



REPUBLIC OF TÜRKİYE
ALTINBAŞ UNIVERSITY
Institute of Graduate Studies
Civil Engineering

**THE SOLUTION OF INCLINED SOIL LAYERS
SUPPORTING THE FOUNDATION OF
REINFORCED CONCRETE STRUCTURE BY
MODELING WITH FINITE ELEMENTS**

Bassam Wazir BDAIWI

Master's Thesis

Supervisor

Prof. Dr. Zeki HASGÜR

Istanbul, 2023

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The thesis titled THE SOLUTION OF INCLINED SOIL LAYERS SUPPORTING THE FOUNDATION OF REINFORCED CONCRETE STRUCTURE BY MODELING WITH FINITE ELEMENTS prepared by BASSAM BDAIWI and submitted on 7/4/2023 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Bassam Wazir BDAIWI

Signature



DEDICATION

First of all, praise be to God who enabled me to complete this thesis.

I would like to acknowledge, to express my appreciation and deep gratitude to my adviser Prof. Dr. Zeki HASGÜR for his invaluable support, endless patience, and continuous guidance during my master's studies.

Besides my advisor, I'd like to thank Prof. Dr. Akram S. Mahmoud for his valuable guidance and help. I'm grateful for his encouragement and practical advice towards my academics and research. His excellent insights helped me tactfully overcome hurdles and dead ends in my research. I truly value his time investment and patience and for responding to my many questions at all hours.

All goals in life are not possible without the support of everyone around, either close or far. The support and encouragement of my beloved family have been instrumental in providing me with the opportunity to obtain my master's degree, so I would like to thank my father Wazir Bdaiwi, my mother, my sister, and my brothers. In addition, this thesis was possible due to the support of my beloved family.

Of course, this long stage for master's studies would not have been so easy without all the colleagues and friends. Thanks to Mohammed Hashim, for being a great friend and making many good moments to remember. Better times will come for other memories.

I would also like to thank everyone who supported me and wished me well to complete my studies.

ABSTRACT

THE SOLUTION OF INCLINED SOIL LAYERS SUPPORTING THE FOUNDATION OF REINFORCED CONCRETE STRUCTURE BY MODELING WITH FINITE ELEMENTS

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Date: April/2023

Pages: 153

This study deals with the use of finite element analysis to study the response of an RC building that has inclined supporting leads in the foundations. These buildings have a lot of weaknesses that need to be found and then properly developed. Therefore, shear walls had been built for these buildings to reduce seismic forces. A verification study was performed to analyze the RC building using SAP2000 software, which was collected from previous literature. Several RC buildings were studied to evaluate the seismic performance of these buildings under the influence of change in the degree of inclination of the foundations (0° , 10° , 20° & 40°), the number of storeys (8, 12, 16 & 20 storey), the span length (4, 5 & 6) m, and the storey height (3, 3.5 & 4) m. The buildings were analyzed using the SAP2000 software using the time history and response spectrum analysis methods under the influence of the EL-Centro N-S 1940 earthquake acceleration record.

The results were shown that the values of base shear, time period and roof displacements decreased by 23%, 33% and 55% respectively, when the degree of foundation inclination of the building increased from 0° to 20° , due to the difference in stiffness and geometry of the buildings having inclined foundation. While these values increased by 68%, 53.28% and 137.6% respectively, when the No. of stories increased by 50%. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings. The increases in time period due to decrease the stiffness of RC buildings and it has more displacements at tip of the buildings. Using the response spectrum method, when

the storeys number were 12 the values of displacements decreased by 56% when the degree of the foundation inclination increased from 0° to 40° , at the 12th storey level. In the case presence of shear walls, the values of base shear, time period and roof displacements increased by 50% and decrease by (48% and 60%) respectively, under the influence of the increase in the degree of inclination of the foundations.

Keywords: Multi-Story RC Building, SAP2000, Seismic, Inclined Foundations, Finite Element Analysis and El-Centro 1940 Earthquake.



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ABBREVIATIONS

RC	:	Reinforced Concrete
FEM	:	Finite Element Method
RSA	:	Response Spectrum Analysis
MDOF	:	Multi Degree of Freedom
SDOF	:	Single Degree of Freedom
3D	:	Three-Dimensional
2D	:	Two-Dimensional
No.	:	Number
pp.	:	Page
Hz	:	Hertz
m	:	Meter
mm	:	Millimeters
Sec.	:	Second
SSI	:	Soil Structure Interaction
kN	:	Kilonewton
$\hat{f}_c$	:	(Grade of Concrete)
G+3	:	Four Storeys Building
SAP2000	:	Software of Analysis Program

LIST OF SYMBOLS

f	: Frequency
ω	: Angle Frequency
T	: Time Period
K	: Structural Stiffness
M	: Mass
C	: Damping Coefficient
P	: External Force
$\ddot{U}$	: Absolute Acceleration
$\dot{U}$	: Relative Velocity
U	: Relative Displacement
θ	: Rotation
S_a	: Spectral Acceleration
ξ	: Damping Ratio
T_n	: Natural Vibration Period Values
T_B	: Period Values
T_C	: Period Values
T_D	: Period Values
$u_{\max}$	: The Peak Deformation of a SDOF
S_v	: Spectral Velocity
S_d	: Spectral Displacement

- S : Soil Factor
- η : Damping Correction Factor
- $r(t)$: Response Quantity
- r_o : Absolute Value of $r(t)$



1. INTRODUCTION

1.1 GENERAL

Earthquakes are destructive occurrences that primarily take place near the boundaries of regions of the earth's crust known as tectonic plates. Waves are formed at the earth's surface during movement in these areas along faults, and these waves have the potential to be quite destructive. All significant earthquakes are followed by minor tremors called aftershocks. Throughout the first week of the original earthquake, they are typically at their peak in terms of size and number. As a result, earthquake-related disasters are riskier since they might cause very large re-shaking of damaged structures. The size of the aftershocks from a number of moderate earthquakes (6+ magnitude on the Richter scale) was very similar to that of the main earthquake. In time, aftershocks become weaker and less frequent [1].

As shown in Figure 1.1, the loading is further simplified in multistory buildings with equal-weight floors as a collection of loads that are applied at different floor lines and are arranged in a triangular pattern, with the top load being bigger than the bottom load. Seismically resistant constructions must be detailed appropriately because they are made to withstand these lateral stresses through inelastic action. These loads can range from a few percent to close to 50% of the building's gravity weight and are frequently stated as a percentage of that weight. When an earthquake shakes a building, vertical loads are also produced, but these forces rarely cause the vertical load-resisting system to become overloaded. The simplified response shape shown in Figure 1.2 can be used to get a general concept of how a building would behave during an earthquake [2].

The static techniques outlined in building codes are based on a single-mode response with straightforward modifications for higher mode effects. Despite being suitable for straightforward regular buildings, the streamlined approaches do not account for the full spectrum of seismic behavior of intricate structures. As a result, the method of choice for designing structures with distinctive or irregular geometry is dynamic analysis. The response spectrum and time-history analysis are the two dynamic analysis techniques. The favored method is response spectrum analysis since it is simpler to apply. If it's crucial to

describe inelastic response characteristics or include time-dependent effects while calculating the structure's dynamic response, the time-history approach is applied [3].

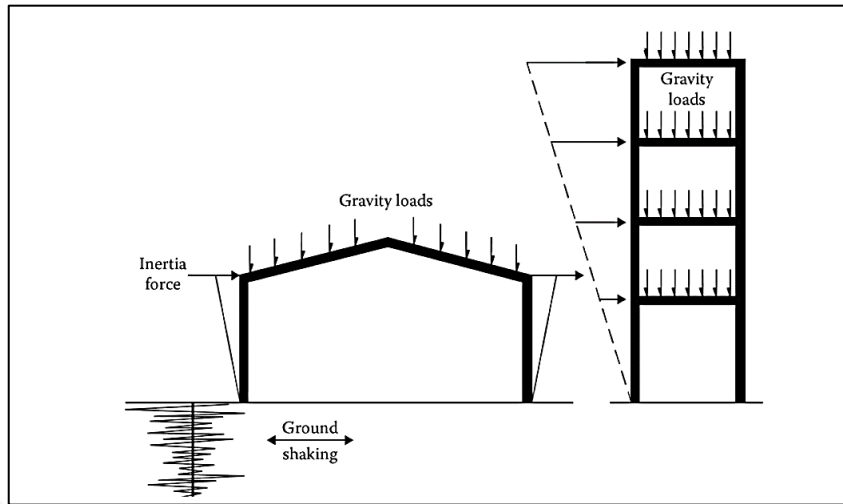


Figure 1.1: Seismic Loading.

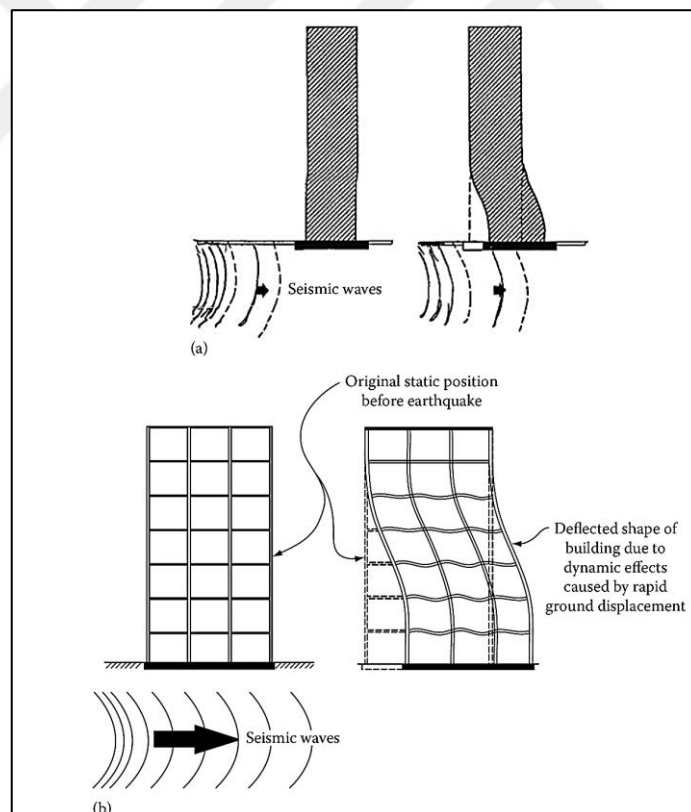


Figure 1.2: Building Behavior During Earthquakes.

Buildings are often constructed on sloping land in hilly areas due to the lack of flat land there. Both in plan and elevation, the buildings built in the hilly area are very

asymmetrical. Building on a sloped ground behaves differently than on a level ground. Figure 1.3, shown the difference in stiffness and geometry of the buildings having inclined foundation. Strong earthquakes frequently damage buildings built in hilly areas. One of a structural engineer's most difficult tasks is to design a building that is seismically resistant and has inclined supporting foundations [4].

This study deals with the use of finite element analysis to study the response of an RC building that has inclined supporting leads in the foundations. The effect of these buildings exhibits when subjected to seismic loads differs from buildings that have flat support points in the foundations. These buildings have a lot of weaknesses that need to be found and then properly developed. The seismic performance of the RC buildings was investigated to obtain results that give the possibility of an appropriate analysis and design of these buildings. Therefore, shear walls had been built for these buildings to reduce seismic forces. The buildings were analyzed using the SAP2000 software.

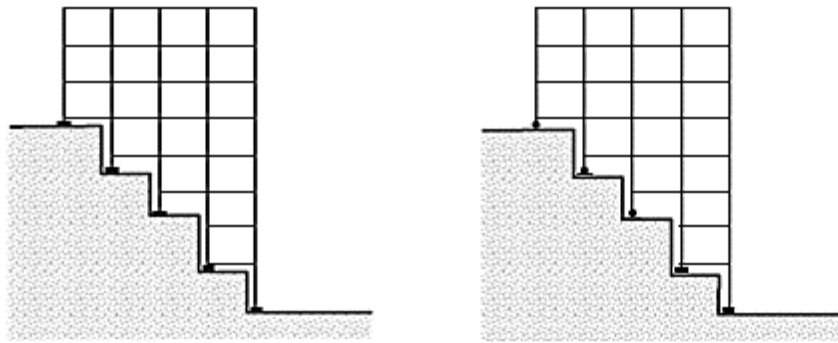


Figure 1.3: Buildings Having Inclined Supporting Foundations.

1.2 VERIFICATION STUDY

The verification studies were performed for analyzing RC building by using SAP2000 software, where there collected from the previous literature.

1.3 PARAMETRIC STUDY

Several RC buildings were studied to evaluate the seismic performance of these buildings under the influence of change in four parameters. These parameters are the degree of inclination of the foundations (0° , 10° , 20° & 40°), the number of storeys (8, 12, 16 & 20 storey), the span length (4, 5 & 6) m, and the storey height (3, 3.5 & 4) m. In addition,

these buildings had been built in the presence and absence of shear walls to reduce seismic forces. The buildings were analyzed using the SAP2000 software using the time history and response spectrum analysis method under the influence of the EL-Centro N-S 1940 earthquake acceleration record. The results were shown the values of the base shear, time period, roof displacements and storey's drift.

1.4 AIM OF STUDY

This study aimed to verify the stability of multi-storey structures with sloping foundations under the influence of seismic load. The case studies were based on the time history and response spectrum analysis of buildings, where evaluated the performance of buildings under the influence of the El Centro N-S 1940 earthquake acceleration record of the imperial valley earthquake using SAP2000 software.

1.5 OBJECTIVES OF STUDY

The objectives of study can be summarized as follows:

- a. Evaluation of the seismic performance of multi-storey RC buildings.
- b. Models verified by comparing the results of a present work with the results available in the previous literature.
- c. Studying the effect of parameters (degree of inclination of foundations, number of storeys, span length and storey height) on multi-storey RC buildings.
- d. Study the effect of the presence or absence of shear walls in buildings and compare the obtained results.
- e. The buildings were analyzed using the SAP2000 software using the time history and response spectrum analysis method under the influence of the EL-Centro N-S 1940 earthquake acceleration record.
- f. The results were shown the values of the base shear, time period, roof displacements and storey's drift.

1.6 LIMITATIONS OF THIS STUDY

- a. Degree of inclination of foundations ranging (0° to 40°).
- b. The number of storeys ranging (8 to 20) storeys.

- c. The number of spans ranging (4 to 6) m.
- d. The storey height ranging (3 to 4) m.

1.7 THESIS OUTLINE

- a. Chapter one includes an introduction that demonstrates the importance of studying buildings under the influence of seismic loads, especially those that have inclined foundations. In addition to the research objectives.
- b. Chapter 2 presents a general overview of the literature available on seismic analysis of RC buildings using finite element software.
- c. Chapter three shows the verification study.
- d. Chapter four shows the parametric study.
- e. Chapter five includes the main conclusions of the work that has been developed and recommendations for future research, as shown in Figure 1.4.

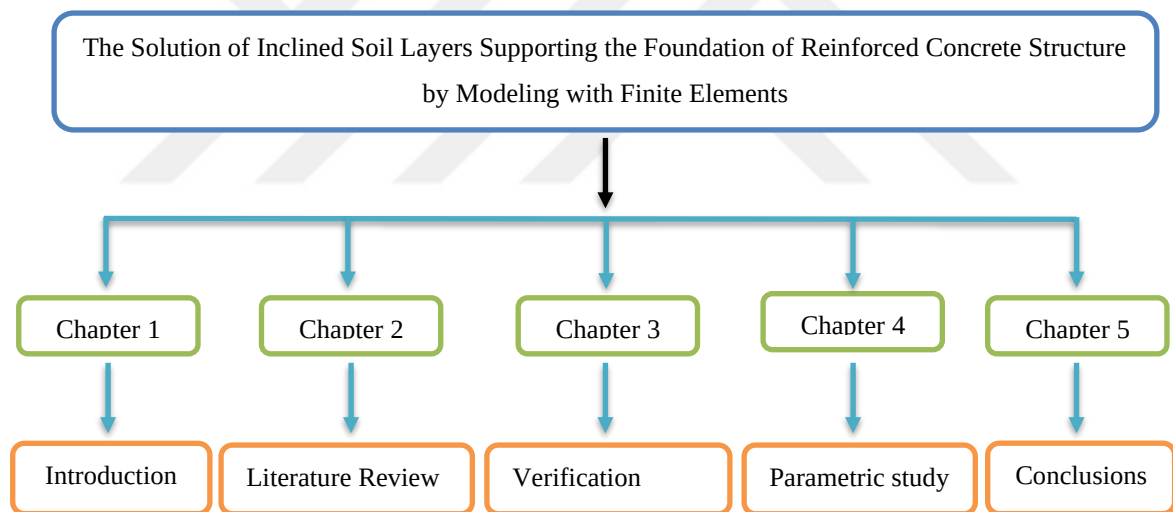


Figure 1.4: Layout of This Study.

2. LITERATURE REVIEW

2.1 GENERAL

Multi-storey buildings have always been of interest to many researchers as they are analyzed and designed to resist static loads. However, many buildings are subject to seismic loads, and consequently the building is damaged and may even fail. Therefore, buildings must be designed to resist both static and seismic loads. Another problem also emerged, which is the exposure of buildings that rest on an inclined ground to seismic loads, and therefore the necessary precautions must be taken in the design. Below are mentioned some studies on the design and analysis of multi-storey buildings under the influence of seismic loads using the SAP 2000 software.

2.2 STRUCTURAL VIBRATION BEHAVIOR

Dynamic excitations such as earthquakes cause vibrations within the structure unlike static actions and thus affect the structural response. The vibration behaviour of a structural system is characterized by a number of parameters, including [5]:

- a. Frequency – stiffness and mass.
- b. Damping.
- c. Energy dissipation.

Frequency (f) is the first parameter which represents the relationship between structural stiffness (k) and mass (m), as shown in equation 2.1. The frequency is also inversely proportional to the time period (T) [5].

$$f = \frac{1}{T} = \frac{1}{2\pi} * \omega \quad (2.1)$$

With the circular frequency, as shown in equation 2.2.

$$\omega = \sqrt{\frac{k}{m}} \quad (2.2)$$

The relevant accelerations appear in a frequency range of approximately 0.5 to 10 Hz for earthquakes, as shown in Figure 2.1 [5].

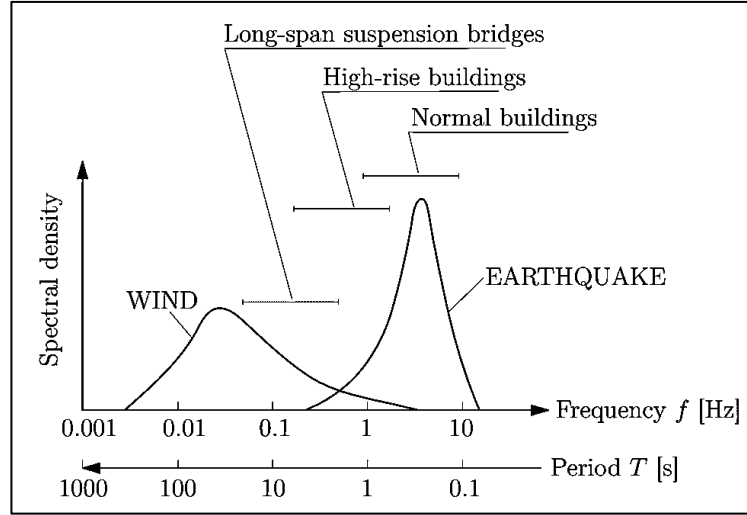


Figure 2.1: Spectral Density of the Action Effects Wind and Earthquake in Relation to the Range of the Natural Frequency of Main Types of Structures [5].

Equation 2.3 to equation 2.8, shown the solution of the motion equation with N degree of freedom system [6]. Figure 2.2, shown the multi degree of freedom (MDOF) system.

$$M \ddot{U} + C \dot{U} + K U = P \quad (2.3)$$

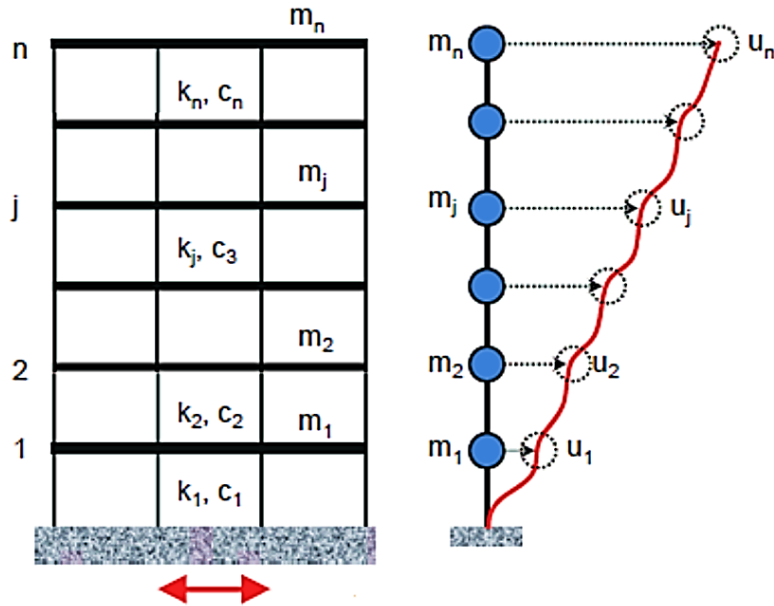


Figure 2.2: MDOF System.

The motion equations according to equation 2.3 for the system in Figure 2.2 shown below:

The mass matrix $[M]$ is:

$$[M] = \begin{bmatrix} m_1 & 0 & 0 & \dots & 0 & 0 \\ & m_2 & 0 & \dots & 0 & 0 \\ & & m_3 & \dots & 0 & 0 \\ & & & \ddots & \vdots & \vdots \\ \text{Symm.} & & & & m_{n-1} & 0 \\ & & & & & m_n \end{bmatrix} \quad (2.4)$$

The stiffness matrix [K] is:

$$[K] = \begin{bmatrix} k_1 & -k_1 & 0 & \dots & 0 & 0 \\ & k_1 + k_2 & -k_2 & \dots & 0 & 0 \\ & & k_2 + k_3 & \dots & 0 & 0 \\ & & & \ddots & \vdots & \vdots \\ & & & & \ddots & -k_j & 0 \\ \text{Symm.} & & & & & k_j + k_{n-1} & -k_{n-1} \\ & & & & & & k_{n-1} + k_n \end{bmatrix} \quad (2.5)$$

The damping matrix [C] is:

$$[C] = \begin{bmatrix} c_1 & -c_1 & 0 & \dots & 0 & 0 \\ & c_1 + c_2 & -c_2 & \dots & 0 & 0 \\ & & c_2 + c_3 & \dots & 0 & 0 \\ & & & \ddots & \vdots & \vdots \\ & & & & \ddots & -c_j & 0 \\ \text{Symm.} & & & & & -c_j + c_{n-1} & -c_{n-1} \\ & & & & & & c_n \end{bmatrix} \quad (2.6)$$

The displacement vector {U} is:

$$\{U\}^T = \{u_1 \ u_2 \ u_3 \ \dots \ u_{n-1} \ u_n\}^T \quad (2.7)$$

The external load vector {P} is:

$$\{P\}^T = \{p_1 \ p_2 \ p_3 \ \dots \ p_{n-1} \ p_n\}^T \quad (2.8)$$

2.3 CALCULATION METHODS AND NUMERICAL MODELLING

The finite element method (FEM) is one of the methods that helped to solve many computational problems and model complex engineering structures. This method has been

introduced in many engineering programs that are used in structural analysis, and among these programs is the SAP 2000 software [7]. SAP 2000 was used in the modeling and analysis of all the studied cases.

