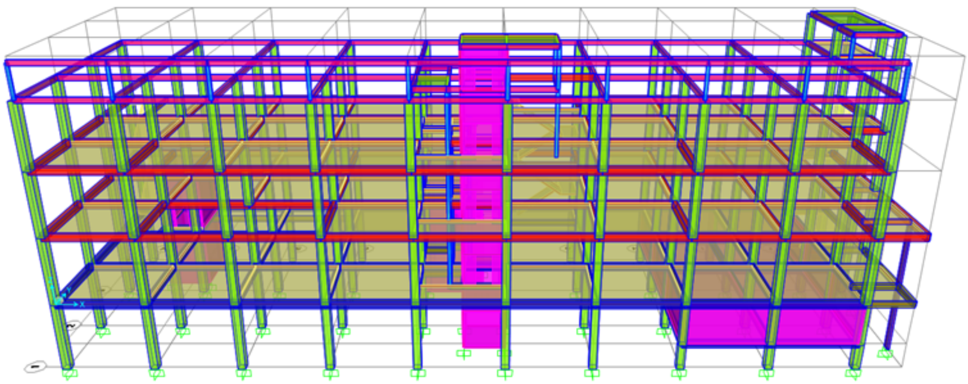


Figure 3. 3D Model SAP2000 V24 Main Structure of the KC BTN Cirebon Building

The research objective of this case research on the office building of the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon) is to determine and examine the suitability of the structural model created in the SAP2000 version 24 software in calculating earthquake-resistant buildings according to SNI 1726:2019. Therefore, a definition of the load pattern from the perspective created in SAP2000 is needed, referencing SNI 1727:2020 on "Minimum load for the design of buildings and other structures." These loads are summarized in Table 2 with reference to the design data and review of the main components in the construction of this building (SNI 1727: 2020).

Table 2. Design Load Patterns Model SAP2000 V24 KC BTN Cirebon Building Structure

Load Pattern Name	Input Material Type	Standard Reference	Load Self Weight
Dead (D)	Concrete + Rebar Steel	SNI 1727:2020	24 + 78,5 kN/m^3
Super Dead (SIDL)	MEP	SNI 1727:2020	10 kg/m^3
Live (L)	Floor Plate	SNI 1727:2020	4,79/2,4/3,83 kN/m^3
Live roof (Lr)	Roof Plate	SNI 1727:2020	0,96 kN/m^2
Rain ®	Roof	SNI 1727:2020	0,196 kg/m^2
Seismic (S)	Structure Quake	SNI 1726:2019/ASCE 7-16	Spectrum Data

Source: KC BTN Cirebon Building Design Data

Then, based on the loading data, a load combination is created based on calculations according to Article 2.3.1 in SNI 1727:2020 regarding general loads and earthquake loads in SNI 1726:2019. Combining these loads is important to ensure that the designed structure can withstand all loads and meet the applicable design standards. The load combination for the SAP2000 v24 structural model in the design of the KC Bank BTN Cirebon building is determined using parameters such as the S_{DS} value and redundancy (ρ) of 1,3, following SNI 1726:2019.

Table 3. Load Combinations Model SAP2000 V24 KC BTN Cirebon Building Structure

Load Combinations for Structure Model KC BTN Cirebon in SAP2000 V24														
1.	1,4	D	+	1,4	SIDL									
2.	1,2	D	+	1,2	SIDL	+	1,6	L	+	0,5	Lr			
3.	1,2	D	+	1,2	SIDL	+	1,6	L	+	0,5	R			
4.	1,2	D	+	1,2	SIDL	+	1,6	Lr	+	1	L			
5.	1,2	D	+	1,2	SIDL	+	1,6	R	+	1	L			
6.	1,2	D	+	1,2	SIDL	+	1	L	+	0,5	Lr			
7.	1,2	D	+	1,2	SIDL	+	1	L	+	0,5	R			
8.	0,9	D	+	0,9	SIDL									
9.	1,34	D	+	1,34	SIDL	+	1,3	Ex	+	0,39	Ey	+	1	L
10.	1,34	D	+	1,34	SIDL	+	1,3	Ex	-	0,39	Ey	+	1	L
11.	1,34	D	+	1,34	SIDL	-	1,3	Ex	+	0,39	Ey	+	1	L
12.	1,34	D	+	1,34	SIDL	-	1,3	Ex	-	0,39	Ey	+	1	L
13.	1,34	D	+	1,34	SIDL	+	0,39	Ex	+	1,3	Ey	+	1	L
14.	1,34	D	+	1,34	SIDL	+	0,39	Ex	-	1,3	Ey	+	1	L
15.	1,34	D	+	1,34	SIDL	-	0,39	Ex	+	1,3	Ey	+	1	L

16.	1,34	D	+	1,34	SIDL	-	0,39	Ex	-	1,3	Ey	+	1	L
17.	0,76	D	+	0,76	SIDL	+	1,3	Ex	+	0,39	Ey			
18.	0,76	D	+	0,76	SIDL	+	1,3	Ex	-	0,39	Ey			
19.	0,76	D	+	0,76	SIDL	-	1,3	Ex	+	0,39	Ey			
20.	0,76	D	+	0,76	SIDL	-	1,3	Ex	-	0,39	Ey			
21.	0,76	D	+	0,76	SIDL	+	0,39	Ex	+	1,3	Ey			
22.	0,76	D	+	0,76	SIDL	+	0,39	Ex	-	1,3	Ey			
23.	0,76	D	+	0,76	SIDL	-	0,39	Ex	+	1,3	Ey			
24.	0,76	D	+	0,76	SIDL	-	0,39	Ex	-	1,3	Ey			

Source: SNI 1726:2019 and SNI 1727:2020

To represent the response spectrum curve in the modeling case research of SAP2000 version 24, we need the planned earthquake data based on the regional coordinates required for the performance analysis of the structure of the branch Bank Tabungan Negaraoffice building (KC BTN Bank, Cirebon). The data obtained from the website or application "RSA PuSGeN Desain Spektra Indonesia 2021 by Cipta Karya" can be viewed by referring to the 2017 national earthquake map.

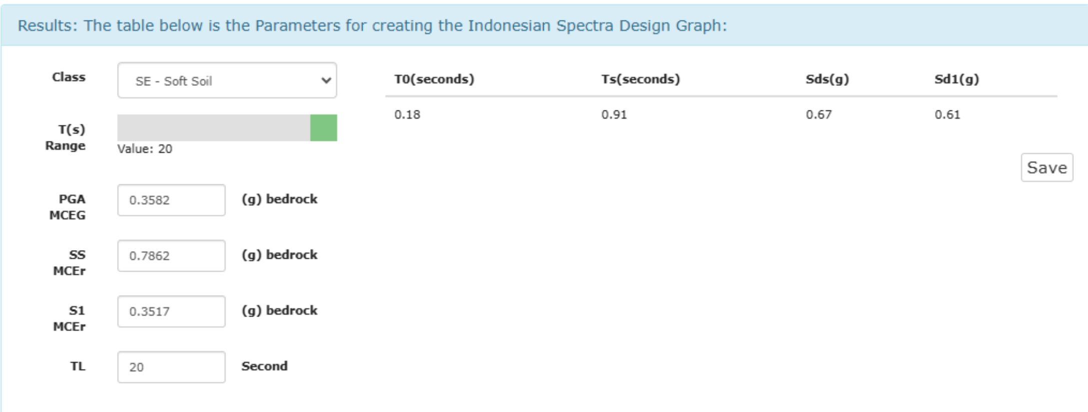


Figure 4. RSA 2021 PuSGeN by Cipta Karya untuk Koordinat Wilayah Cirebon

Then, design data is required according to the applicable standards in the design of the model of the structural elements of the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon) above with SAP2000 v24. The soil investigation (SPT) results at the location showed clay and sand at a depth of up to 30 meters. Therefore, it is categorized as a soft soil site (SE) for which the data is obtained from Table 5 Article 5.3 SNI 1726:2019 and refers to the building design data (Dumaria et al., 2024).