It is possible to analyze and design buildings under the influence of seismic loads using a variety of computational methods, including:

- a. Time history analysis.
- b. Response spectrum analysis.

2.3.1 Time History Analysis

The method of time history is the study of buildings response step-by-step under the influence of earthquakes to see the dynamic response of this structure with each time increment. Therefore, knowing is essential the representative earthquake time history of the structure to evaluate its dynamic response under the influence of earthquakes [8]. Figure 2.3, shown the time history of El Centro N-S 1940 earthquake acceleration record [9].

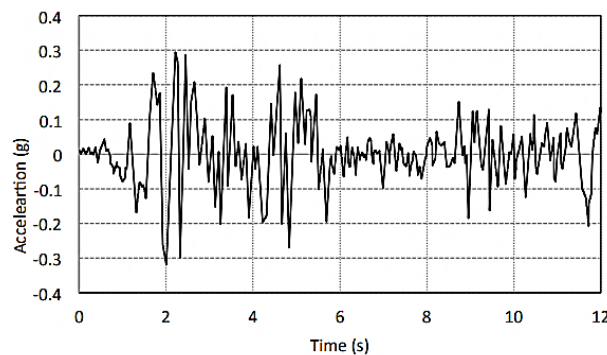


Figure 2.3: Time History of El Centro N-S 1940 Earthquake Acceleration Record [9].

2.3.2 Response Spectrum Analysis

Response-spectrum analysis (RSA) is a linear-dynamic statistical analytic technique that calculates the contribution made by each natural mode of vibration to estimate the maximum seismic response that an essentially elastic structure will likely experience. Response-spectrum analysis measures pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a specific time history and damping level, offering insight into dynamic behavior. It is feasible to enclose the response

spectrum in such a way that each realization of the structural period's peak response is represented by a straight line. The equation of motion for a large number of SDOF systems under earthquake excitation can be solved to produce a response spectrum, as shown in equation 2.3 and Figure 2.4.

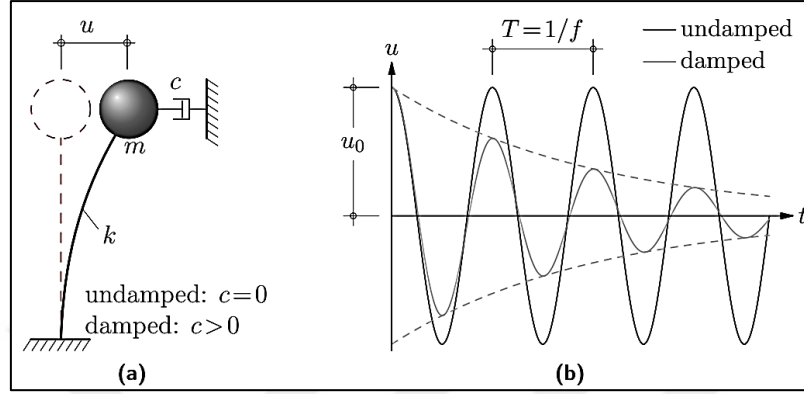


Figure 2.4: (a) SDOF System and (b) Harmonic Vibration of an Undamped and Damped SDOF-System [5].

Response peak values are defined as the absolute maximum value of the response quantity $r(t)$ that changes with time, as shown in equation 2.9 [10].

$$r_o = \max|r(t)| \quad (2.9)$$

where r_o is the absolute value of $r(t)$. The peak value of a response quantity (such as displacement, velocity, or acceleration) is plotted against the entire range of interest of the natural vibration period values T_n to form the response spectrum of a quantity.

The peak deformation of an SDOF with period (T_n) and damping (ξ) is shown in equation 2.10 [10].

$$u_{max} = \omega_n^2 S_a(T_n, \xi) = \left(\frac{T_n}{2\pi}\right)^2 S_a(T_n, \xi) \quad (2.10)$$

Equation 2.11 shown the convert spectral (S_a) acceleration into spectral velocity (S_v) and spectral displacement (S_d) [10].

$$S_a = \omega * S_v = \omega^2 * S_d \quad (2.11)$$

The proposed spectral forms are shown in Figure 2.5 and equation 2.12 [11].

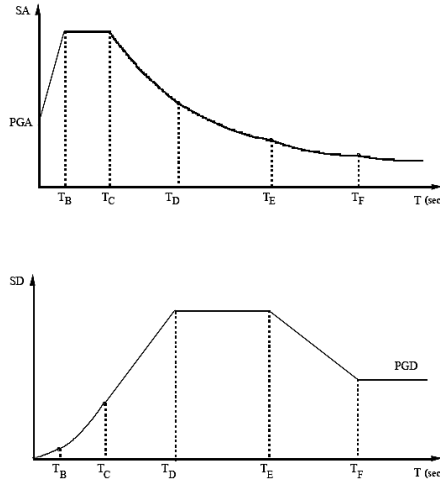


Figure 2.5: Control Periods for Compatible Acceleration and Displacement Spectra.

$$S_a(T_n, \xi) = \begin{cases} \alpha_g S [1 + (\eta 2.5 - 1) (T/T_B)] & , \quad \text{if } 0 \leq T \leq T_B \\ \alpha_g S \eta 2.5 & , \quad \text{if } T_B \leq T \leq T_C \\ \alpha_g S \eta 2.5 (T_C/T) & , \quad \text{if } T_C \leq T \leq T_D \\ \alpha_g S \eta 2.5 (T_C T_D / T^2) & , \quad \text{if } T_D \leq T \leq 4 \text{ sec.} \end{cases} \quad (2.12)$$

Where S is the soil factor, while the period values T_B , T_C , and T_D alter the form of the spectrum in accordance with the soil conditions. η is the damping correction factor, as shown in equation 2.13 [11].

$$\eta = \sqrt{10/(5 + \xi)} \geq 0.55 \quad (2.13)$$

Figure 2.6, shown the response spectrum of the El Centro N-S earthquake acceleration [7].

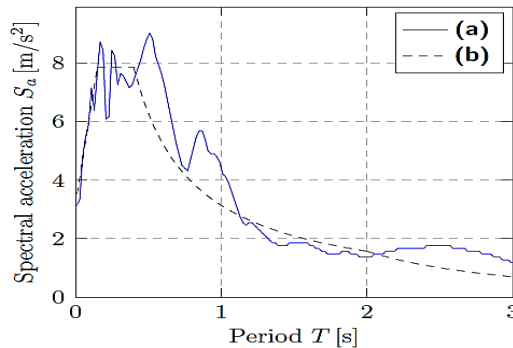


Figure 2.6: (a) Elastic Response Spectrum of El Centro N-S Earthquake Acceleration with 5% Damping and (b) Smoothed Response Spectrum According to [EN 1998-1].

2.4 ANALYSIS OF MULTI STOREY BUILDING HAVING FLAT SUPPORT POINTS

There is a lot of previous literature on seismic analysis using SAP2000 software, as shown below:

Safina et al. in 2008 [12] In Caracas, Venezuela, a research was conducted on the seismic reaction of nine moment resisting reinforced concrete structure frames. Low-rise (three to four storeys), medium-rise (six to eight storeys), and high-rise (thirteen to seventeen storeys) RC frame constructions according to various Venezuelan Standards (i.e., buildings built before 1967, between 1967 and 1982, and after 1982). SAP2000 was chosen for the modeling and nonlinear analysis of the buildings, as well as the dimensioning and reinforcing details.

Poluraju et al. in 2011 [13] The G+3 building was subjected to a nonlinear pushover analysis to assess its performance in the event of future earthquakes. In the X and Y directions, the structure had three bays. The mass of the storeys was calculated, as well as the lateral loads, in accordance with IS1893. Two types of beam dimensions and two types of column dimensions existed. The finite element program SAP2000 was chosen for modeling the building. Nonlinear frame components were used to model beams and columns.

Rahman et al. in 2012 [14] In Madinah, Saudi Arabia's western region, a non-linear static analysis was carried out for an 8-storey reinforced concrete building under the influence of seismic loads. The first five storeys of the building were 3.2 meters tall, and the rest three stories followed by 4.2, 2.4 and 5 meters. The plan is 40 by 40 meters. The analysis included the use of SAP2000. By cross sectional fiber analysis, another program called XTRACT was utilized to compute the moment curvature and the P-M (axial force(P)-bending moment(M)) interaction of frame members.

Bhagat, et al. in 2015 [15] A 10-storey building was analyzed using SAP 2000 software after it was damaged by the Gurkha earthquake. The building was analyzed in three dimensions and the values of traffic analysis and nonlinear response history analysis were obtained. The obtained results indicated that the building is not able to resist seismic loads.

Kolekar, et al. in 2017 [16] Dynamic analysed by response spectrum analysis and time-date analysis of a G+12 RC multi-story framed building for the Koyna and Bhuj earthquakes, and the interactions of these buildings were compared using the SAP2000 software. Various acceptable criteria were developed using two chronological dates (Koyna and Bhuj) (base shear, deck offset, deck drift). Time-date analysis, rather than response spectrum analysis, is recommended based on the results because it predicts structural interaction more accurately. The same building is also subject to facile analysis, with results indicated that the structure is seismically sound.

Mahajan & Krishna in 2017 [17] In comparison to a regular building, it was investigated how reinforced concrete structures with horizontal irregularity (L-, T-, plus-, and I-shaped plan arrangements) behaved during earthquakes with and without infill walls. SAP2000 was used to perform dynamic analysis utilizing the response spectrum for regular and irregular buildings. The plus shaped plan building was the most flexible of their forms, while the regular building was the stiffest. All structures with infill walls were more rigid than equivalent structures without infill walls. The irregular shaped buildings (L, T, I and plus shaped) had a higher displacement than the regular shaped buildings due to the decrease in stiffness.

Bhatt in 2020 [18] Two adjacent buildings were analyzed without space between them. Each building consists of 4 floors, but the height of the floors differs. This analysis is performed using El-Centro earthquake data and building performance evaluation using SAP 2000 software. It was concluded from the results of the analysis that the drift values between floors in the highest building were greater in the case of no pounding than in the pounding case, in contrast to the building with the lowest height.

Ambavaram, et al. in 2021 [19] The SAP 2000 program was adopted to design five buildings with the same dimensions, and the values of the non-linear time history and confrontation distances representing the displacement responses were obtained. Shorter standoff distances, as well as standoff lengths longer than 10 m, have a significant impact on interactions for high-rise buildings. Between single and double bracings, there is no obvious difference in building response.

Bhonsale & Pandey in 2021 [20] SAP 2000 structural analysis programming was used to evaluate steel structures, all types of garages, low-rise and high-rise buildings, and portal frame designs for multi-storey RCC college buildings with a G+3 configuration (ground floor plus three other floors). This RCC G+3 structure was designed using SAP2000, then the software calculated the bending moments, maximum shear strength and maximum member displacement.

2.5 ANALYSIS OF MULTI STOREY BUILDING HAVING INCLINED FOUNDATION

Buildings that are resting on sloped ground differ from those that are resting on plain ground. Because these constructions' mass and stiffness fluctuate along the vertical and horizontal axes and cause the centers of mass and rigidity to not coincide on various floors, they require torsional analysis in addition to lateral analysis when subjected to earthquake forces. One of the most frequently used lateral load resisting technologies in buildings is shear walls because they perform better during earthquakes. In multistory reinforced concrete buildings, shear walls are the best option for resisting lateral loads. They significantly reduce the lateral sway of structures by giving them enormous strength and stiffness in the orientation direction [21].

The SAP 2000 software had been used to analyze multi-storey buildings having inclined foundation, as shown in the previous literature below:

Vaidya in 2015 [22] The building on sloping ground was analyzed to resist seismic loads. Four mathematical models were worked on, one of which is a concrete structure without shear walls, and the rest contains shear walls in different locations. Response spectrum analysis is carried out by using finite element software SAP 2000 to determine the building performance in terms of story drift, displacements, and maximum forces in the columns.

Kamble and Bhalchandra in 2016 [23] A reinforced concrete building with an inclined foundation was analyzed using the SAP 2000 software under the influence of seismic loads using the time-history analysis method, considering the presence or absence of shear walls. The results obtained showed that the building on a sloping ground with shear walls was less susceptible to damage.

Mistry & Shah in 2016 [24] The building was studied on plain ground, setback building, and setback building with step back building. These buildings had been dynamically analyzed using SAP 2000 software. This research examined the response spectrum and time history of the Bhuj and Chamoli earthquakes, considering features such as base shear, axial force, and moments. For each case, the earthquake's time histories had been applied at various angles and the most severe analysis had been studied.

Pawar, et al. in 2016 [25] A reinforced concrete building was analyzed using the SAP 2000 software under the influence of seismic loads using the response spectrum analysis method, taking into account the presence of shear walls. The results obtained showed that buildings on sloping ground were more susceptible to damage.

Nayak & Uttekar in 2017 [26] The impact of earthquakes on an 8-storey concrete structure based on a foundation inclined at angles (15° , 30° , 45° , 60°) was studied and analyzed using SAP 2000 software. The performance of the building was analyzed under the influence of seismic loads. A comparison was made of the building in case of the presence or absence of an infill wall. From the obtained results it was concluded that the shaft most affected by earthquakes is the short column, by comparing the obtained values of top storey displacement, drift, base shear and time period.

Ramya in 2019 [27] The time period of the structure and base shear were verified. The natural period of the buildings erected on the slopes of the hill was determined and then an attempt was made to obtain the best curve through a parametric study. Due to the lack of data, the SAP 2000 software was used to analyze 270 models of buildings in which the angle of inclination, dimensions or height changed, and thus obtain an empirical relationship to know the time period of buildings on sloped lands.

Thejaswini, et al. in 2020 [28] The finite element method was used to examine the behavior of step back buildings considering the effect of soil structure interaction (SSI). A continuous modeling approach was used to examine the structures on ground slopes of 20° , 25° , and 30° . For both fixed and variable underlying conditions, time history analysis is used to illustrate findings such as frequency and storey displacements.

Gómez, et al. in 2021 [29] To know the performance of buildings in the Chilean hills, an analytical study was conducted to assess the impact of these buildings through flexible and non-linear linear analysis. Here four different buildings were analyzed in a two-dimensional manner, each of which has a different inclination angle (0, 15, 30 & 45) degree, respectively. Under the influence of seismic loads, several minor differences were observed due to the topographical factors, but the gradual design of the bases caused the largest differences in values. Therefore, the buildings whose bases have a large angle of inclination are more at risk of collapsing due to the accumulated shear forces.

Tejaswi, et al. in 2021 [30] Using the SAP 2000 software, a three-dimensional analysis of four concrete buildings, each consisting of seven floors, was performed. The analysis was conducted on normal and sloped ground with (0, 10, 20 and 30) degrees, respectively. From the results of the analysis obtained from the SAP 2000 software, the values of shear strength, bending moment and deflection were compared in the studied buildings, and then compared with the values found manually.

Jammula & Konda in 2021 [31] Due to the unavailability of plain ground, the buildings were constructed on sloping ground. A 9-storey building resting on a sloping ground with two different angles was analyzed, as well as two 3- and 9-storey buildings resting on a plain ground. The buildings were analyzed under the influence of seismic loads using the SAP2000 software, in the case of the presence or absence of shear walls. The results of the obtained analysis showed that the buildings based on plain ground were more stable, and the presence of shear walls helps the buildings avoid failure of the structural elements.

2.6 OTHER ENGINEERING SOFTWARES FOR ANALYZING MULTI-STOREY BUILDINGS HAVING INCLINED FOUNDATION

Santos, et al. in 2013 [32] A model of a conventional reinforced concrete building (the building model) was designed to facilitate comparisons between codes. This structure was built using two different computer programs, SAP2000 and SOFiSTiK, using seismic inputs based on multiple seismic codes. Some important conclusions were drawn when comparing the results.

SUJAY and ARASAIAH in 2017 [33] Using the ETABS software, multi-storey building (G+10) with inclined foundations at different angles (5, 10 & 15) degrees was analyzed under the influence of seismic loads. The results had been shown the values of the storey shear, displacements, and storey drift.

Kumar and Malviya in 2018 [34] Using STAAD Pro software, an 8-storey reinforced concrete building with inclined foundations at different angles (0, 10 & 15) degrees was analyzed under the influence of seismic loads.

Islam and Pastariya in 2020 [35] Using STAAD Pro software, a 15-storey reinforced concrete building with flat or inclined foundations at different angles (10, 20, 30 & 40) degrees was analyzed under the influence of seismic loads. The results obtained showed that the best case was for the building that had a foundation inclined at an angle of 30°.

Chaitra and Rajesh in 2021 [36] Using the ETABS software, multi-storey buildings (G+10 and G+15) with a flat or inclined foundation were analyzed under the influence of seismic loads.

2.7 CONCLUDING REMARKS

- a. The literature review has suggested that many researchers have done much experimental and analytical work in the field of seismic evaluation of RC buildings on normal and inclined ground using SAP 2000 software.
- b. The main objective of many research works was to understand the behavior of the building under the influence of seismic loads and the extent to which it maintains its safety and operability, especially when the building is located on an inclined ground.
- c. In many studies, it was found that buildings that rest on an inclined ground have higher base displacement and shear values than ordinary buildings, and therefore they are more susceptible to damage when exposed to seismic loads.
- d. Buildings with shear walls were less susceptible to damage under the influence of seismic loads.

3. VERIFICATION MODEL ANALYSIS

3.1 GENERAL

In this chapter, the verification studies were performed for analyzing RC building, where there collected from the previous literature. Several case studies were based on the time history analysis of buildings, where evaluated the performance of buildings under the influence of the El Centro N-S 1940 earthquake acceleration record of the imperial valley earthquake using SAP2000 software.

3.2 CASE STUDIES TO MODELLING BY SAP 2000 SOFTWARE

3.2.1 First Case Study

Nitya and Arathi in 2016 [37] A seven-storey RC building was studied and the plan of this building was in a plus shape. SAP2000 software was used to analyze the building. The building was analyzed using the time history analysis method (the building exposed to the El-Centro earthquake acceleration). Description of the building and 3D model of the building shown in Table 3.1 and Figure 3.1 respectively.

Table 3.1: Description of the Building.

No. of Stories	7
Height of the story	3 m
Dimension of beam	0.45 m x 0.23 m
Column size	0.5 m x 0.3 m
Thickness of slab	0.16 m
Number of spans in both direction (X & Y)	4 x 4
Length of each span	4 m
$\hat{f}_c$ (Grade of concrete)	30 N/mm ²
Steel type	S420 N/mm ²
Steel Modulus Elasticity	2 * 10 ⁵ MPa

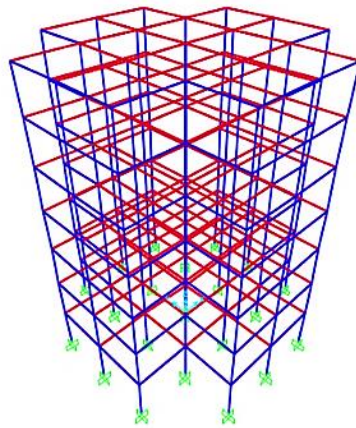


Figure 3.1: 3D Model of G+6 Storey Building.

After modeled the building follow these steps:

- Define the function of time history, as shown in Figure 3.2 and Figure 3.3.
- Define load cases, as shown in Figure 3.4 and Figure 3.5.
- Run analysis, as shown in Figure 3.6.
- Show the results (maximum base shear and displacement), as shown in Figure 3.7 and Figure 3.8.

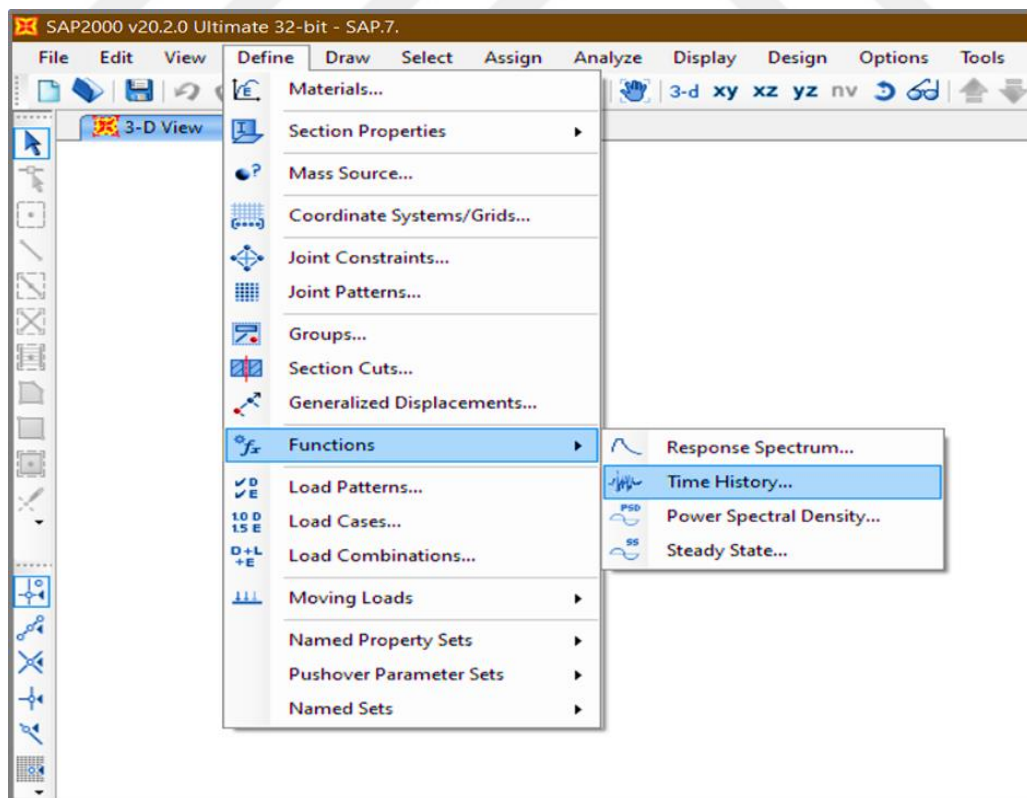


Figure 3.2: Time History Function Definition.

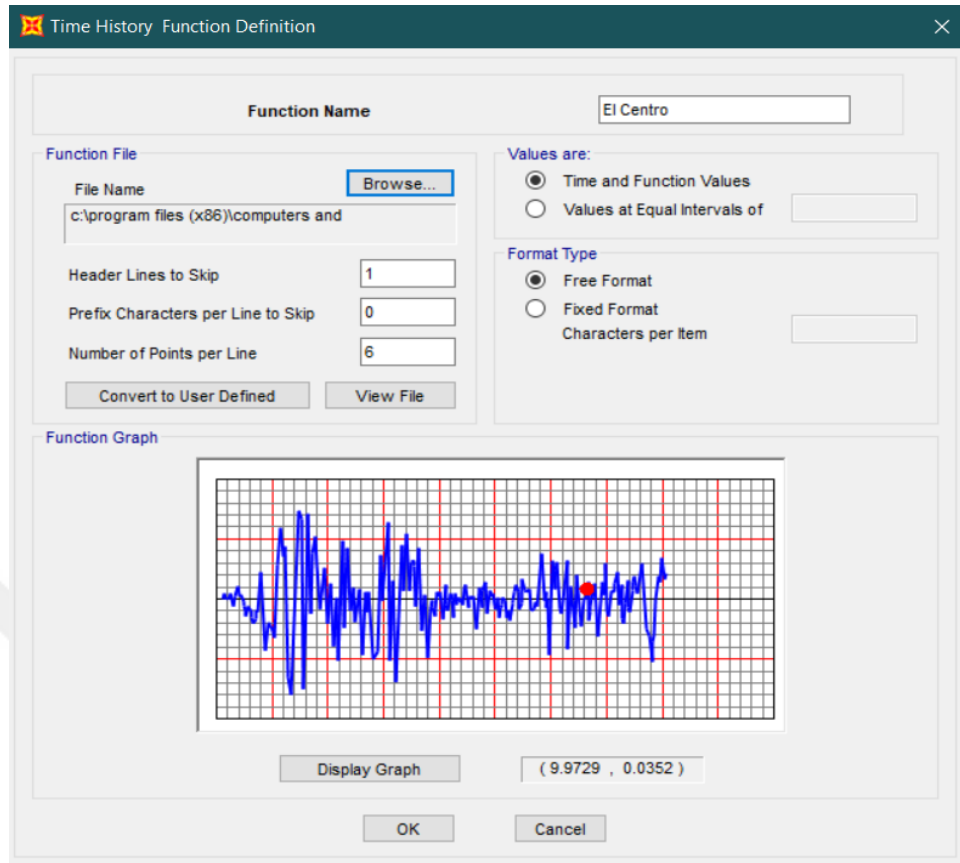


Figure 3.3: Time History Function Definition.

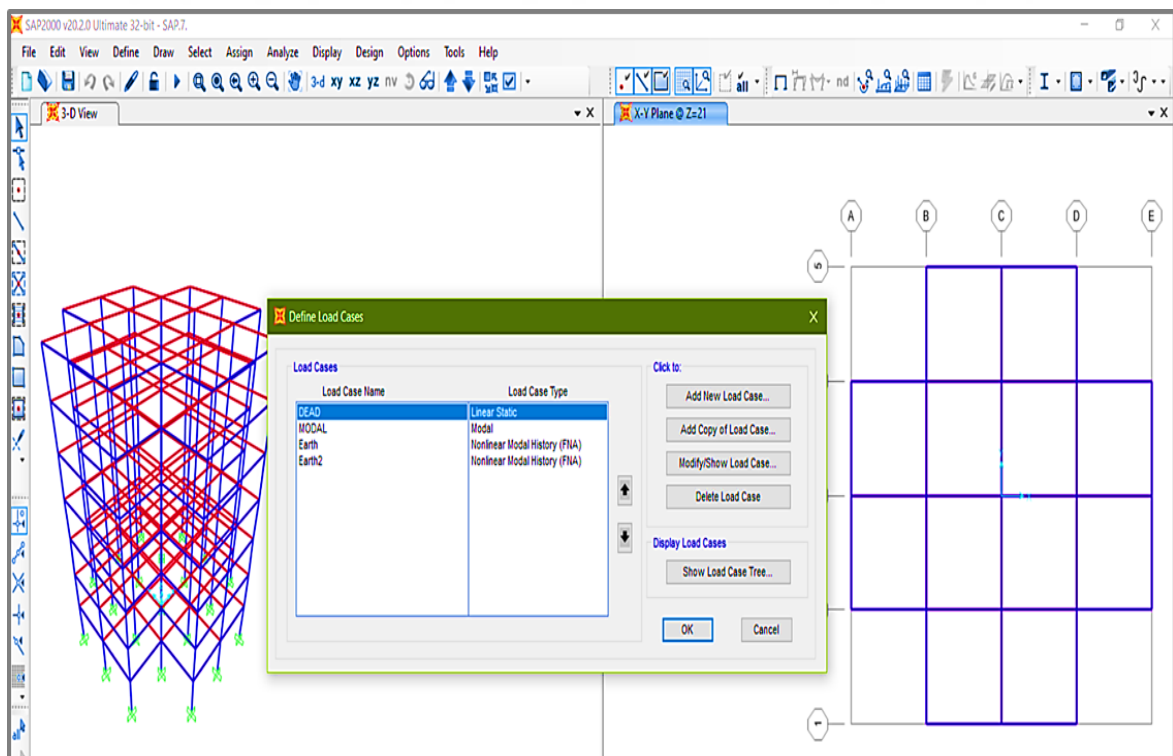


Figure 3.4: Define Load Cases.

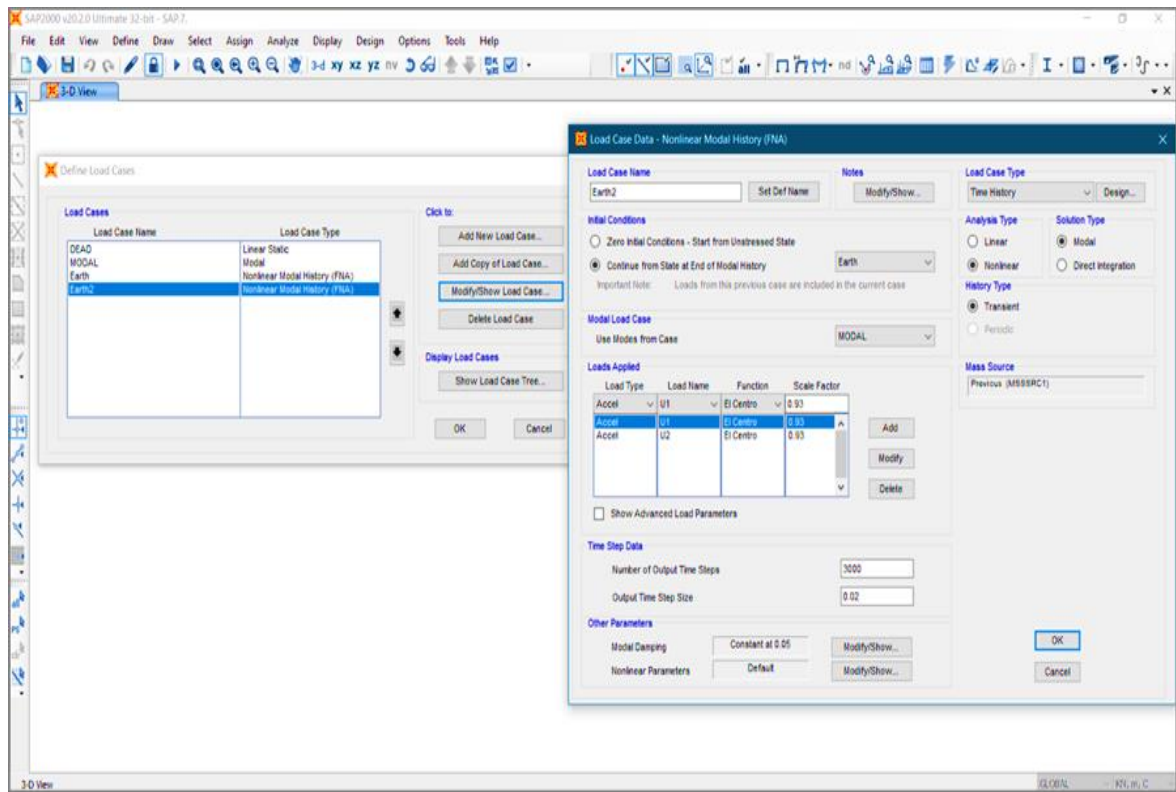


Figure 3.5: Define Load Cases.

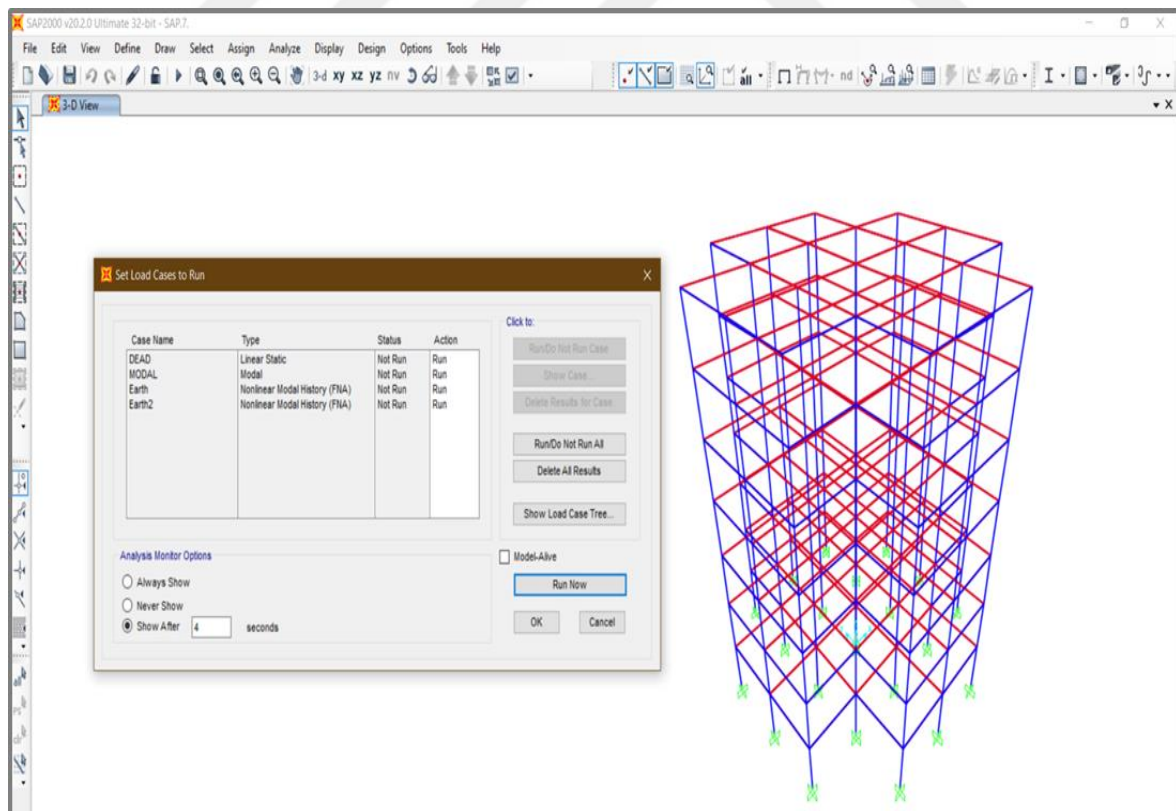


Figure 3.6: Run Analysis.

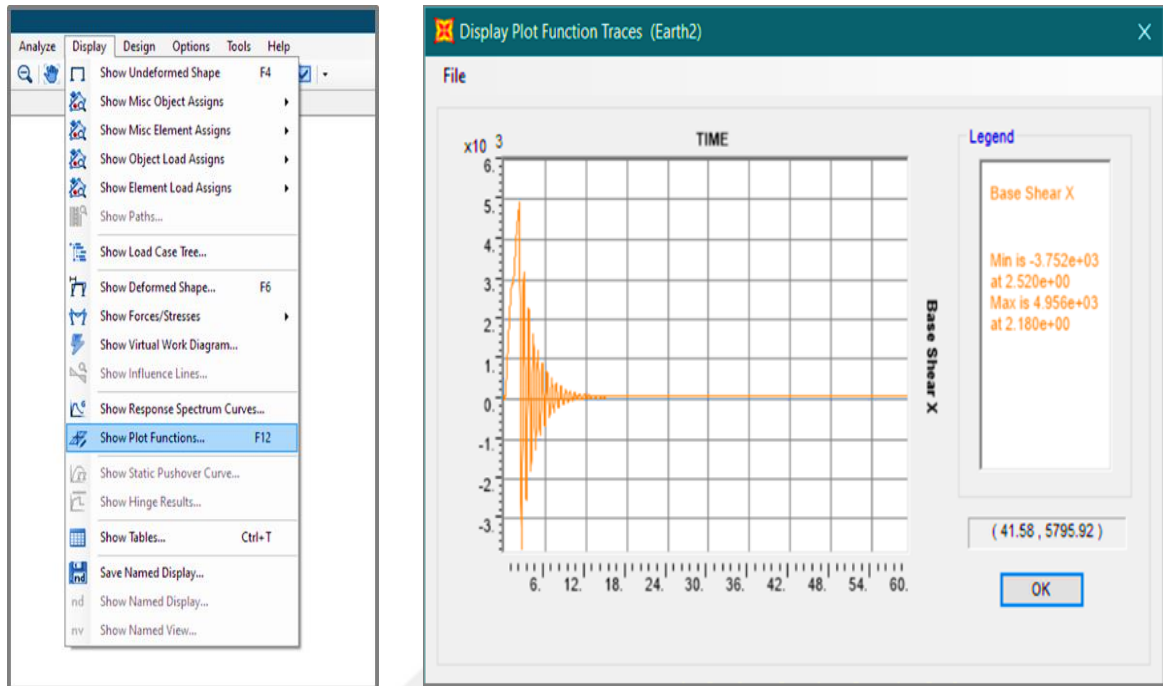


Figure 3.7: Maximum Base Shear (kN).

Joint Displacements

File View Edit Format-Filter-Sort Select Options

Units: As Noted

Filter:

	Joint Text	OutputCase	CaseType Text	StepType Text	U1 m	U2 m
	9	Earth2	NonModHist	Max	0	
	9	Earth2	NonModHist	Min	0	
	10	Earth2	NonModHist	Max	0.010093	0.02068
	10	Earth2	NonModHist	Min	-0.012885	-0.02642
	11	Earth2	NonModHist	Max	0.024549	0.04505
	11	Earth2	NonModHist	Min	-0.030854	-0.05623
	12	Earth2	NonModHist	Max	0.037878	0.066276
	12	Earth2	NonModHist	Min	-0.046713	-0.081216
	13	Earth2	NonModHist	Max	0.048884	0.083682
	13	Earth2	NonModHist	Min	-0.059332	-0.101587
	14	Earth2	NonModHist	Max	0.057454	0.096967
	14	Earth2	NonModHist	Min	-0.069041	-0.11698
	15	Earth2	NonModHist	Max	0.063249	0.105992
	15	Earth2	NonModHist	Min	-0.075841	-0.127294
	16	Earth2	NonModHist	Max	0.066492	0.110851
	16	Earth2	NonModHist	Min	-0.079869	-0.132946

Record: << < 1 > >> of 3192

Add Tables... Done

Joint Displacements

- Assembled Joint Masses
- Base Reactions
- Joint Accelerations - Absolute
- Joint Accelerations - Relative
- Joint Displacements
- Joint Displacements - Absolute
- Joint Reactions
- Joint Velocities - Absolute
- Joint Velocities - Relative
- Modal Load Participation Ratios
- Modal Participating Mass Ratios
- Modal Participation Factors
- Modal Periods And Frequencies
- Total Energy Components

Figure 3.8: Show Tables.

Table 3.2 and Figure 3.9, shown the verified results of base shear and displacements values with the previous articles of (Nitya and Arathi) [37].

Table 3.2: Compared of Storey Displacements Between [Nitya and Arathi] [37] and the Present Work.

Storey No.	Present work (m)	Nitya and Arathi work [37] (m)	(D_{Pres}/D_{ref})
7	0.066466	0.064	1.04
6	0.063232	0.061	1.04
5	0.057434	0.058	0.99
4	0.04887	0.048	1.02
3	0.037869	0.038	1.00
2	0.024545	0.024	1.02
1	0.010075	0.01	1.01
Mean			1.02
Variance			0.00035
Standard Division			0.017

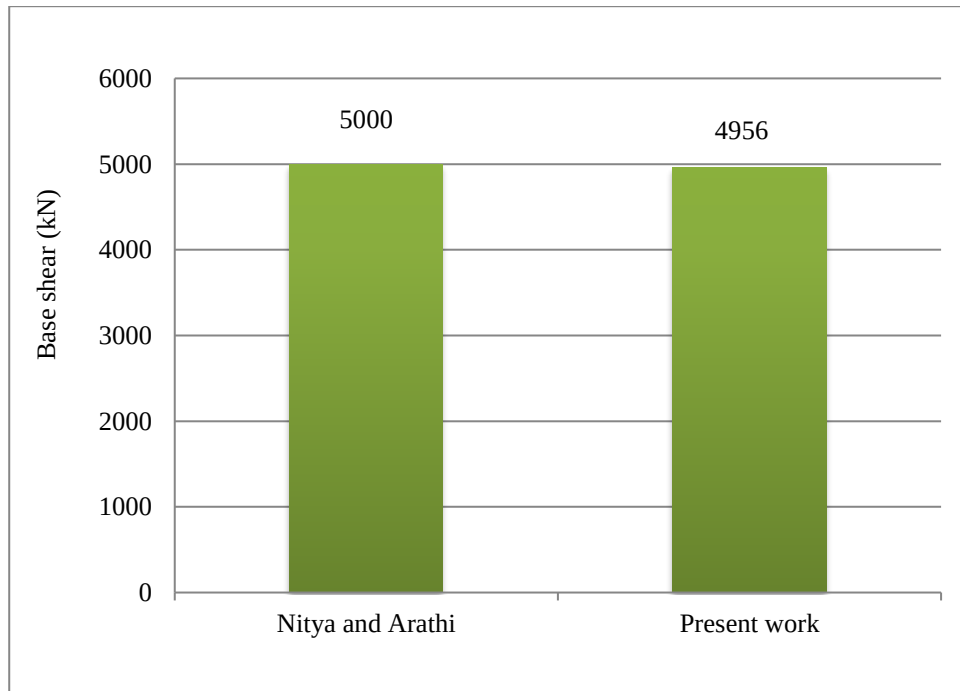


Figure 3.9: Compared Between Maximum Base Shears.

3.2.2 Second Case Study

Verma, et al. in 2019 [38] A reinforced concrete building was studied using the SAP2000 program where the nonlinear time history method was used in the analysis under the influence of the El-Centro earthquake acceleration. Description of the building and 3D model of the building shown in Table 3.3 and Figure 3.10 respectively.

Table 3.3: Description of the Building.

No. of Stories	10
Height of the story	3.1 m
Dimension of beam	(0.45 x 0.23) m
Column size	(0.5 x 0.5) m
Thickness of slab	0.15 m
Number of spans in X-direction	4
Number of spans in Y-direction	3
Length of each span	5 m
Live load	3.5 kN/m ²
Dead load	3.75 kN/m ²
$\hat{f}_c$ (Grade of concrete)	25 N/mm ²
Steel type	S420 N/mm ²

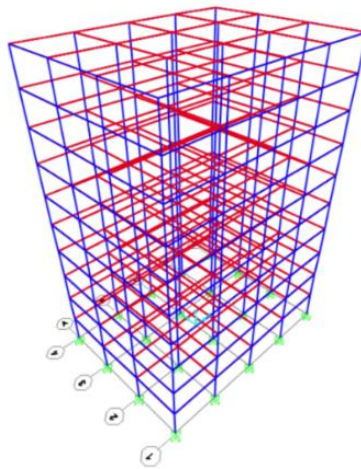


Figure 3.10: 3D Model of G+9 Storey Building.

Figure 3.11 and Figure 3.12, shown the verified results of base shear and displacements at top tip of building values with the previous articles of (Arjit Verma & Alhamd Farqaleet) [38].

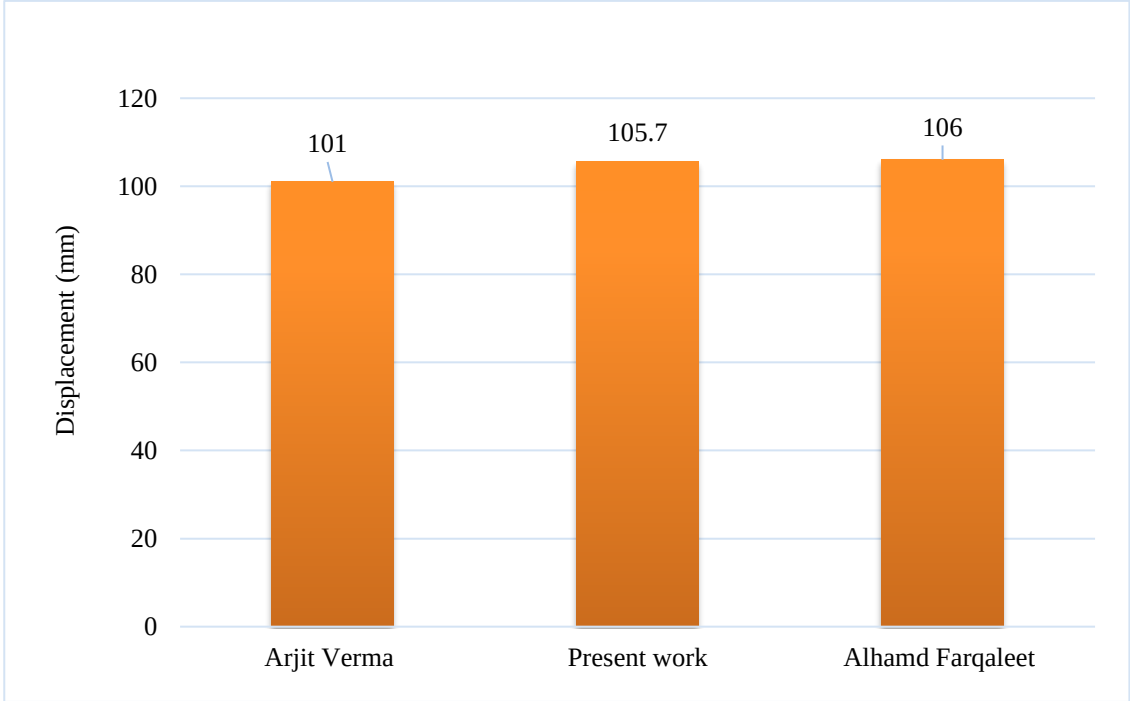


Figure 3.11: Compared Between Maximum Base Shear (kN).