In addition, the building risk category II is obtained from Table 3 of Article 4.1.2 SNI 1726:2019 because of its use as an office building. Furthermore, for the earthquake importance factor, I_e = 1 in Table 4, according to the provisions of Article 10.3.1.1 SNI 1726:20 provision 19, because it refers to building risk category II. Site coefficients F_a = 1,3 and F_v = 2,6, as they refer to the calculated value of S_s at the location and the provisions in Tables 6 and 7 according to Article 6.2 SNI 1726:2019. Then, the response spectrum parameters are S_{MS} = 1,02 and S_{M1} = 0,91 because they refer to the calculated values of F_a and F_v and the provisions in the same Table in SNI 1726:2019.

Next, the Seismic Design Category or KDS = D refers to the calculation results of S_{DS} and S_{D1} values at the location and the provisions in Tables 8 and 9 in Article 6.5 of SNI 1726:2019. Meanwhile, the structural system is a Special Moment Resisting Frame (SMRF) reinforced concrete frame with values R = 8, Ω_0 = 3, and C_d = 5. The data was obtained from Table 12 Article 7.2.2 SNI 1726:2019. Then, the upper limit coefficient C_u = 1,4 because it refers to the S_{D1} value = 0,6, which is greater than the parameter 0,4. This provision is obtained from Table 17 Article 7.8.2 of SNI 1726:2019. The values of the fundamental period approach are $T_{a\ Min}$ = 0,546 seconds and $T_{a\ Max}$ = 0,764 seconds.

Response spectrum S_a = 0.6096 first mode of vibration 1 second, obtained from the comparison of the calculated results for the natural vibration period of the structure T_c, with the fundamental period value obtained from the PuSGeN website. Scale factor $g \times \frac{I_e}{R}$ = 1,226 is used in the definition of load cases data from the response spectrum for earthquakes in the X and Y directions in the building structure model SAP2000 version 24. In addition, the effective seismic weight (mass source SAP2000) is 100% for all dead loads and a minimum of 25% for live floor loads. The data was obtained from the provisions of Article 7.7.2 SNI 1726:2019.

Table 4. Design Load Patterns Model SAP2000 V24 Struktur KC Bank BTN Cirebon

Parameter	Value
PGA (g)	0,3582
S_S (g)	0,7862
S_1 (g)	0,3517
F_a	1,3
F_v	2,6
S_{MS} (g)	1,02
S_{M1} (g)	0,91
S_{DS} (g)	0,6814
S_{D1} (g)	0,6096
T_S (sec)	0,89
T_0 (sec)	0,18
T_L (sec)	20