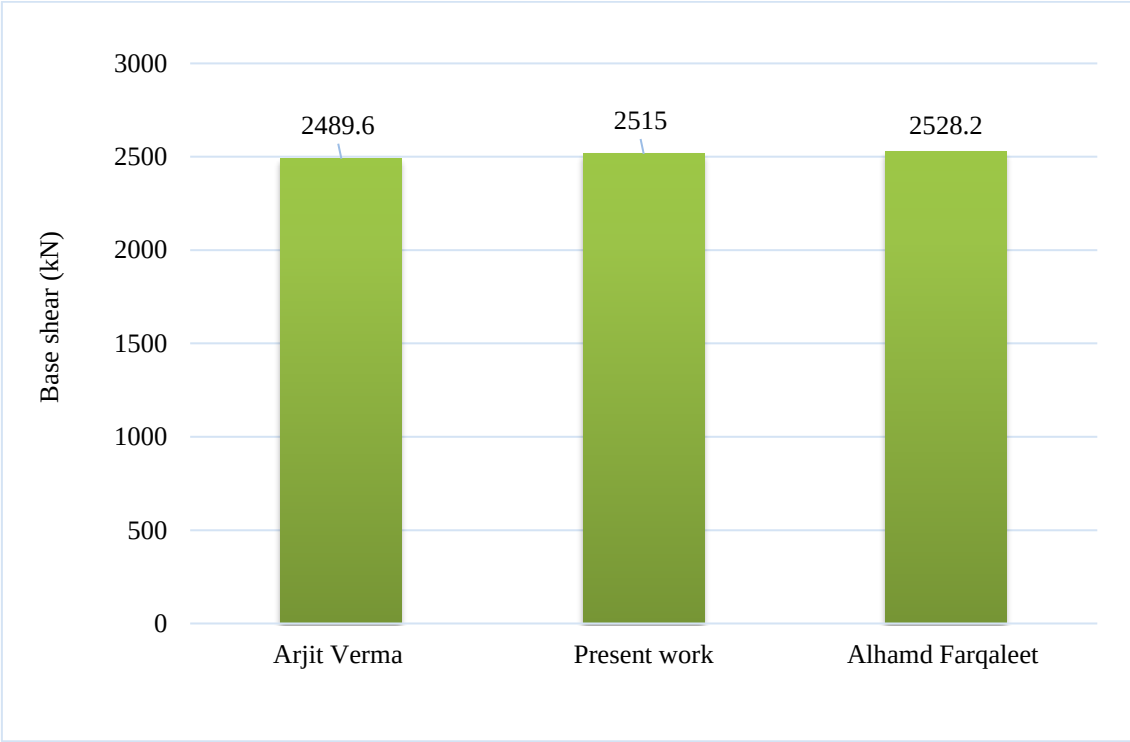


Figure 3.12: Compared Between Maximum Displacement (mm).

3.2.3 Third Case Study

Mahajan and Krishna in 2017 [17] Using the SAP software, reinforced concrete buildings with irregular shapes were studied in the presence or absence of infill walls under the influence of seismic loads, and compared to normal buildings (L, T, plus and I-plan layout). Description of the building shown in Table 3.4.

Table 3.4: Description of the Building.

No. of Stories	8
Height of the story	3 m
Dimension of beam	0.23 m x 0.4 m
Column size	0.45 m x 0.45 m
Thickness of slab	0.2 m
Number of spans in both direction (X & Y)	3 x 3
Length of each span	5 m
Live load on floors	3 kN/m ²
Live load on roof	1.5 kN/m ²
Floor finish	1 kN/m ²
Roof treatment	1.5 kN/m ²
$\hat{f}_c$ (Grade of concrete)	25 N/mm ²
Steel type	S420 N/mm ²

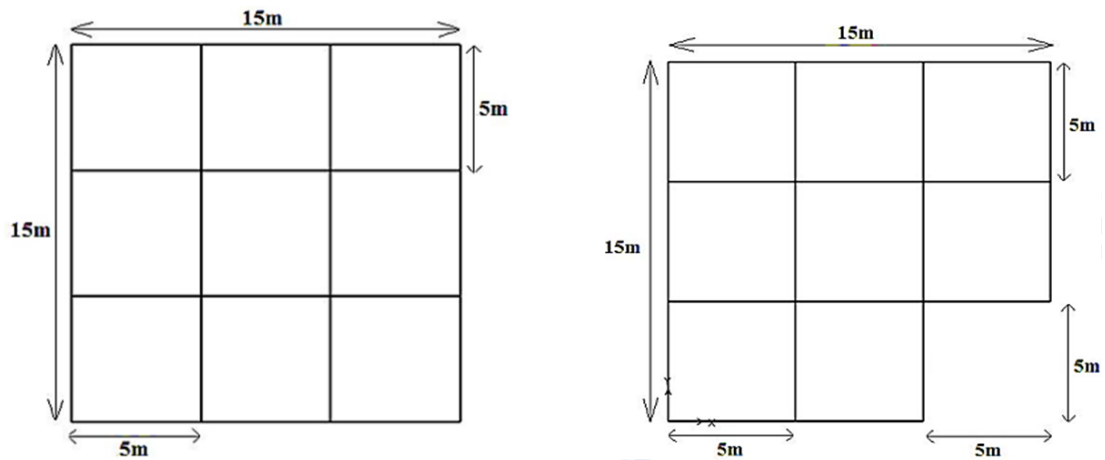


Figure 3.13: Regular Building and L - Shaped Plan Layout.

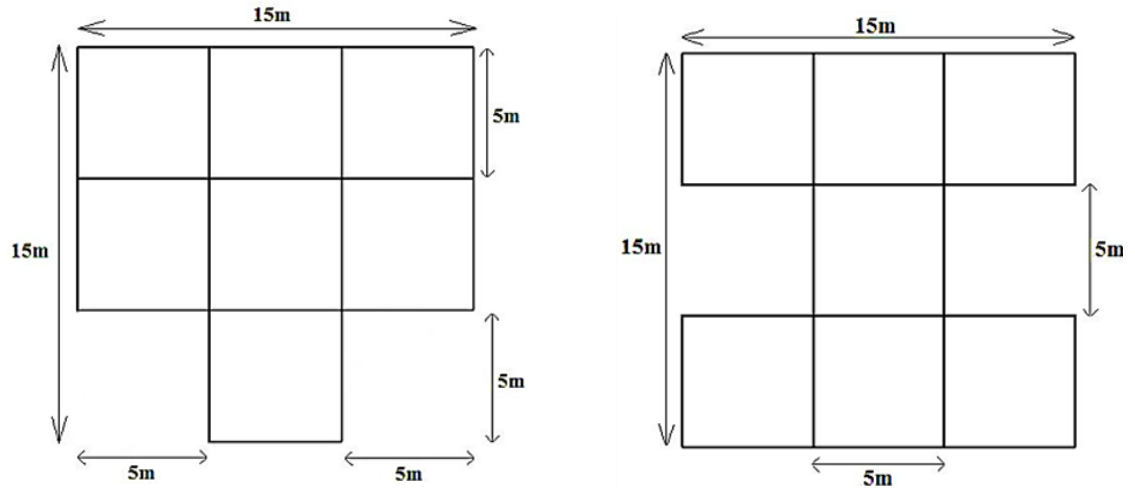


Figure 3.14: T- Shaped and I - Shaped Plan Layout.

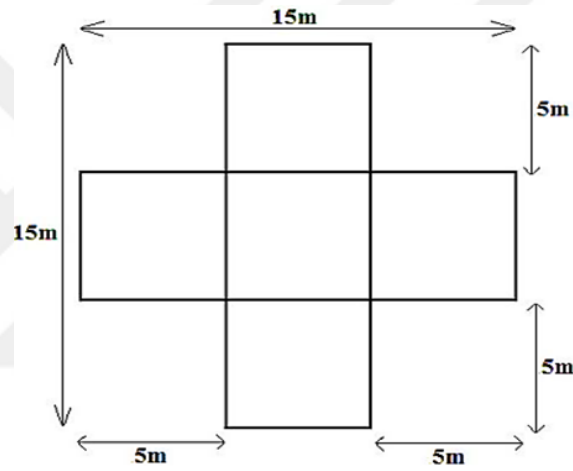


Figure 3.15: Plus-Shaped Plan Layout.

Table 3.5 and Table 3.6, shown the verified results of time period values with the previous articles of (Mahajan and Krishna) [17].

Table 3.5: Values of Time Period (sec.) by Mahajan and Krishna [17].

Mode	Time period of structures having plan shape (sec.)				
	Regular	L	T	I	Plus
1	1.0533	1.0318	1.0558	1.0655	1.0707
2	1.0153	1.0318	1.0556	1.0625	1.0707
3	1.0015	1.079	1.089	1.0106	1.0117

Table 3.6: Values of Time Period (sec.) by Present Work.

Mode	Time period of structures having plan shape (sec.)				
	Regular	L	T	I	Plus
1	1.0991	1.0928	1.0824	1.0820	1.0562
2	1.0991	1.0904	1.0824	1.0391	1.0562
3	0.9347	0.9278	0.9172	0.9318	0.8967

3.2.4 Fourth Case Study

Abdel-Raheem , et al. in 2010 [39] In this study, the seismic performance of multi-storey buildings were examined. Nonlinear time-history analysis was used for evaluation of response spectra procedures and equivalent static. SAP 2000 software was used for analysis. Description of the building and 3D model of the building shown in Table 3.7 and Figure 3.16 respectively.

Table 3.7: Material and Dimensional Details.

No. of Storeys	6
Height of the story	3 m
Dimension of beam	(0.7 x 0.25) m
Dimension of column1	(0.45 x 0.45) m
Dimension of column2	(0.9 x 0.9) m
Dimension of column3	(1.2 x 1.2) m
Thickness of slab	0.15 m
Number of spans in both direction (X & Y)	3 x 3
Length of each span	6 m
Live load	2 kN/m ²
$\hat{f}_c$ (Grade of concrete)	25 N/mm ²
Steel type	S 420 N/mm ²

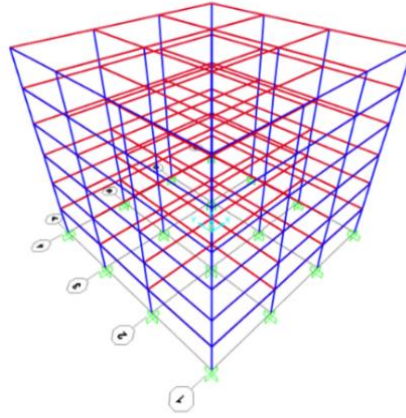


Figure 3.16: 3D Model of 6 Storey Building.

Table 3.8 and Table 3.9, shown the verified results of time period values with the previous articles of (Abdel-Raheem , et al.) [39].

Table 3.8: Values of Time Period (sec.) by Abdel-Raheem , et al. [39].

Mode	Time period of building having column size (sec)		
	Column1 (0.45 x 0.45) m	Column2 (0.9 x 0.9) m	Column3 (1.2 x 1.2) m
1	0.681	0.476	0.436

Table 3.9: Values of Time Period (sec.) by Present Work.

Mode	Time period of building having column size (sec)		
	Column1 (0.45 x 0.45) m	Column2 (0.9 x 0.9) m	Column3 (1.2 x 1.2) m
1	0.689	0.479	0.438

3.2.5 Fifth Case Study

Kakde and Kasheef in 2021 [40] Using Altadena ground motions in SAP2000, evaluated the constructions that were resting on sloping ground that was extra exposed to heavy winds. Used SAP-2000 to run all the simulations. Based on the structure's time period and other characteristics, the structural performance was assessed. The parametric analysis has considered fundamental time period, which is a crucial factor to explain performance of any construction during seismically activated conditions. The findings of the Time period

comprised by the constructions without shear walls located at various slopes (i.e., 20°, 30°, 40°). The building resting upon the ground that is 40 degrees inclined has the lowest magnitude of time taken for oscillations of the structure during an earthquake compared to the other constructions, which have a considerably bigger value.

Table 3.10: Material and Dimensional Details.

No. of Stories	16
Height of the story	3 m
Dimension of beam	(0.3 x 0.53) m
Dimension of column	(0.3 x 0.6) m
Thickness of slab	0.15 m
Number of spans in both direction (X & Y)	6 x 6
Length of each span	3 m
Slab dead load	3.75 kN/m ²
Super imposed load	3 kN/m ²
External and Internal wall load	15 kN/m
$\hat{f}_c$ (Grade of concrete)	30 N/mm ²
Steel type	S 420 N/mm ²

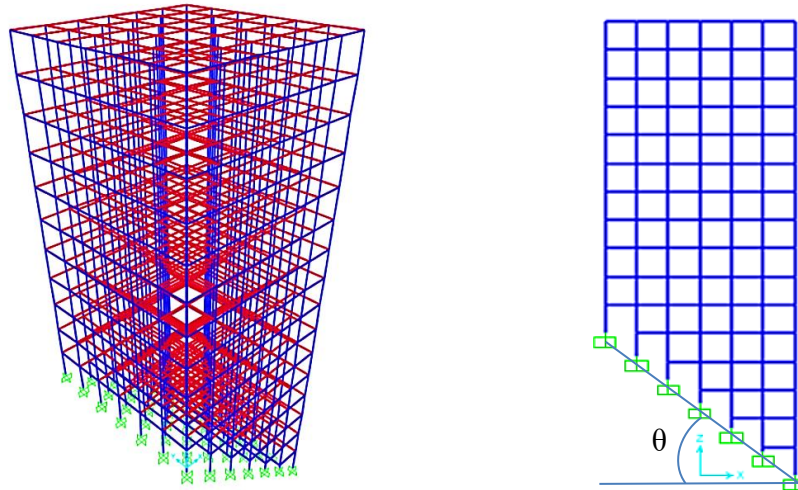


Figure 3.17: 3D & 2D Model of 16 Storey Stepback Building Inclined with an Angle of 40°.

Figure 3.18, Figure 3.19 and Table 3.11, shown the verified results of time period and displacements values with the previous articles of (Kakde and Kasheef) [40].

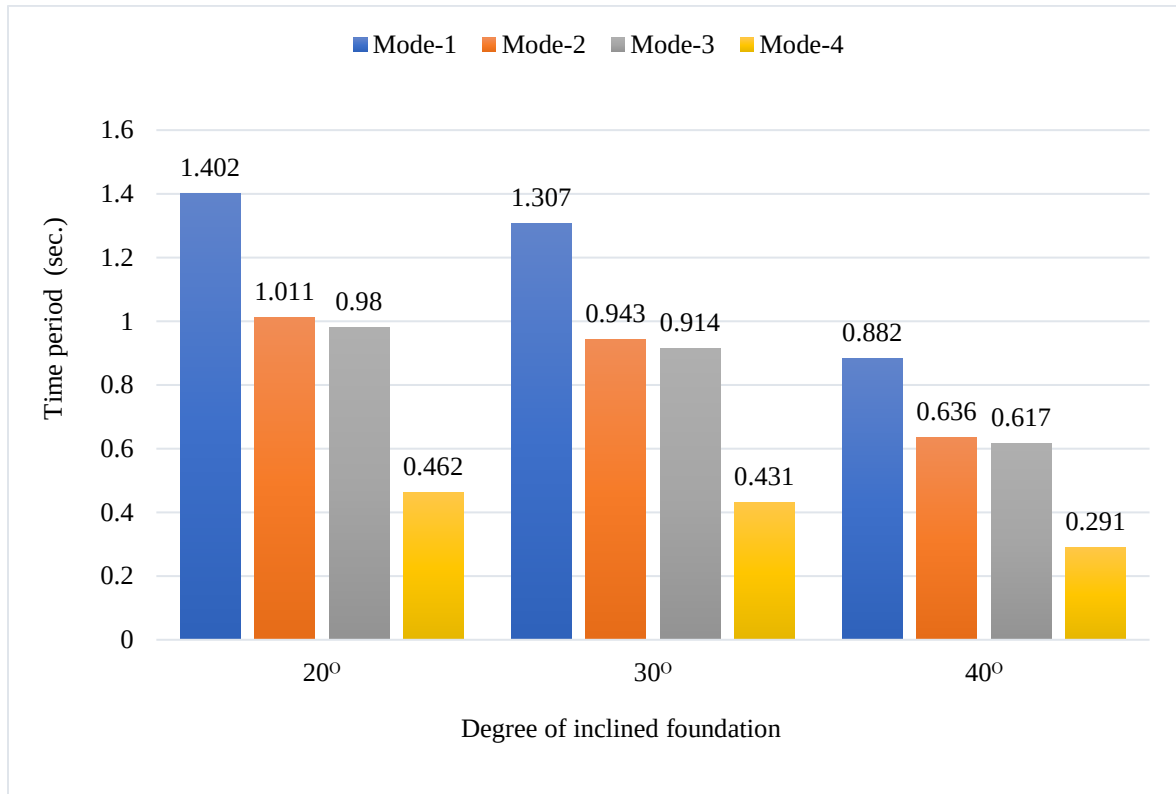


Figure 3.18: Value of Time Period Based on Degree of Inclined Foundation by (Kakde and Kasheef) [40].

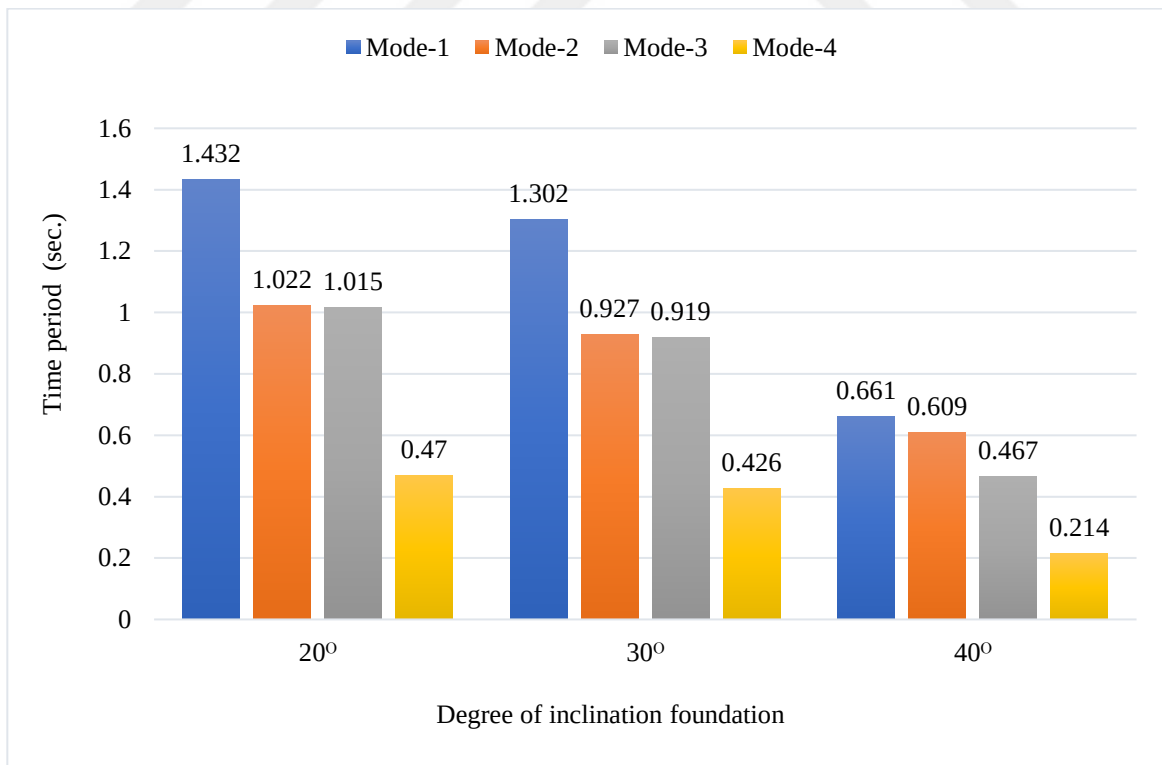


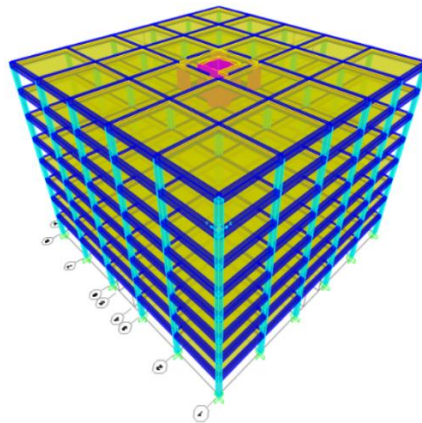
Figure 3.19: Value of Time Period Based on Degree of Inclined Foundation by the Present Work.

Table 3.11: Verified Results of Displacements Values.

Storey level	Displacements (mm) by Present work			Displacements (mm) by (Kakde and Kasheef) [40]		
	20°	30°	40°	20°	30°	40°
16	58.391	39.373	76.099	59.8	39.1	76.42
15	56.812	38.26	73.904	58	36.1	74.12
14	54.795	36.805	70.936	55.5	33.1	70.93
13	52.292	34.977	67.081	52.4	30.8	66.97
12	49.304	32.756	62.321	48.7	28.4	62.24
11	45.842	30.13	56.656	44.4	26	56.74
10	41.923	27.106	50.127	39.6	23.5	50.61
9	37.66	23.709	42.817	34.8	21	44.47
8	33.004	19.982	34.859	31.2	18.5	39.87
7	27.982	15.983	26.4	27.4	15.9	35.02
6	22.641	11.787	17.684	23.3	13.3	29.78
5	17.051	7.487	10.452	19.1	10.7	24.41
4	11.309	3.404	5.348	14.6	8.1	18.66
3	5.647	0.88	2.153	10	5.5	12.78
2	1.508	0.132	0.433	5.4	3	6.901
1	0.205	0.017	0.012	1.2	0.7	3.17

3.2.6 Sixth Case Study

Beedallah & Mohaisen in 2021 [41] Using the SAP 2000 program, a reinforced concrete building (G + 7) was analyzed in the case of shear walls under the influence of seismic loads.

**Figure 3.20:** 3D Model of Building (G+7) with Shear Walls.

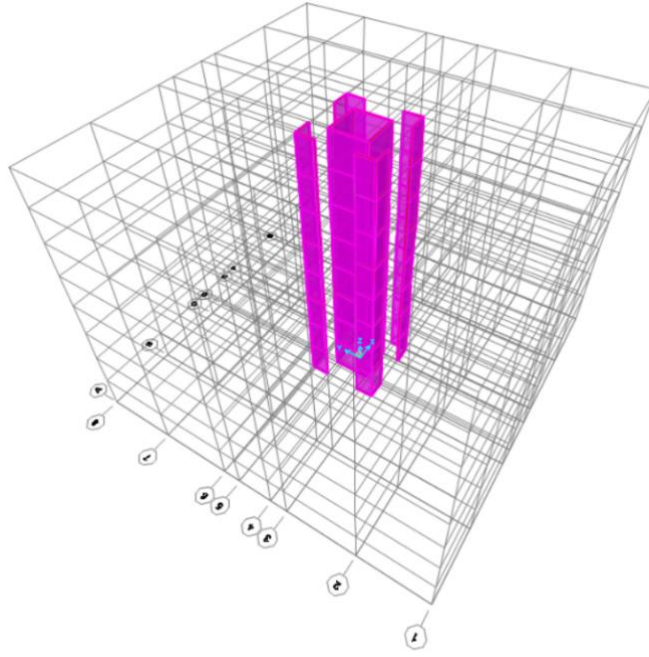


Figure 3.21: 3D View of Shear Walls.

Table 3.12: Material and Dimensional Details.

No. of Stories	8
Height of the story	3 m
Dimension of beam	(0.6 x 0.4) m
Dimension of column	(0.4 x 0.4) m
Thickness of slab	0.2 m
Thickness of shear walls	0.2
Number of spans in both direction (X & Y)	5 x 5
Length of each span	6 m
Live load	2 kN/m ²
Superimposed dead load	3.25 kN/m ²
$\hat{f}_c$ (Grade of concrete)	25 N/mm ²
Steel type	S420 N/mm ²

Table 3.11 and Figure 3.22, shown the verified results of time period and displacements values with the previous articles of (Beedallah & Mohaisen) [41].

Table 3.11: Compared Values of Time Period Between (Beedallah & Mohaisen) [41] and the Present Work.

Mode No.	Present work	Beedallah & Mohaisen [41]
	Time period (Sec.)	Time period (Sec.)
1	1.028	0.977
2	0.863	0.757
3	0.863	0.757
4	0.339	0.324
5	0.273	0.219
6	0.273	0.219
7	0.270	0.193
8	0.270	0.140
9	0.199	0.138
10	0.149	0.137
11	0.149	0.137
12	0.140	0.133

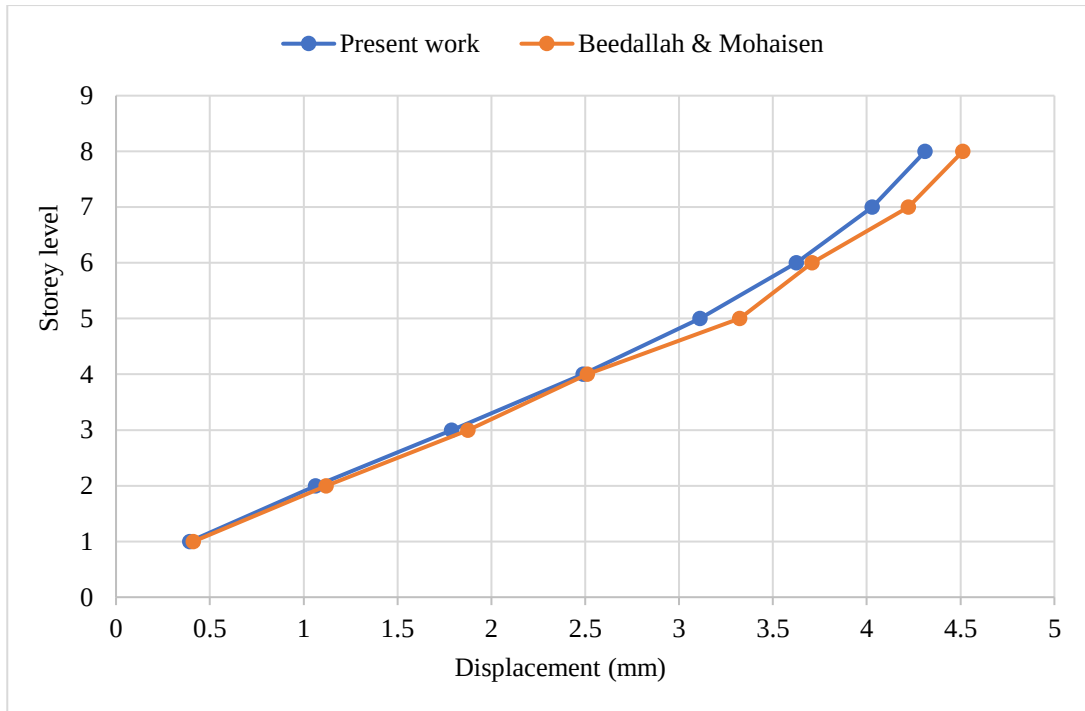


Figure 3.22: Displacements Values of Each Storey.

3.3 CONCLUDING REMARK

- a. After modeling and analyzing all models, all results obtained in the current work were close to the results of previous literature. The results showed the values of base shear, displacements, and time period.
- b. The verification modeling process was useful because it gave a perception of the results obtained by previous researchers, as well as developed the skill of using the SAP2000 software and gave confidence in the results obtained in the present work.
- c. The percentage of error in the results obtained from the applied models didn't exceed 5%. For example, in the first study case, the maximum base shear value and maximum displacement in the present work were 4956 kN and 66.466 mm respectively, while their values were 5000 kN and 64 mm respectively, according to the results of (Nitya and Arathi).

4. PARAMETRIC STUDY OF RC BUILDINGS

4.1 GENERAL

This chapter deals with the use of finite element analysis to study the response of an RC building that has inclined supporting leads in the foundations. The effect of these buildings exhibit when subjected to seismic loads differs from buildings that have flat support points in the foundations. These buildings have a lot of weaknesses that need to be found and then properly developed. The seismic performance of the RC buildings was investigated to obtain results that give the possibility of an appropriate analysis and design of these buildings. Therefore, shear walls had been built for these buildings to reduce seismic forces. All results obtained in the presence and absence of shear walls were compared. The base shear of buildings on slopes for different shear walls configuration is increased by approximately 30-40%. The reduction in lateral displacements is observed similar to that of models on level ground due to the provision of shear walls in both directions. The time period of the shear wall model decreased by 20-30% with the effect of the span length, while it decreased by 80-90% with the effect of the storey height. The buildings were analyzed using the SAP2000 software using the time history analysis method under the influence of the EL-Centro N-S 1940 earthquake acceleration record. The results had been shown the values of the base shear, time period, roof displacements and storey's drift. In addition, the response spectrum method was used in the analysis of buildings that have inclined foundations.

4.2 MODEL DESCRIPTION AND STUDY METHODOLOGY

Several RC buildings were studied to evaluate the seismic performance of these buildings under the influence of a change in four parameters. These parameters are the degree of inclination of the foundations (0° , 10° , 20° & 40°), the number of storeys (8, 12, 16 & 20 storey), the span length (4, 5 & 6) m, and the storey height (3, 3.5 & 4) m, as shown in Figure 4.1.

The results were obtained by modeling 288 analyzed building cases in the SAP 2000 software and these results had been shown in 128 figures. The analysis had been done in the presence and absence of shear walls. These results depend on the parameters, where the

effect of the change in the degree of foundation inclination and the storey number appears in all 128 figures, while the effect of the span length and storey height are shown in several cases where one of them is constant and the other is variable in order to show the effect of the variable parameter, as shown in Figure 4.2.

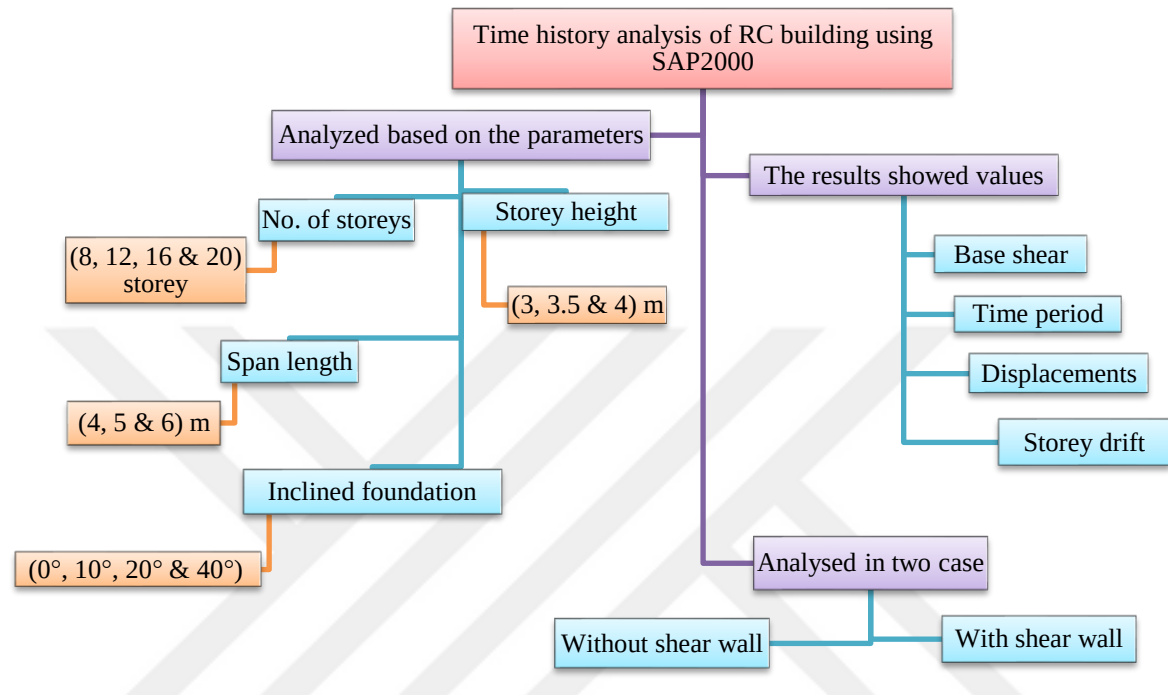


Figure 4.1: Time History Analysis of the RC Building Using SAP2000.

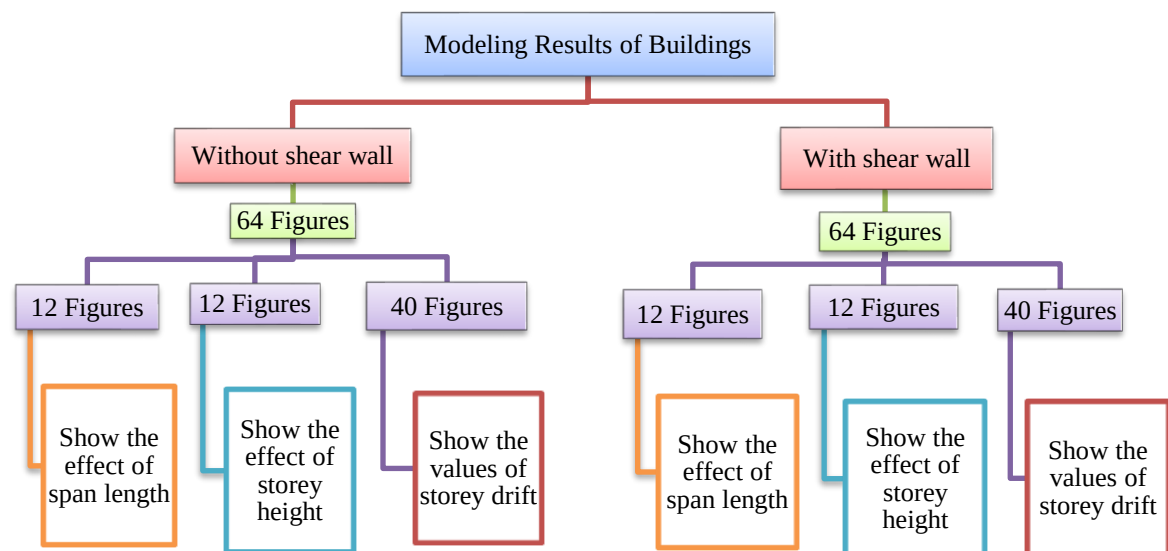


Figure 4.2: Modeling Results of the Time History Analysis of Buildings.

In addition, using the response spectrum method, the analysis had been performed in the presence and absence of shear walls and the results of each case were shown in 20 figures, as shown in Figure 4.3.

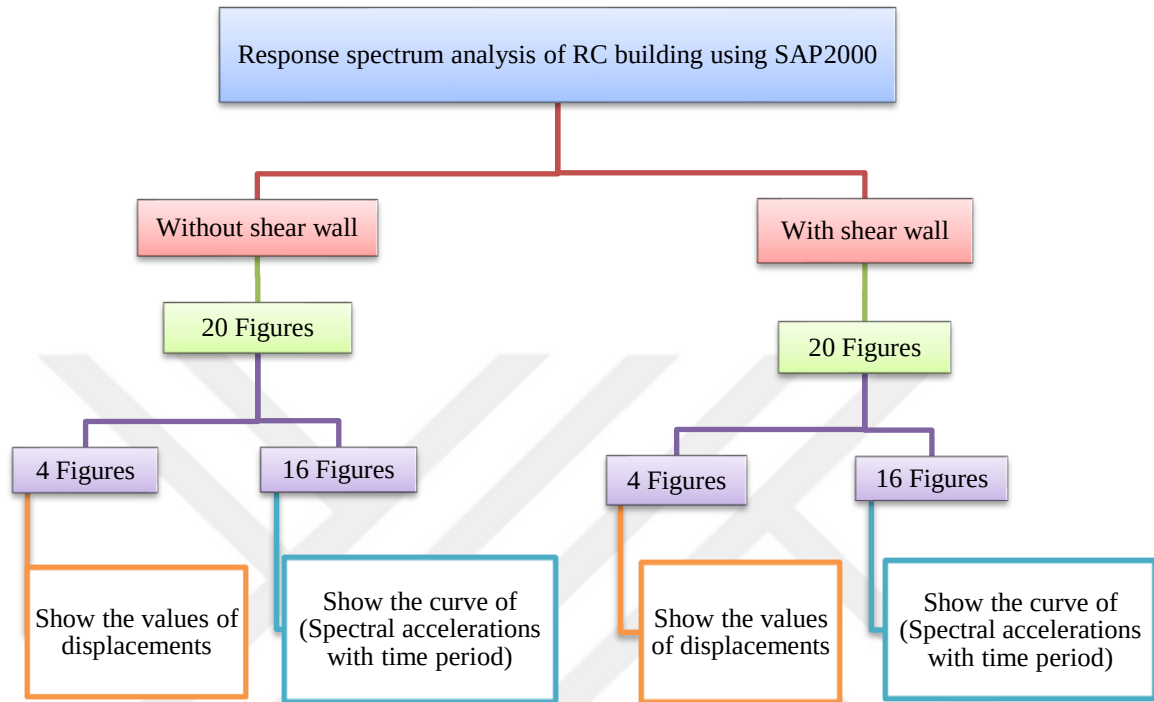


Figure 4.3: Modeling Results of the Response Spectrum Analysis of Buildings.

The study methodology shown below:

- Review the different studies of the researchers that were collected from previous studies.
- Several multi-storey RC buildings had been selected and modeled.
- Conducting a dynamic analysis on a chosen building model, with the results of the analysis shown in a manner of graphs.
- Modeled the type of support as a fixed.
- Ignored the effect of soil structure interaction.
- Using SAP2000 software, multi-storey buildings with sloping foundations were analyzed under the influence of seismic loads.

Table 4.1, shown the buildings description where there collected from the previous literature of (Nitya and Arathi) [37] and (Mahajan and Krishna) [17].

Table 4.1: The Buildings Description.

Dimension of beam	0.23 m x 0.4 m
Column size	0.45 m x 0.45 m
Thickness of slab	0.15 m
Number of spans in both direction (X & Y)	4 x 4 (squared spans)
Thickness of shear wall	0.3 m
Live load on floors	3 kN/m ²
Live load on roof	1.5 kN/m ²
Floor finish	1 kN/m ²
Roof treatment	1.5 kN/m ²
$\hat{f}_c$ (Grade of concrete)	25 N/mm ²
Steel type	Fe 415 N/mm ²

4.3 MODELING RESULTS OF BUILDINGS THAT HAVING DIFFERENT DEGREE OF FOUNDATION INCLINATION

4.3.1 Modeling Results of Buildings Without Shear Wall

The value of the base shear, Time period and displacements decreased as the degree of foundation inclination of the building increased, as shown below:

- As shown in Figure 4.10, the value of base shear decreased by (14%, 23% & 42%) at the degree of the foundation inclination increased from 0° to (10°, 20° & 40°) respectively, when the No. of storeys were 8. While its value remained constant at the inclination angle (0° to 20°), then its value decreased by 9.3% at the inclination angle 40° (when the No. of storeys were 20).
- As shown in Figure 4.15, the value of time period decreased by (11%, 33% & 75%) when the degree of the foundation inclination increased from 0° to (10°, 20° & 40°) respectively, when the No. of storeys were 8. While its value decreased by (5%, 13% & 30%) when the degree of the foundation inclination increased from 0° to (10°, 20° & 40°) respectively, when the No. of storeys were 20.
- As shown in Figure 4.16, the value of displacements in X direction decreased by (18%, 55% & 95%) when the degree of the foundation inclination increased from 0° to (10°, 20° & 40°) respectively, when the No. of storeys were 8. While its value decreased by

(9%, 19% & 40%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, when the No. of storeys were 20.

The value of the base shear, Time period and displacements increased as the No. of storeys increased. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings. The increases in time period due to decrease the stiffness of RC building and it have more displacements at tip of buildings, as shown below:

- a. As shown in Figure 4.10, the value of base shear increased by (46%, 108% & 112%) when the No. of storeys increased from 8 to (12, 16 & 20) respectively, when the degree of the foundation inclination 0° . While its value increased by (81%, 125% & 233%) when the No. of storeys increased from 8 to (12, 16 & 20) respectively, when the degree of the foundation inclination 40° .
- b. As shown in Figure 4.15, the value of time period increased by (52%, 105% & 159%) when the No. of storeys increased from 8 to (12, 16 & 20) respectively, when the degree of the foundation inclination 0° . While its value increased by (198%, 420% & 642%) when the No. of storeys increased from 8 to (12, 16 & 20) respectively, when the degree of the foundation inclination 40° .
- c. As shown in Figure 4.16, the value of displacements in X direction increased by (157%, 325% & 474%) when the No. of storeys increased from 8 to (12, 16 & 20) respectively, when the degree of the foundation inclination 0° . While its value increased by (936%, 3107% & 7524%) when the No. of storeys increased from 8 to (12, 16 & 20) respectively, when the degree of the foundation inclination 40° .

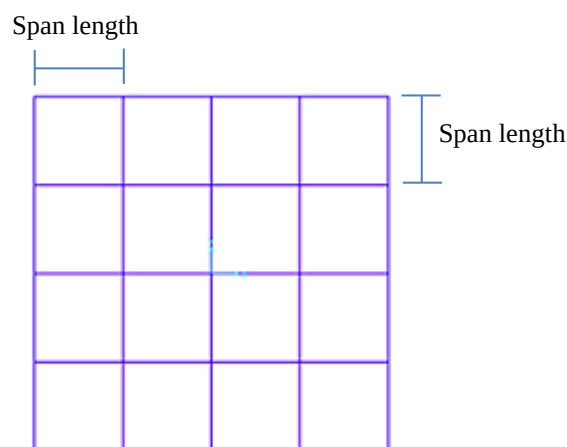


Figure 4.4: Plan of the Building.

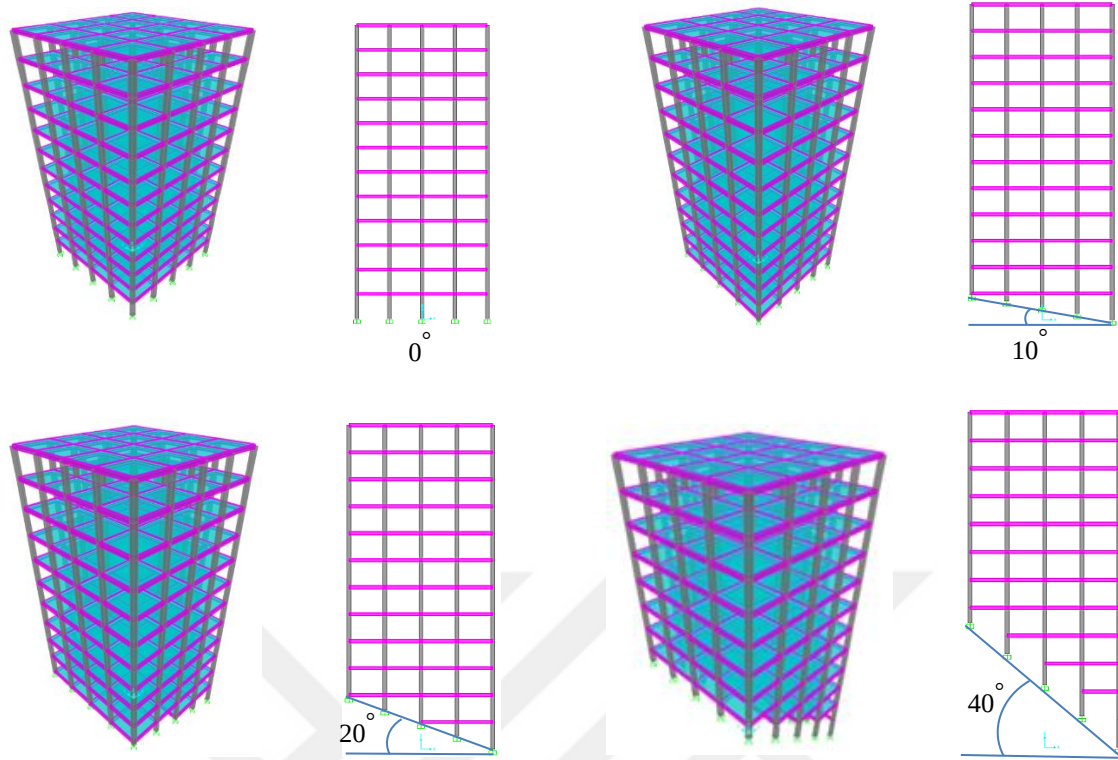


Figure 4.5: 3D & 2D Model of 12 Storey Buildings Having Inclined Supporting Foundations with an Angle (0° , 10° , 20° and 40°).

4.3.1.1 Modeling results based on the no. of storeys and span length without shear wall

The value of the base shear, Time period and displacements increased or decreased when the span length increased. The base shear, time period and roof displacements values increased when the span length increased. However, it may lead to made to redistribution the internals forces and re-arranged the location of plastic hinges. This phenomenon can be accrued because the increasing of span length leads to decreasing the lateral stiffness of beams of studied RC building, as shown below:

- As shown in (Figure 4.6, Figure 4.10 & Figure 4.14), the value of base shear increased by (29% & 54%) when the span length increased from 4 m to (5 & 6) m respectively, when the degree of the foundation inclination 40° and storey number 20. While its value increased by (17% & 82%) when the span length increased from 4 m to (5 & 6) m respectively, when the degree of the foundation inclination 0° and storey number 20.
- As shown in (Figure 4.7, Figure 4.11 & Figure 4.15), the value of time period increased by (10% & 20%) when the span length increased from 4 m to (5 & 6) m respectively,

when the degree of the foundation inclination 40° and storey number 20. While its value increased by (19% & 39%) when the span length increased from 3 m to (5 & 6) m respectively, when the degree of the foundation inclination 0° and storey number 20.

- c. As shown in (Figure 4.8, Figure 4.12 & Figure 4.16), the value of displacements increased by (24% & 31%) when the span length increased from 4 m to (5 & 6) m respectively, when the degree of the foundation inclination 40° and storey number 20. While its value increased by (16% & 45%) when the span length increased from 4 m to (5 & 6) m respectively, when the degree of the foundation inclination 0° and storey number 20.