Source: Design Response Spectrum Data KC BTN Cirebon Building

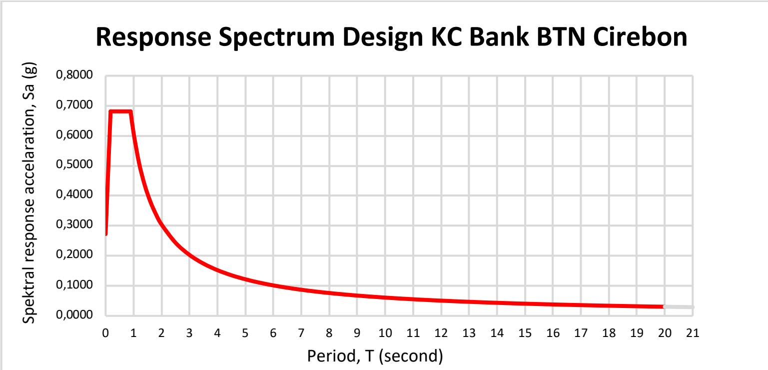
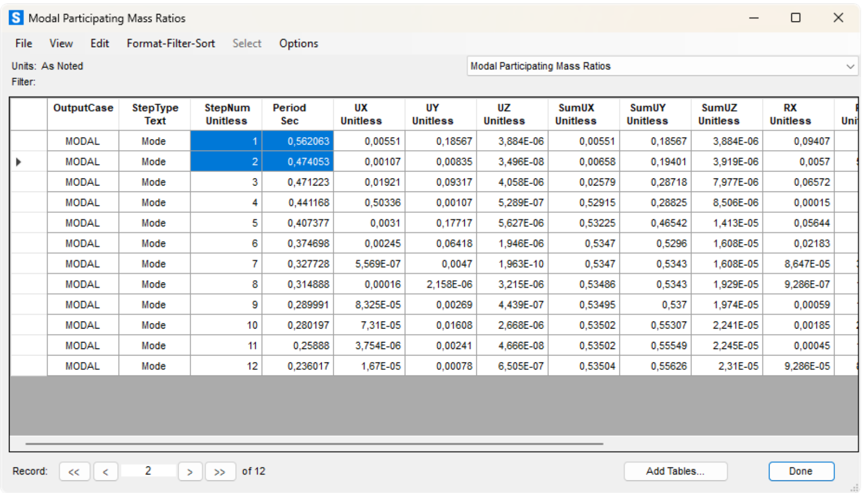


Figure 5. Response Spectrum Curve of KC Bank BTN Cirebon Building

The structural model of the KC BTN Cirebon building, using SAP2000 version 24 software, obtained the structure's fundamental period (T_c) at 0.562063 seconds for the first vibration mode and 0.474053 seconds for the second mode.



Modal Participating Mass Ratios

File View Edit Format-Filter-Sort Select Options

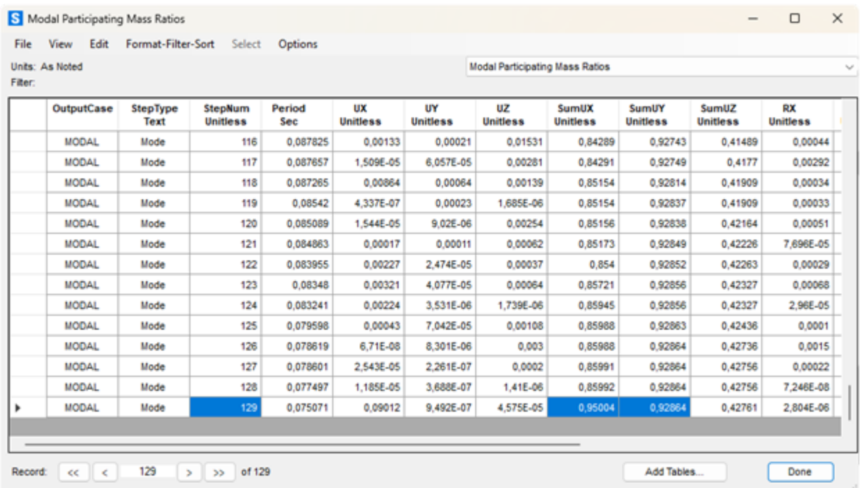
Units: As Noted
Filter:

OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless	UZ Unitless	SumUX Unitless	SumUY Unitless	SumUZ Unitless	RX Unitless
MODAL	Mode	1	0,562063	0,00551	0,18567	3,884E-06	0,00551	0,18567	3,884E-06	0,09407
MODAL	Mode	2	0,474053	0,00107	0,00835	3,496E-08	0,00658	0,19401	3,919E-06	0,0057
MODAL	Mode	3	0,471223	0,01921	0,09317	4,058E-06	0,02579	0,28718	7,977E-06	0,06572
MODAL	Mode	4	0,441168	0,50336	0,00107	5,289E-07	0,52915	0,28825	8,506E-06	0,00015
MODAL	Mode	5	0,407377	0,0031	0,17717	5,627E-06	0,53225	0,46542	1,413E-05	0,05644
MODAL	Mode	6	0,374698	0,00245	0,06418	1,946E-06	0,5347	0,5296	1,608E-05	0,02183
MODAL	Mode	7	0,327728	5,569E-07	0,0047	1,963E-10	0,5347	0,5343	1,608E-05	8,647E-05
MODAL	Mode	8	0,314888	0,00016	2,158E-06	3,215E-06	0,53486	0,5343	1,929E-05	9,286E-07
MODAL	Mode	9	0,289991	8,325E-05	0,00269	4,439E-07	0,53495	0,537	1,974E-05	0,00059
MODAL	Mode	10	0,280197	7,31E-05	0,01608	2,668E-06	0,53502	0,55307	2,241E-05	0,00185
MODAL	Mode	11	0,25888	3,754E-06	0,00241	4,666E-08	0,53502	0,55549	2,245E-05	0,00045
MODAL	Mode	12	0,236017	1,67E-05	0,00078	6,505E-07	0,53504	0,55626	2,31E-05	9,286E-05

Record: << < 2 > >> of 12 Add Tables... Done

Figure 6. Output Results Period Fundamental Structure (T_c) SAP2000 V24

Then, the modal participation reached 90% in the 129th vibration of the mode in the modal participating mass output Table (MPMR) of SAP2000 v 24.



Modal Participating Mass Ratios

File View Edit Format-Filter-Sort Select Options

Units: As Noted
Filter:

OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless	UZ Unitless	SumUX Unitless	SumUY Unitless	SumUZ Unitless	RX Unitless
MODAL	Mode	116	0,087825	0,00133	0,00021	0,01531	0,84289	0,92743	0,41489	0,00044
MODAL	Mode	117	0,087657	1,509E-05	6,057E-05	0,00281	0,84291	0,92749	0,4177	0,00292
MODAL	Mode	118	0,087265	0,00864	0,00064	0,00139	0,85154	0,92814	0,41909	0,00034
MODAL	Mode	119	0,08542	4,337E-07	0,00023	1,685E-06	0,85154	0,92837	0,41909	0,00033
MODAL	Mode	120	0,085089	1,544E-05	9,02E-06	0,00254	0,85156	0,92838	0,42164	0,00051
MODAL	Mode	121	0,084863	0,00017	0,00011	0,00062	0,85173	0,92849	0,42226	7,696E-05
MODAL	Mode	122	0,083955	0,00227	2,474E-05	0,00037	0,854	0,92852	0,42263	0,00029
MODAL	Mode	123	0,08348	0,00321	4,077E-05	0,00064	0,85721	0,92856	0,42327	0,00068
MODAL	Mode	124	0,083241	0,00224	3,531E-06	1,739E-06	0,85945	0,92856	0,42327	2,96E-05
MODAL	Mode	125	0,079598	0,00043	7,042E-05	0,00108	0,85988	0,92863	0,42436	0,0001
MODAL	Mode	126	0,078619	6,71E-08	8,301E-06	0,003	0,85988	0,92864	0,42736	0,0015
MODAL	Mode	127	0,078601	2,543E-05	2,261E-07	0,0002	0,85991	0,92864	0,42756	0,00022
MODAL	Mode	128	0,077497	1,185E-05	3,688E-07	1,41E-06	0,85992	0,92864	0,42756	7,246E-08
MODAL	Mode	129	0,075071	0,09012	9,492E-07	4,575E-05	0,95004	0,92864	0,42761	2,804E-06

Record: << < 129 > >> of 129 Add Tables... Done

Figure 7. Output Results Modal Participating Mass Ratios 90% SAP2000 V24

Based on the preceding analysis, the dynamic response spectrum analysis of the structure aligns well with the regulations outlined in SNI 1726:2019. Subsequently, the output value is compared with the structure's basic period value (T_a).