The Results When the Storey Height (3 m) and Span Length (4 m):

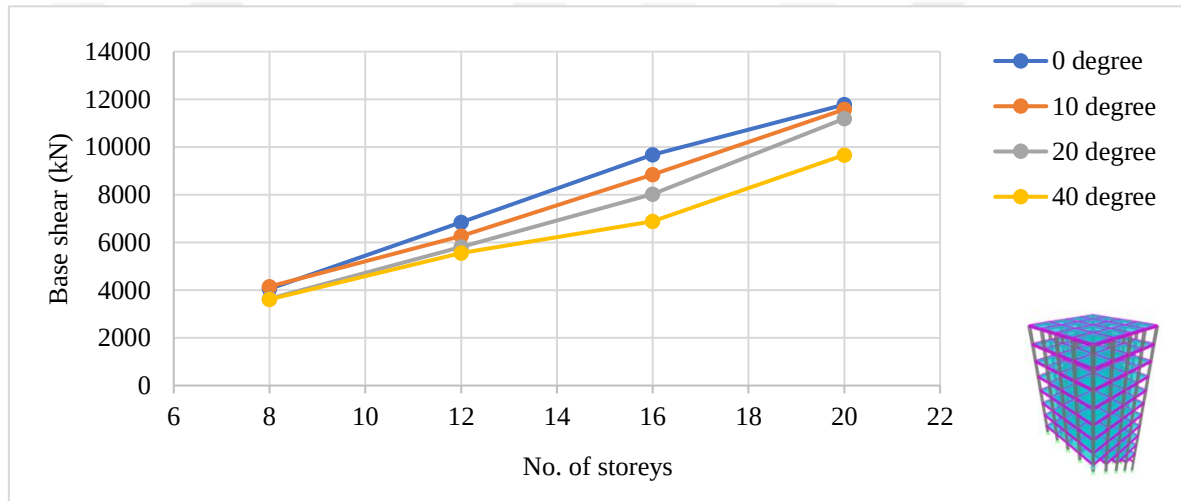


Figure 4.6: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

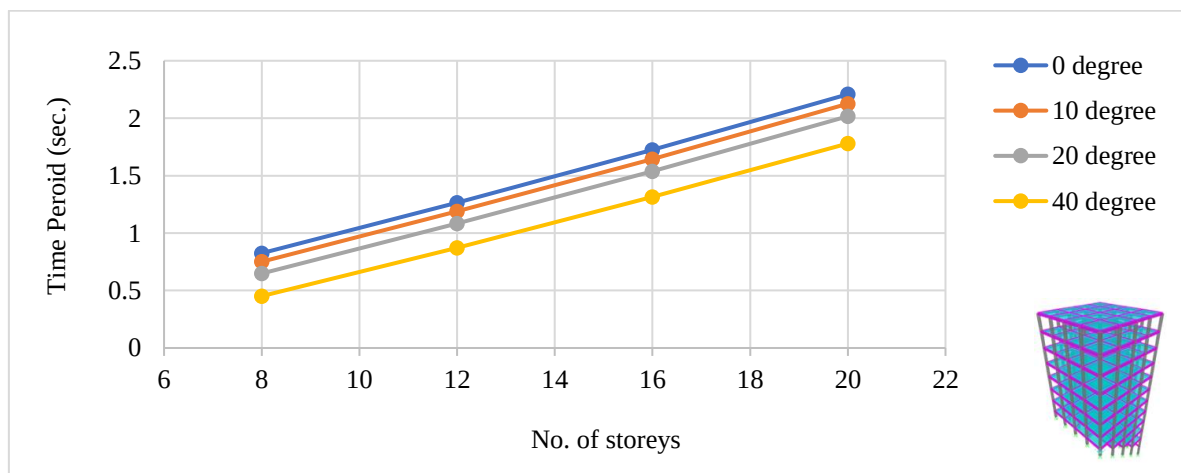


Figure 4.7: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

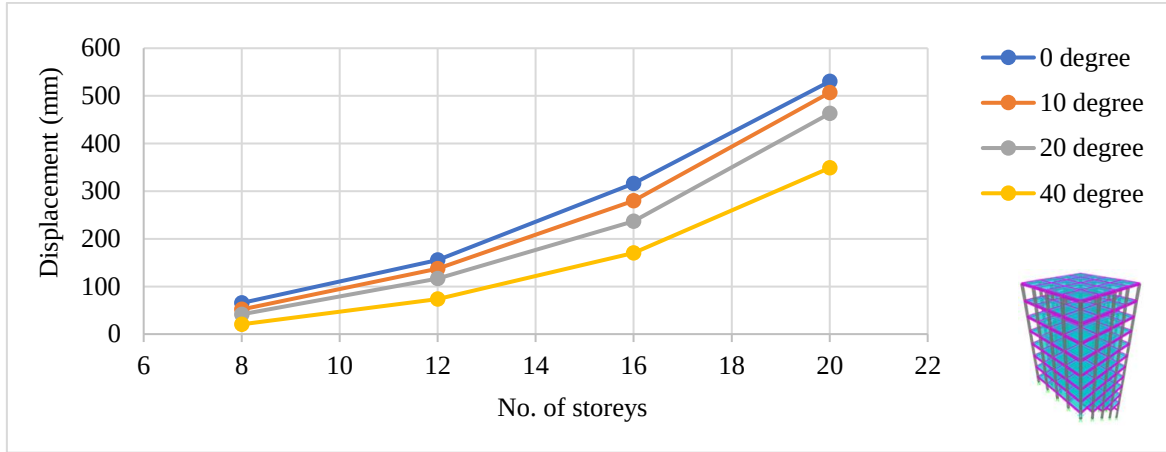


Figure 4.8: Roof Displacements in X Direction.

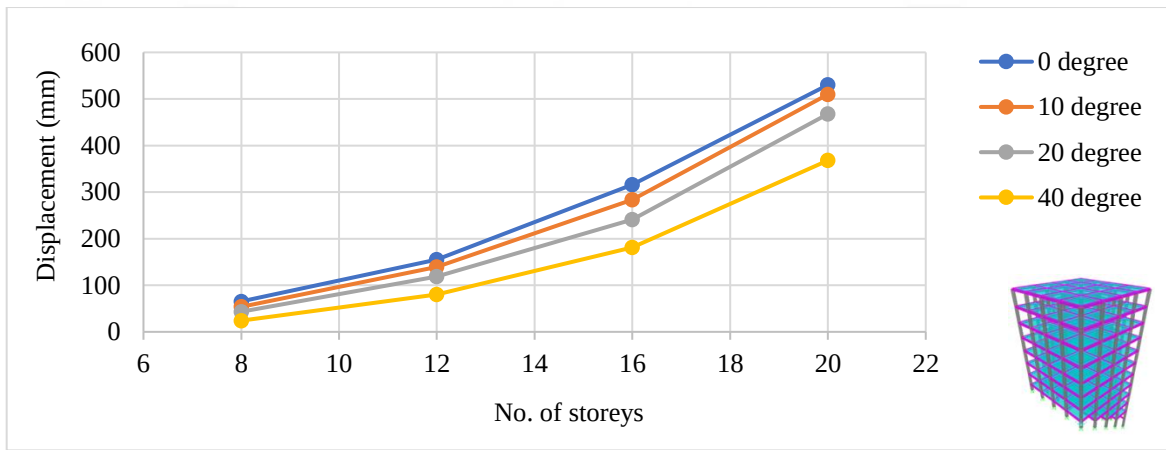


Figure 4.9: Roof Displacements in Y Direction.

The Results When the Storey Height (3 m) and Span Length (5 m):

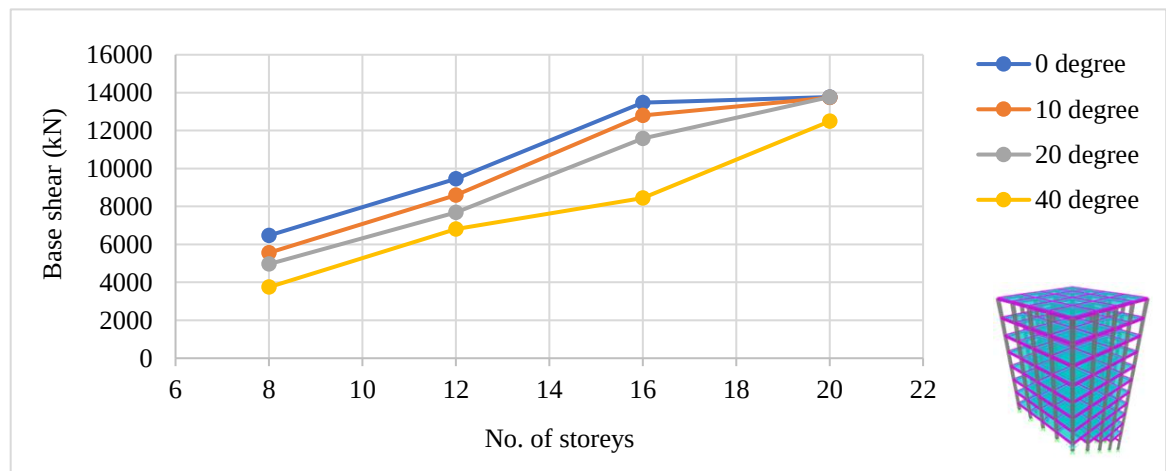


Figure 4.10: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

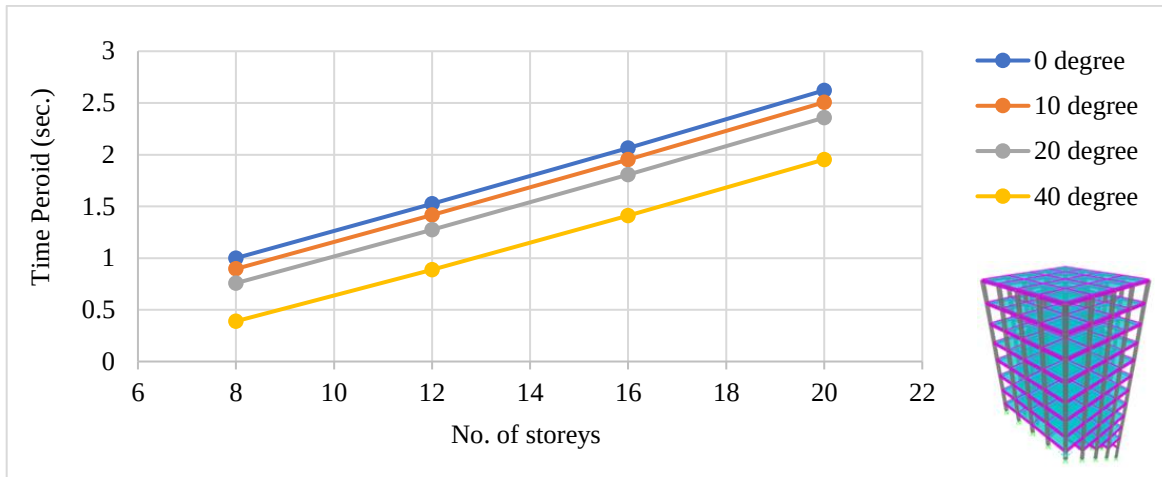


Figure 4.11: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

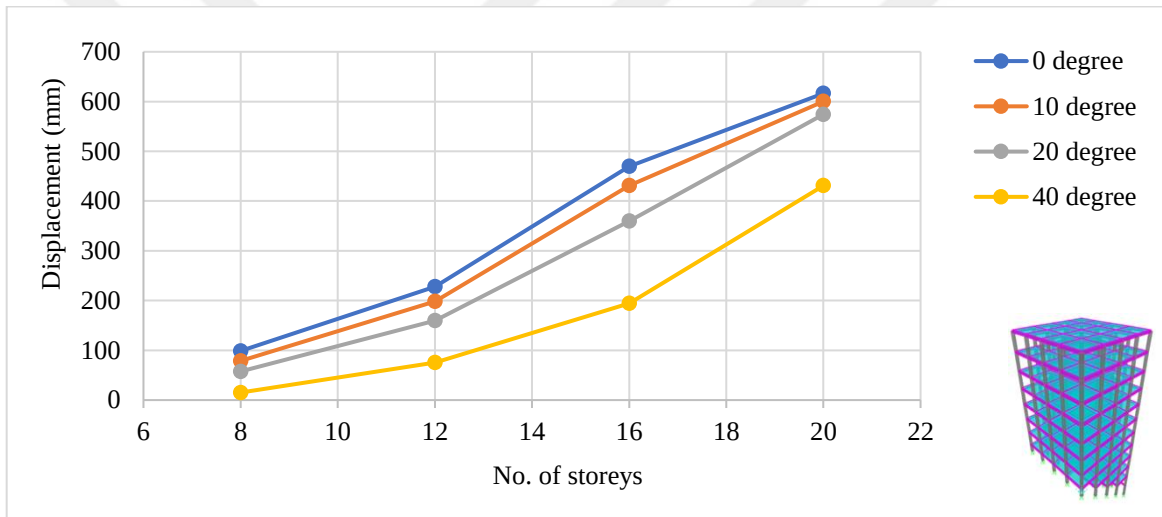


Figure 4.12: Roof Displacements in X Direction.

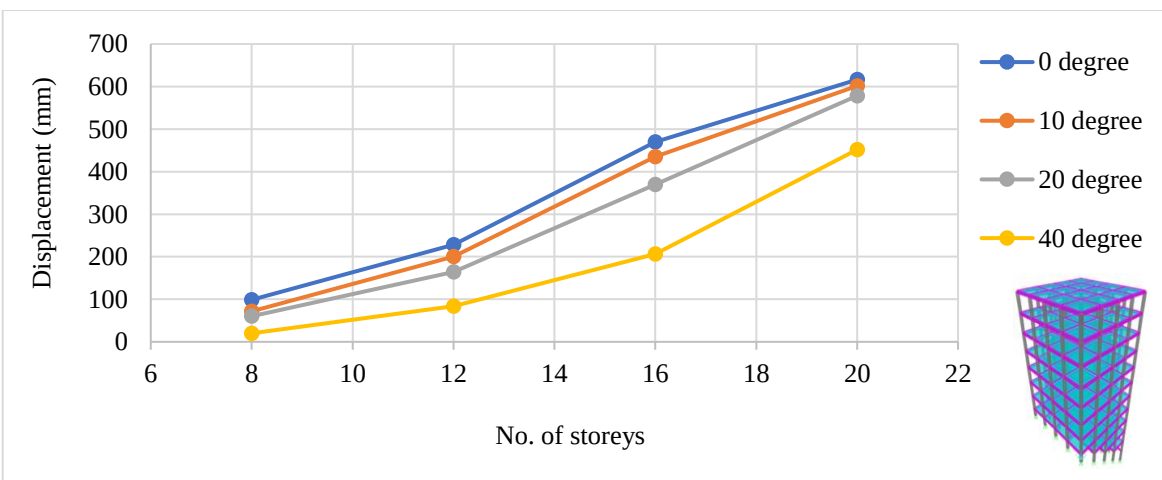


Figure 4.13: Roof Displacements in Y Direction.

The Results When the Storey Height (3 m) and Span Length (6 m):

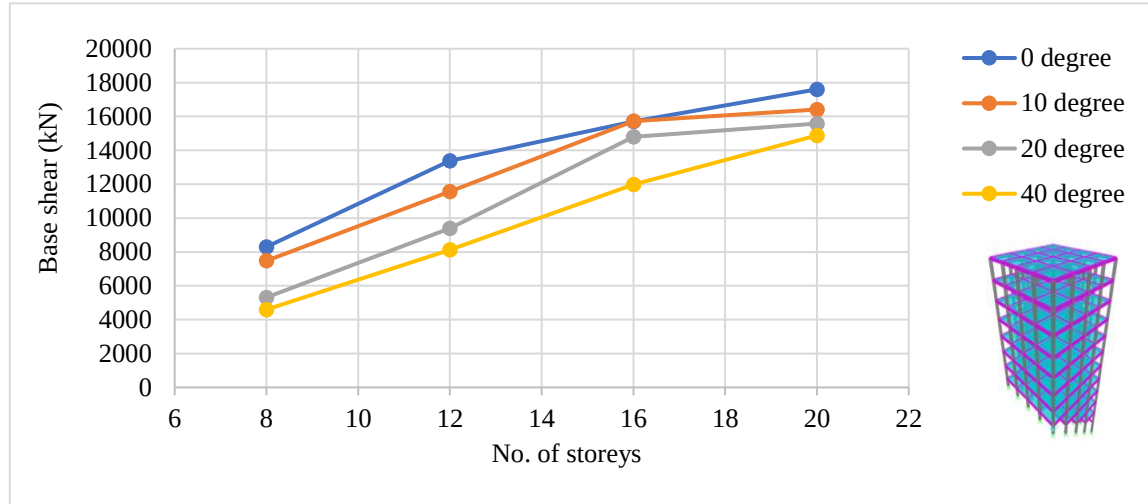


Figure 4.14: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

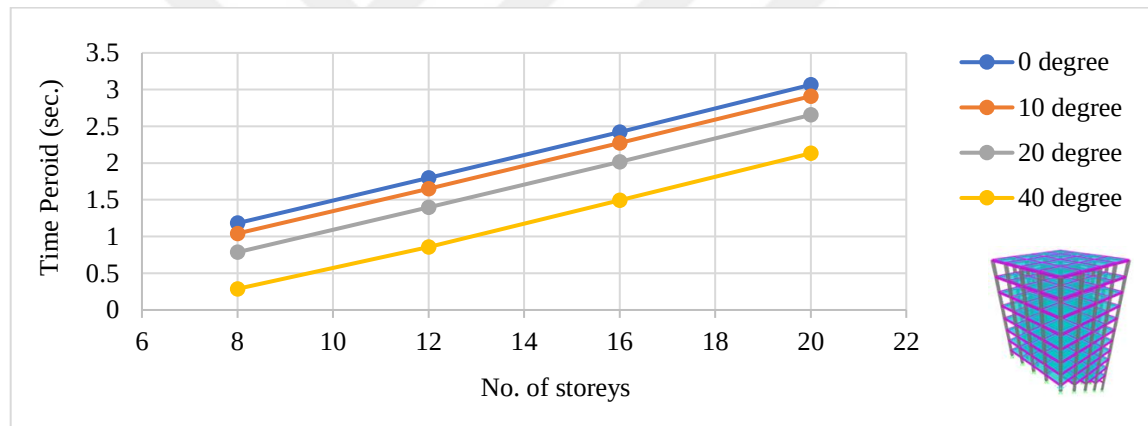


Figure 4.15: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

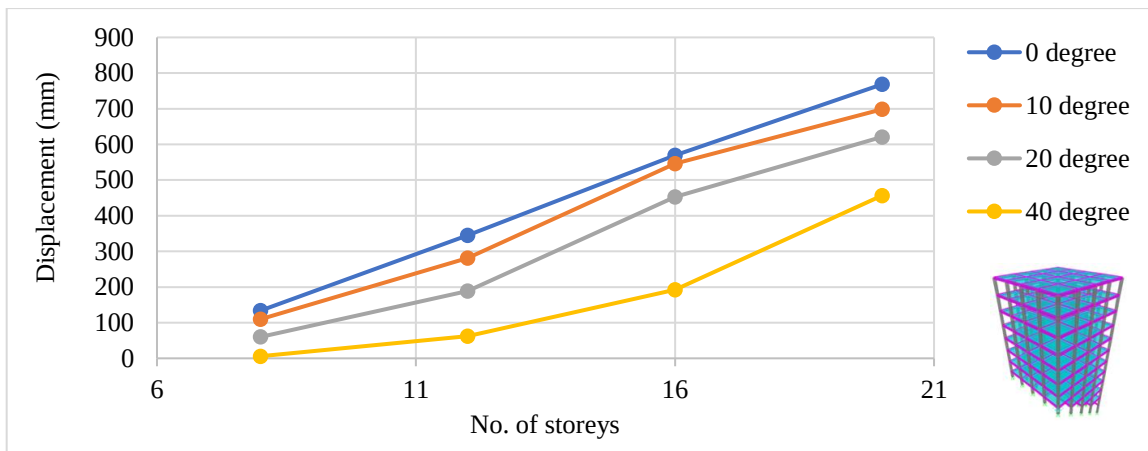


Figure 4.16: Roof Displacements in X Direction.

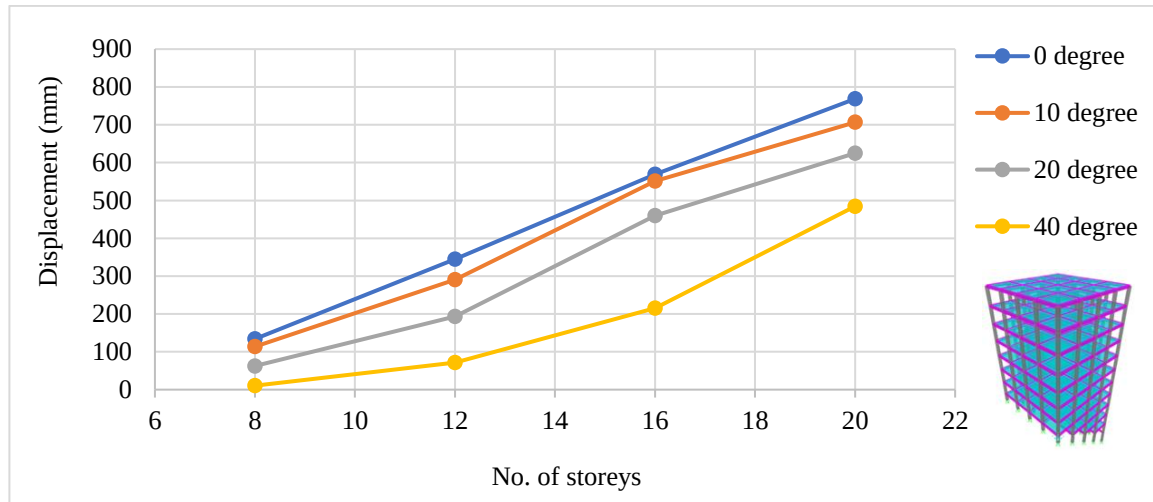


Figure 4.17: Roof Displacements in Y Direction.

4.3.1.2 Modeling results based on the no. of storeys and storey height without shear wall

The value of the base shear, Time period and displacements increased when the storey height increased, as shown below:

- As shown in (Figure 4.18, Figure 4.22 & Figure 4.26), the value of base shear increased by (0% & 6.5%) when the storey height increased from 3 m to (3.5 & 4) m respectively, when the degree of the foundation inclination 40° and storey number 20. While its value increased by (17% & 35%) when the storey height increased from 3 m to (3.5 & 4) m respectively, when the degree of the foundation inclination 0° and storey number 20.
- As shown in (Figure 4.19, Figure 4.23 & Figure 4.27), the value of time period increased by (26% & 63%) when the storey height increased from 3 m to (3.5 & 4) m respectively, when the degree of the foundation inclination 40° and storey number 20. While its value increased by (20% & 42%) when the storey height increased from 3 m to (3.5 & 4) m respectively, when the degree of the foundation inclination 0° and storey number 20.
- As shown in (Figure 4.20, Figure 4.24 & Figure 4.28), the value of displacements in X direction increased by (38% & 144%) when the storey height increased from 3 m to (3.5 & 4) m respectively, when the degree of the foundation inclination 40° and storey number 20. While its value increased by (72% & 180%) when the storey height increased from 3 m to (3.5 & 4) m respectively, when the degree of the foundation inclination 0° and storey number 20.