Table 6. Period Fundamental Structure (T) of Building in X Direction

Period Fundamental Structure (T) of Building in X Direction		
Ta (Min)	< T Output SAP2000 <	Ta (Max)
Ct x hnX	< T Output SAP2000 <	Ta x Cu
0,546	0,562	0,764
T, X Direction:	**0,562**	**OK**

Source: Equations (11)-(15) and SAP2000 V24 Output

Table 7. Period Fundamental Structure (T) of Building in Y Direction

Period Fundamental Structure (T) of Building in X Direction		
Ta (Min)	< T Output SAP2000 <	Ta (Max)
Ct x hnX	< T Output SAP2000 <	Ta x Cu
0,546	0,474	0,764
T, X Direction:	**0,546**	**OK**

Source: Equations (11)-(15) and SAP2000 V24 Output

The output results on the KC BTN Cirebon building structure model using SAP2000 version 24 show a dynamic shear force in the X direction of 2,081.711 kN and a dynamic shear force in the Y direction of 2,082.210 kN. The static value V in the X direction is 2,081.710 kN, and the static value V in the Y direction is 2,081.710 kN. These values were obtained by rescaling the scale factor in the SAP2000 response spectrum data load cases menu, which is 2.208 kN for the X-direction earthquake and 3.089 kN for the Y-direction earthquake. Therefore, the analysis results achieved 100%, indicating that the structural response to the earthquake shear force at the base of the building complies with the SNI 1726:2019 regulations. Thus, the structural strength at the base of the KC BTN Cirebon building has met the required safety limits.

Table 8. Base Shear Reactions Output SAP2000 V24

Direction	$V_{Dinamic}$	V_{Static}	Formula	Check
X	2081,711	2081,710	V_D < 100% V_S	**OK**
Y	2082,210	2081,710	V_D < 100% V_S	**OK**

Source: Equation (16) and SAP2000 V24 Output

The story drift value between permit levels, Δa, is 0,02h in Table 20 of Article 7.12 SNI 1726:2019. The calculation results of the output values of X and Y displacements in SAP2000 v24 for each lateral level of the KC BTN Cirebon building structure have proven to be safe in withstanding the seismic loads of the building structure. Because, from the acquisition of values calculated by reviewing the lateral displacement between the floor levels, the structure produces a deflection force magnitude far beyond the specified permissible limits. Therefore, this structure has met the standards of SNI 1726:2019 regulations. Here are the calculations according to equation (17) or 44 in SNI 1726:2019.

Table 9. Story Drift X Directions Output SAP2000 V24 Checked

Story Drift X Directions of KC Bank BTN Cirebon Building							
Level	Elv (m)	h (mm)	δxe (mm)	δx (mm)	Δx (mm)	Δa (mm)	Check
Roof	12,9	4200	13,17	72,46	29,94	65	**OK**
Floor 3	8,7	4200	7,73	42,52	24,30	65	**OK**
Floor 2	4,5	4500	3,31	18,23	13,12	69	**OK**
Floor 1	0	2800	0,93	5,11	1,21	43	**OK**
Basement	-2,8	1700	0,71	3,90	3,90	26	**OK**
Foundation	-4,5	600	0	0	0	9	**OK**

Source: Equation (17) and SAP2000 V24 Output

Table 10. Story Drift Y Directions Output SAP2000 V24 Checked

Story Drift Y Directions of KC Bank BTN Cirebon Building							
Level	Elv (m)	h (mm)	δxe (mm)	δx (mm)	Δy (mm)	Δa (mm)	Check
Roof	12,9	4200	23,24	127,83	39,94	65	**OK**
Floor 3	8,7	4200	15,98	87,89	42,09	65	**OK**
Floor 2	4,5	4500	8,33	45,80	35,12	69	**OK**
Floor 1	0	2800	1,94	10,68	1,82	43	**OK**
Basement	-2,8	1700	1,61	8,86	8,86	26	**OK**
Foundation	-4,5	600	0	0	0	9	**OK**