The Results When the Storey Height (3 m) and Span Length (6 m):

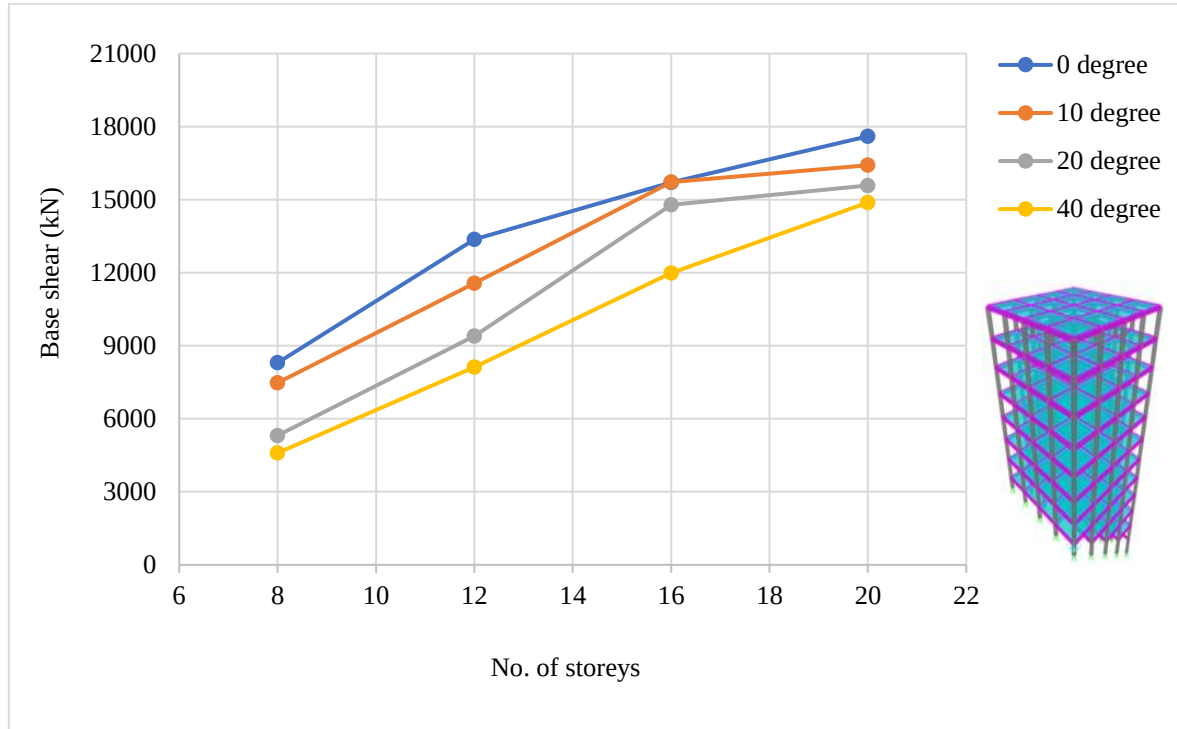


Figure 4.18: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

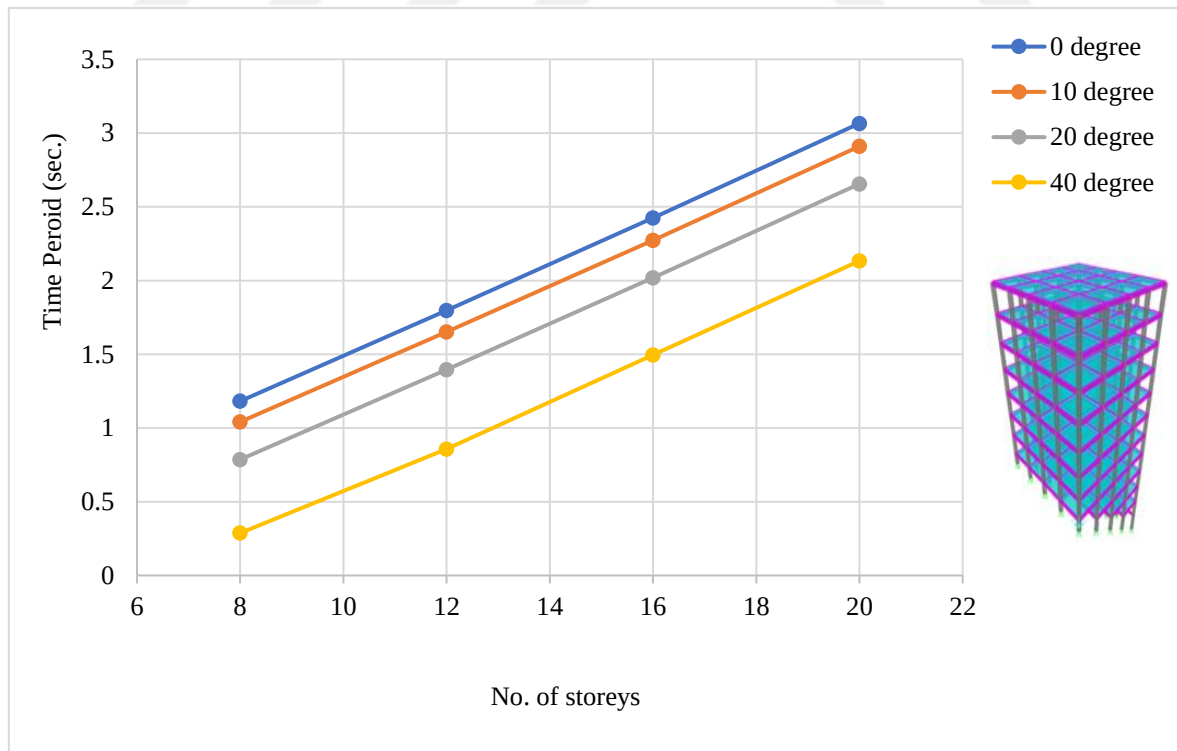


Figure 4.19: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

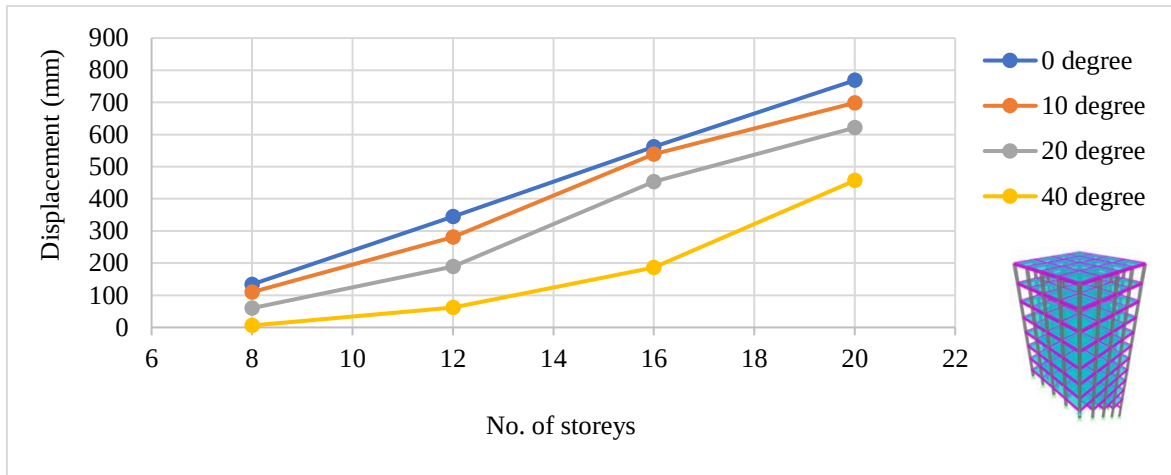


Figure 4.20: Roof Displacements in X Direction.

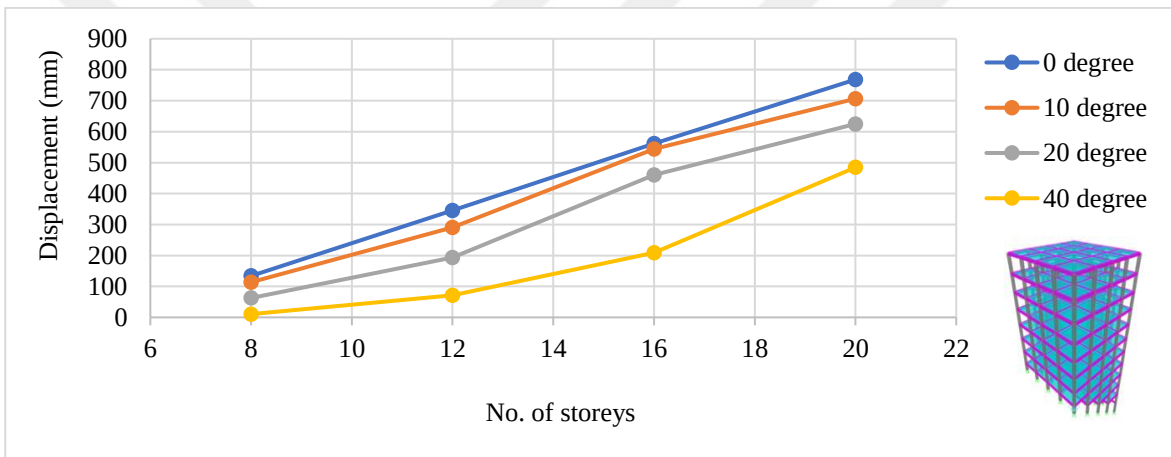


Figure 4.21: Roof Displacements in Y Direction.

The Results When the Storey Height (3.5 m) and Span Length (6 m):

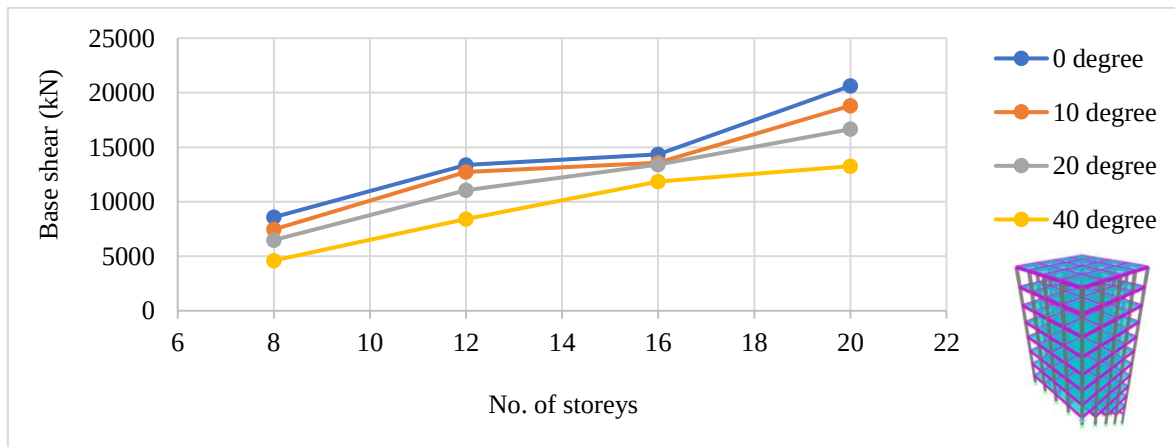


Figure 4.22: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

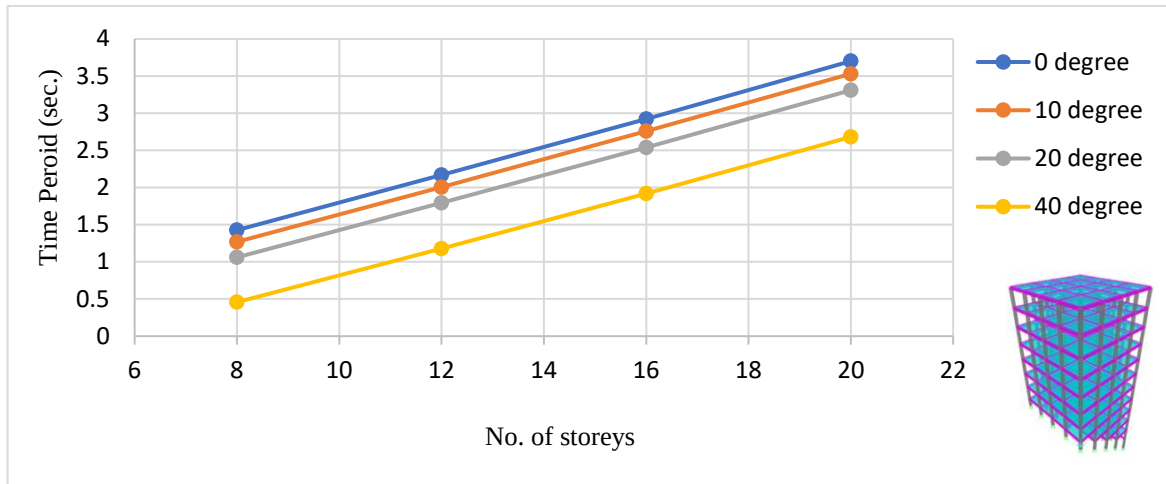


Figure 4.23: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

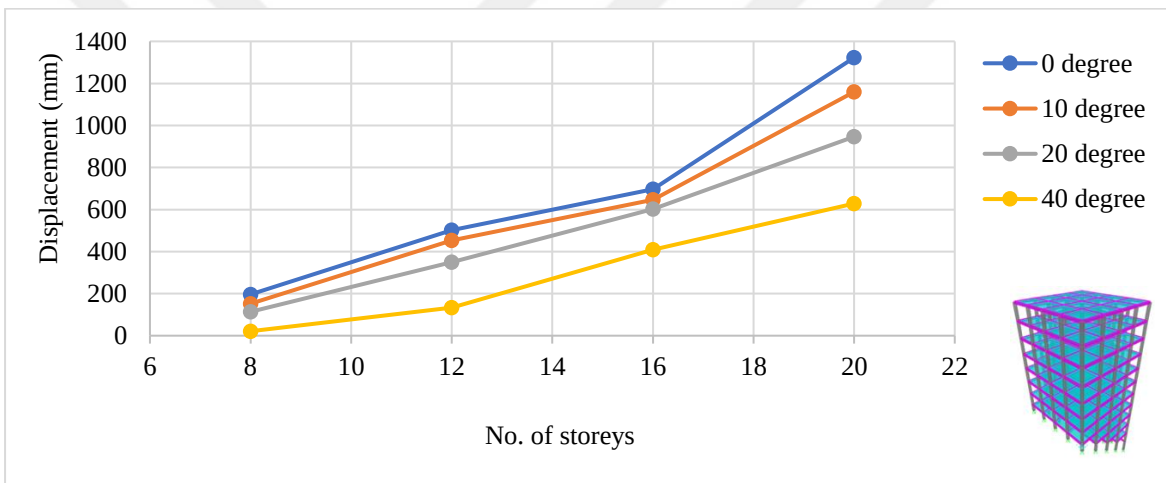


Figure 4.24: Roof displacements in X direction.

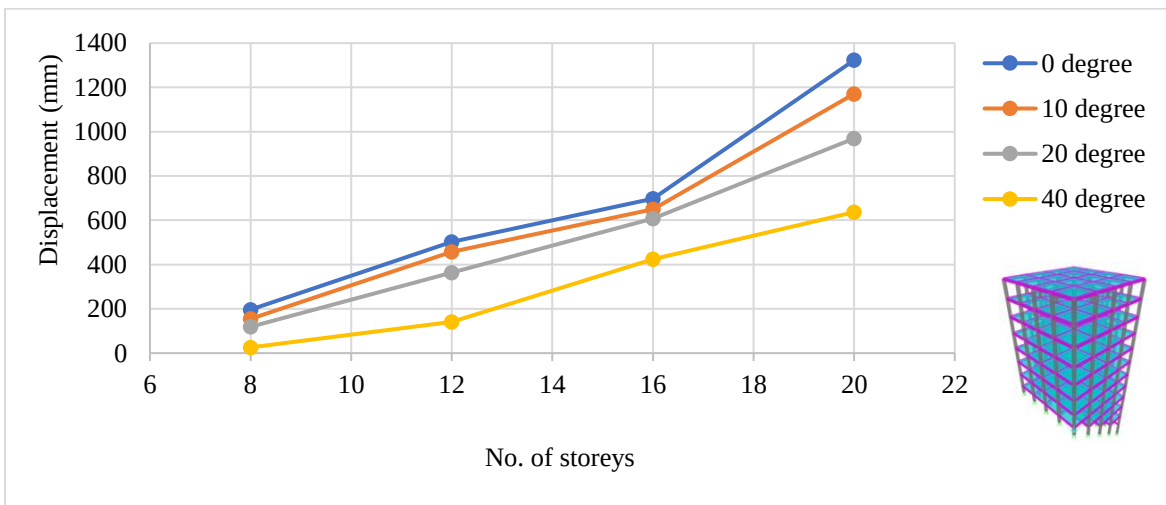


Figure 4.25: Roof Displacements in Y Direction.

The Results When the Storey Height (4 m) and Span Length (6 m):

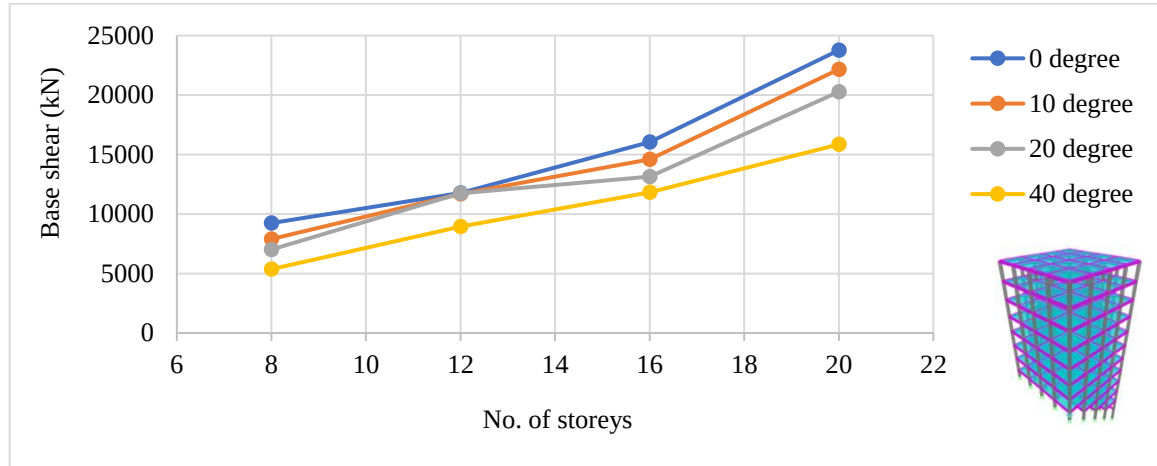


Figure 4.26: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

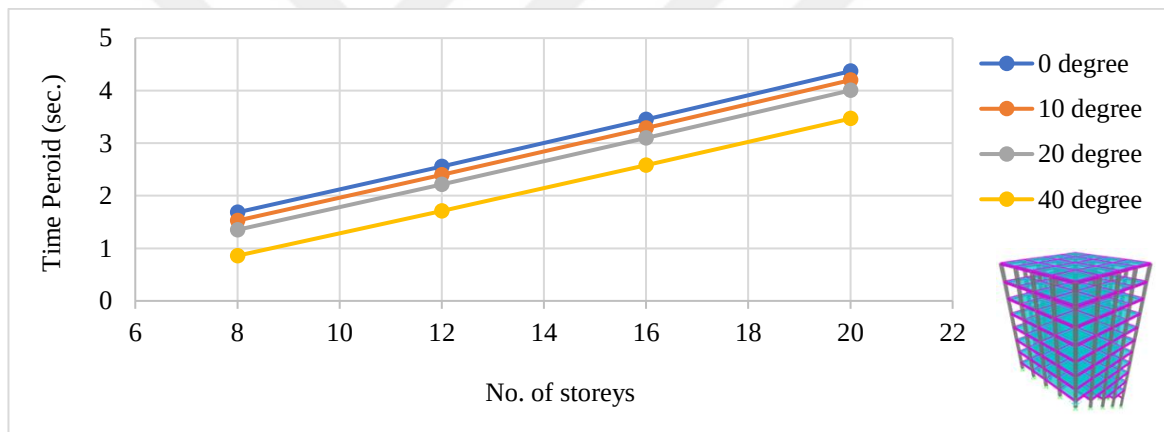


Figure 4.27: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

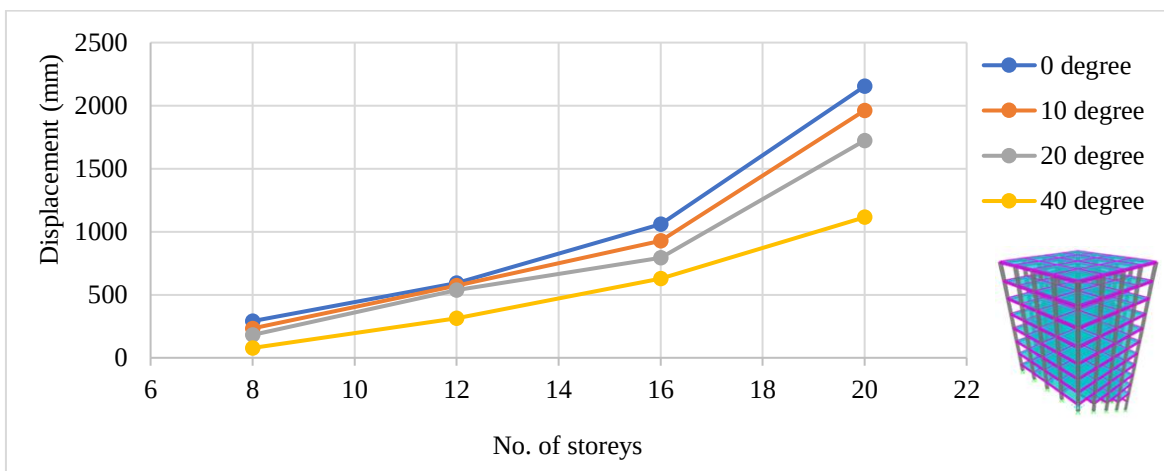


Figure 4.28: Roof Displacements in X Direction.

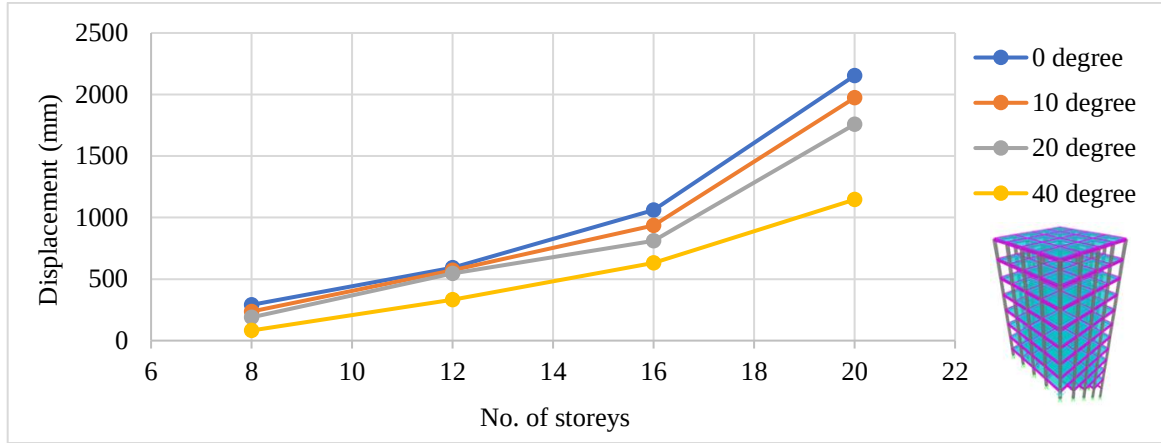


Figure 4.29: Roof Displacements in Y Direction.

4.3.1.3 Storey drift of the buildings without shear wall

As shown in Figure 4.30, storey drift values were found for four buildings under the influence of changes in parameters (foundation inclination, span length, and storey height). The storey drift results were presented in five cases for each building. The effect of the foundation inclination appeared in all cases, while the effect of the span length appeared by comparing the first, second and third cases. As for the effect of the floor height, it appeared by comparing the third, fourth and fifth cases.