Source: Equation (17) and SAP2000 V24 Output

As required in the SNI 1726:2019 guidelines, especially Article 7.8.6, to obtain this value, there is no need to evaluate the dimensions of the structural elements installed in the building in all places. An output table of joint coordinates and displacements is needed to produce the values and obtain deviation results for each floor. This is done by knowing the deviation that occurs from the base coordinates of the foundation to the vertical direction towards the coordinates of the roof structure (beam ring). The permit drift Δ_a is adjusted to the type of building risk category and follows the analysis and data in the KC BTN Cirebon building planning design. This is to make it easier to review the drift calculations that have been carried out.

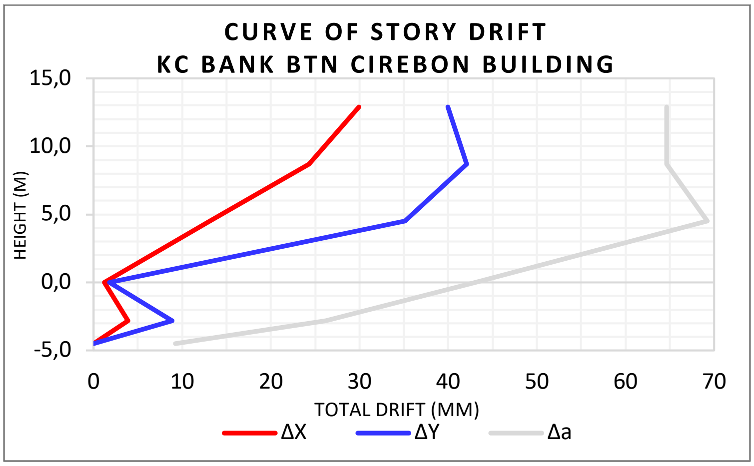


Figure 8. Curve of Story Drift KC Bank BTN Cirebon Building

CONCLUSION

Final conclusion: The SAP2000 v24 modeling case research on the structural performance analysis of the branch Bank Tabungan Negara office building (KC BTN Bank, Cirebon) was successfully conducted based on the review of building design data and key structural elements during the project. The value of the mode information number met the 90% ratio according to Article 7.9.1 of SNI 1726:2019, and it was achieved at vibration mode 129; this is displayed in the output table of MPMR SAP2000. The period of the fundamental structure (T) is 0,562 seconds (T_c) for the vibration period of the structure in the X direction and 0,546 seconds ($T_{a\ Min}$) for the vibration period of the structure in the Y direction, as confirmed by the results calculated in Equation (11)-(15).

Additionally, the base shear reactions were calculated according to the scale factor in Equation (16), and $V_{Dynamic}$ and V_{Static} for each direction were obtained: in the X direction, it was 2,208, and in the Y direction, it was 3,089. Therefore, this result meets the requirements of Article 7.9.1.4.1 in SNI 1726:2019, as shown in the analysis results in Table 8.

Meanwhile, the results of the analysis of seismic force deviations in the X-axis and Y-axis directions for each floor of the building were deemed safe. This is because the calculations from Equation (17) indicate that the displacements obtained from the SAP2000 v24 output are smaller than the allowable displacements (Δ_a) established in Table 20 of the SNI 1726:2019 guidelines. Therefore, there is no need to replace or repair any structural elements of KC BTN Cirebon Bank.

Future research could explore the application of advanced seismic isolation techniques to enhance the building's resilience further. Additionally, investigating the impact of different soil conditions on the building's seismic response would provide valuable insights. Finally, a comparative research analyzing the performance of similar structures designed with different versions of the SNI code could offer a comprehensive understanding of the evolution of seismic design standards in Indonesia.

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