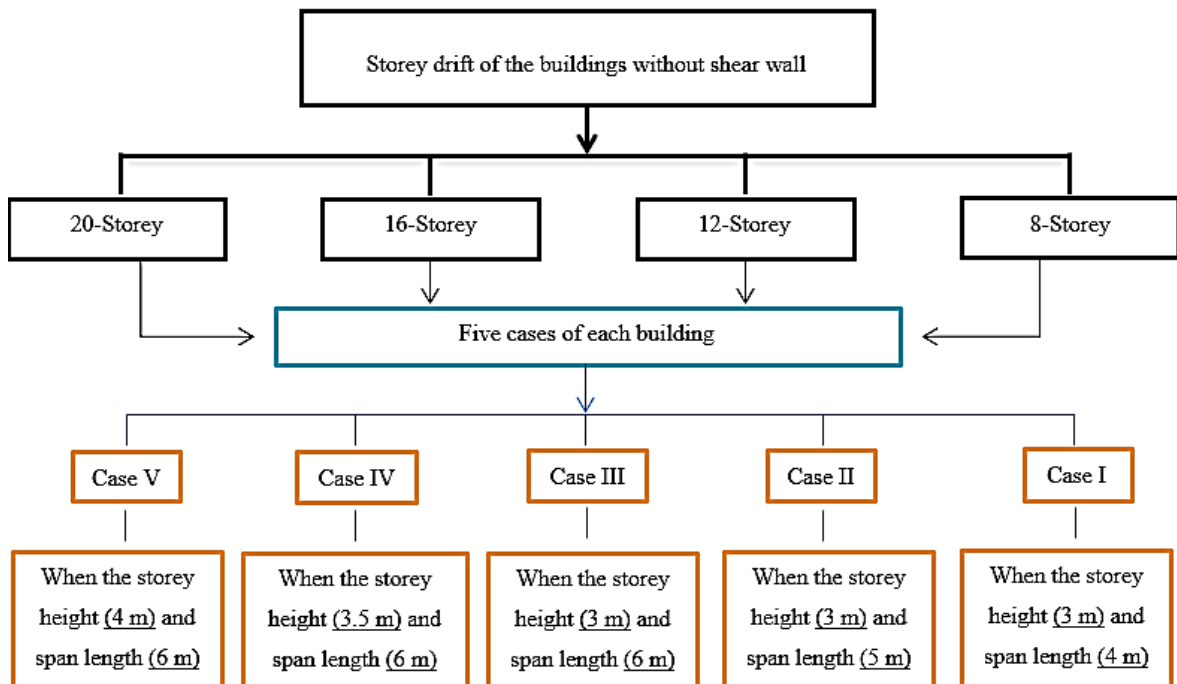


Figure 4.30: Storey Drift of the Buildings Without Shear Wall.

The value of the storey drift decreased when the degree of foundation inclination of the building increased. As shown in Figure 4.41, the value of storey drift decreased by (82.8%, 99.7% & 95.8%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 1st storey level. While its value decreased by (4.7%, 10.4% & 27.3%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 12th storey level.

The value of the storey drift increased when the span length increased. As shown in (Figure 4.41, Figure 4.43 & Figure 4.45), the value of storey drift increased by (46.4% & 116.8%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 1st storey level and the degree of the foundation inclination was 0°). The value of storey drift increased by (33.6% & 93.6%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 12th storey level and the degree of the foundation inclination was 0°). While its value decreased by (66% & 70%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 1st storey level and the degree of the foundation inclination was 40°). Also, its value increased by (24% & 55.8%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 12th storey level and the degree of the foundation inclination was 40°).

The value of the storey drift increased when the storey height increased. As shown in (Figure 4.45, Figure 4.47 & Figure 4.49), the value of storey drift increased by (26.4% & 34.8%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 1st storey level and inclination foundation was 0°). The value of storey drift increased by (33.6% & 93.6%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 12th storey level and inclination foundation was 0°). While its value decreased by (66% & 70%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 1st storey level and the inclination foundation was 40°). Also, its value increased by (24% & 55.8%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 12th storey level and the inclination foundation was 40°).

The Results of Storey Drift When the No. of Storeys were 8:

Case I:

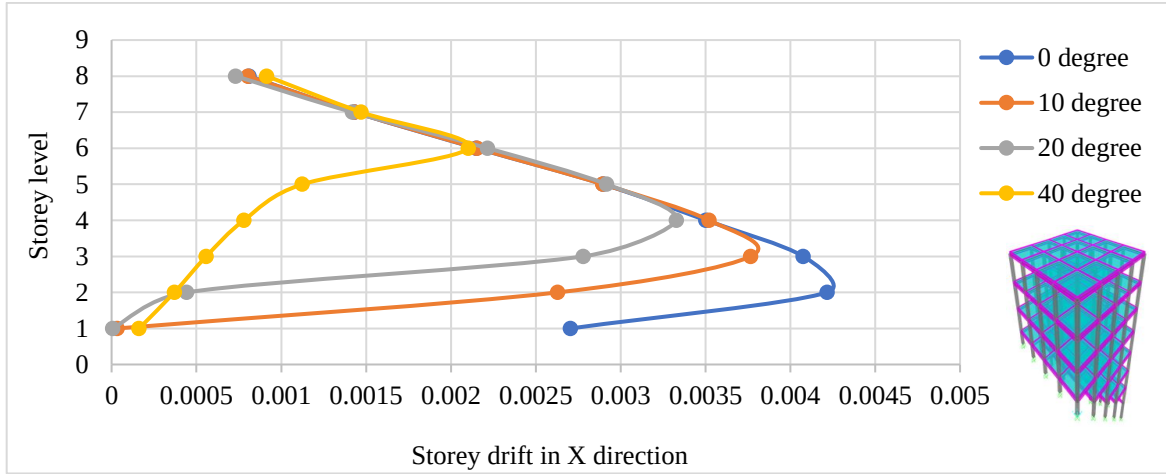


Figure 4.31: Storey Drift in X Direction When the No. of Storeys were 8 (case I).

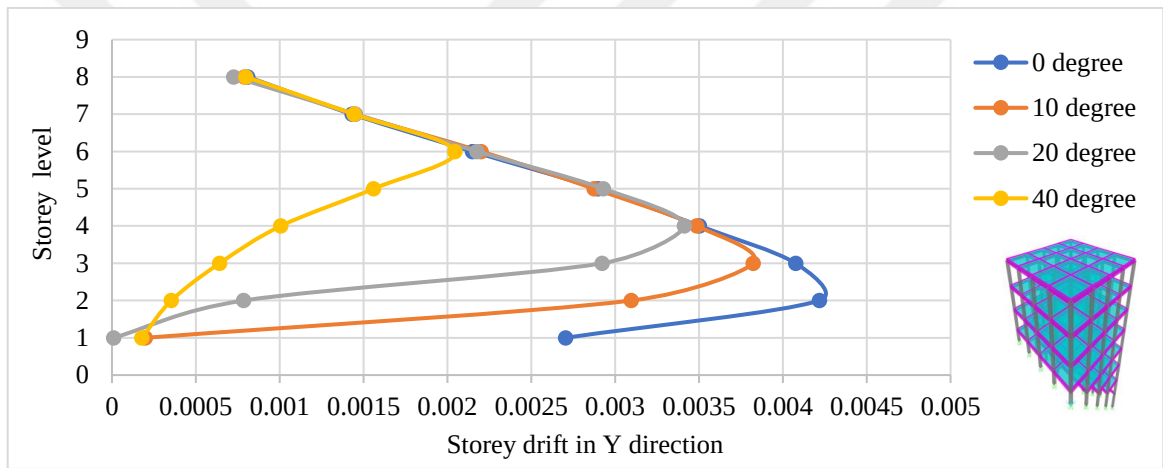


Figure 4.32: Storey Drift in Y Direction When the No. of Storeys were 8 (case I).

Case II:

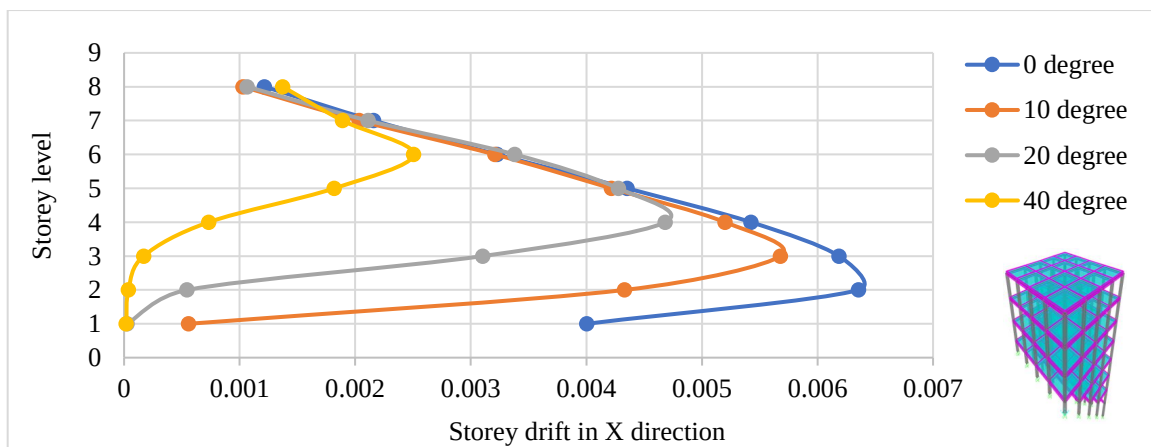


Figure 4.33: Storey Drift in X Direction When the No. of Storeys were 8 (case II).

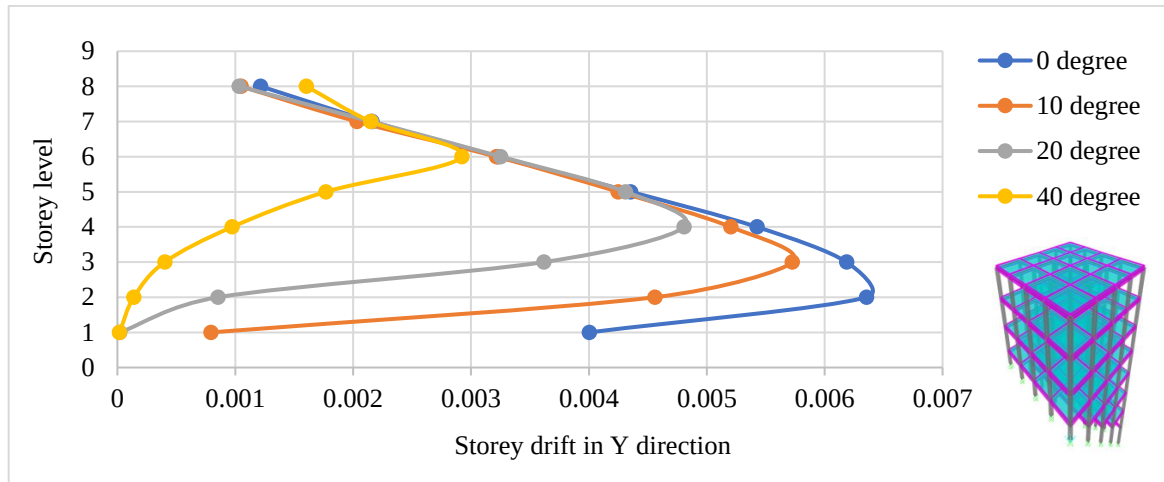


Figure 4.34: Storey Drift in Y Direction When the No. of Storeys were 8 (case II).

Case III:

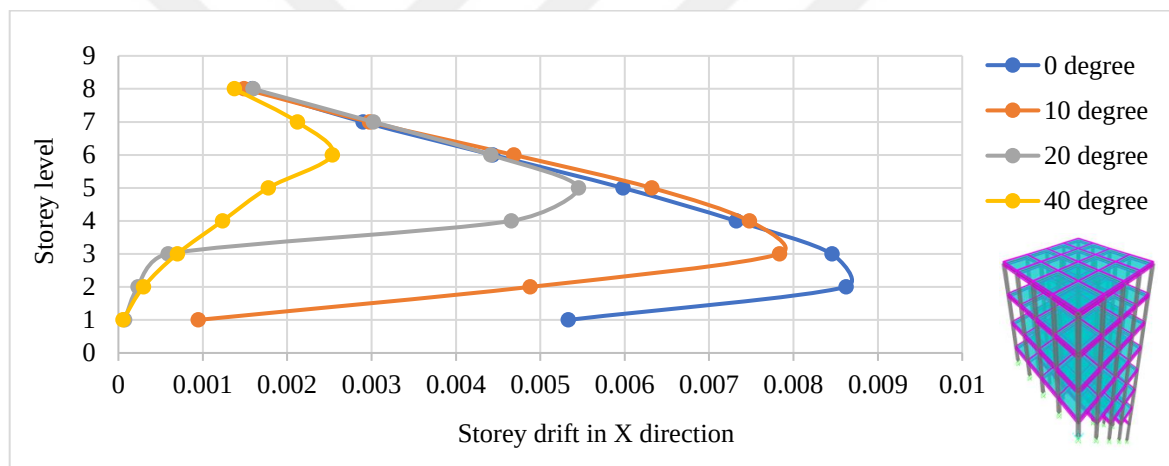


Figure 4.35: Storey Drift in X Direction When the No. of Storeys were 8 (case III).

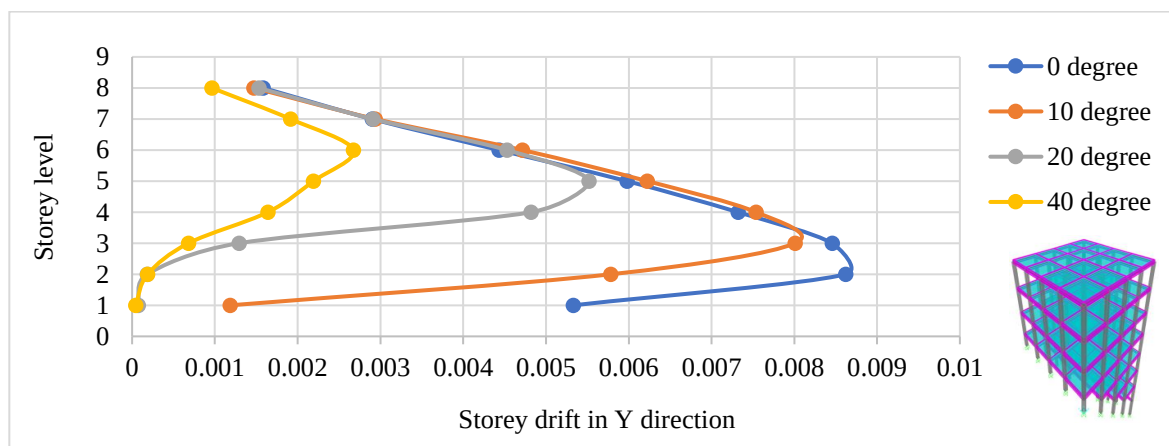


Figure 4.36: Storey Drift in Y Direction When the No. of Storeys were 8 (case III).

Case IV:

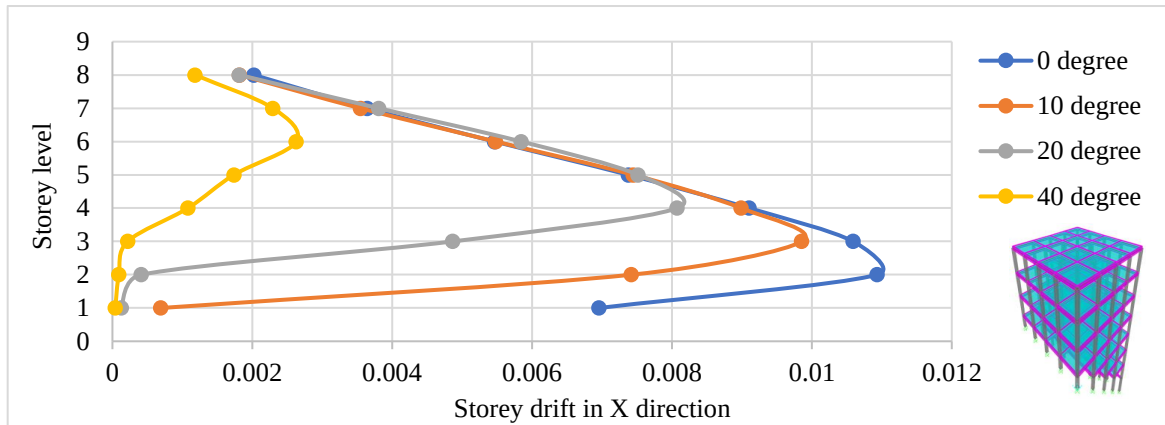


Figure 4.37: Storey Drift in X Direction When the No. of Storeys were 8 (case IV).

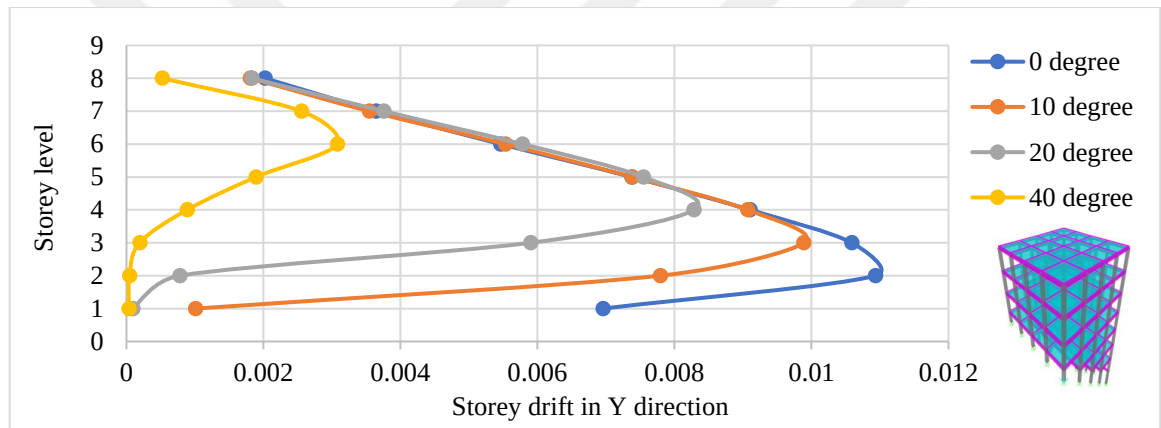


Figure 4.38: Storey Drift in Y Direction When the No. of Storeys were 8 (case IV).

Case V:

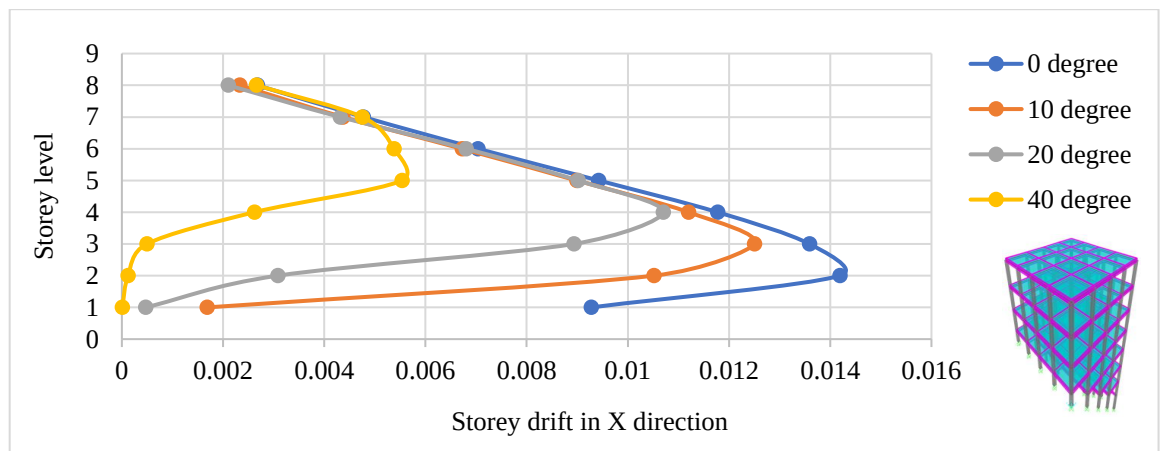


Figure 4.39: Storey Drift in X Direction When the No. of Storeys were 8 (case V).

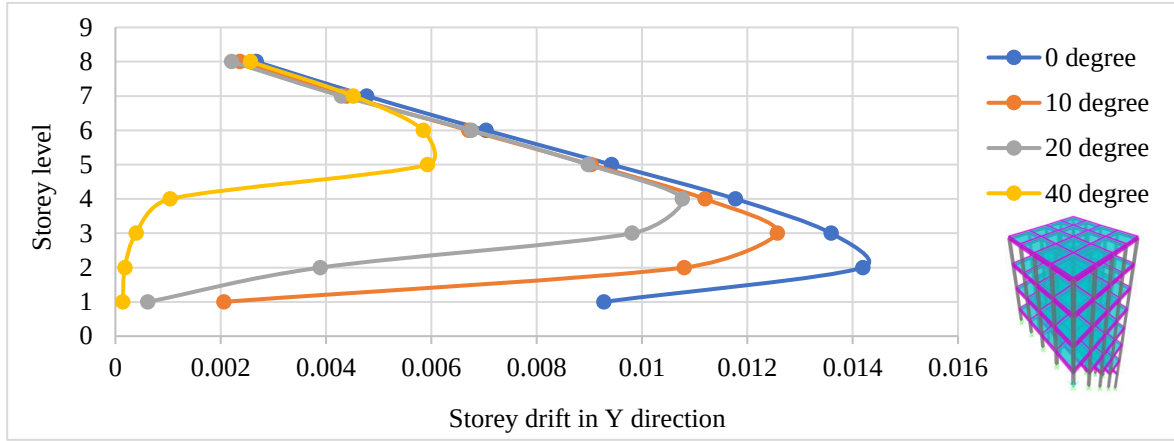


Figure 4.40: Storey Drift in Y Direction When the No. of Storeys were 8 (case V).

The Results of Storey Drift When the No. of Storeys were 12:

Case I:

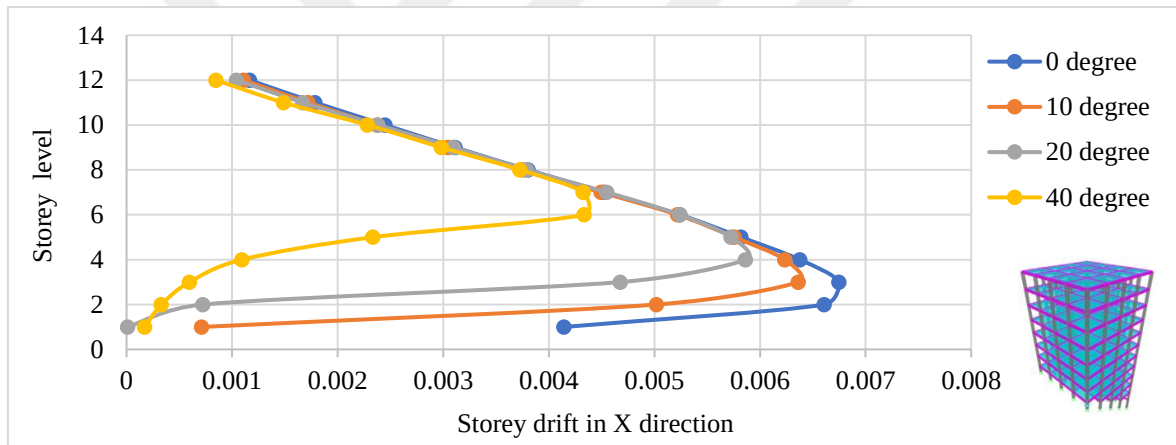


Figure 4.41: Storey Drift in X Direction When the No. of Storeys were 12 (case I).

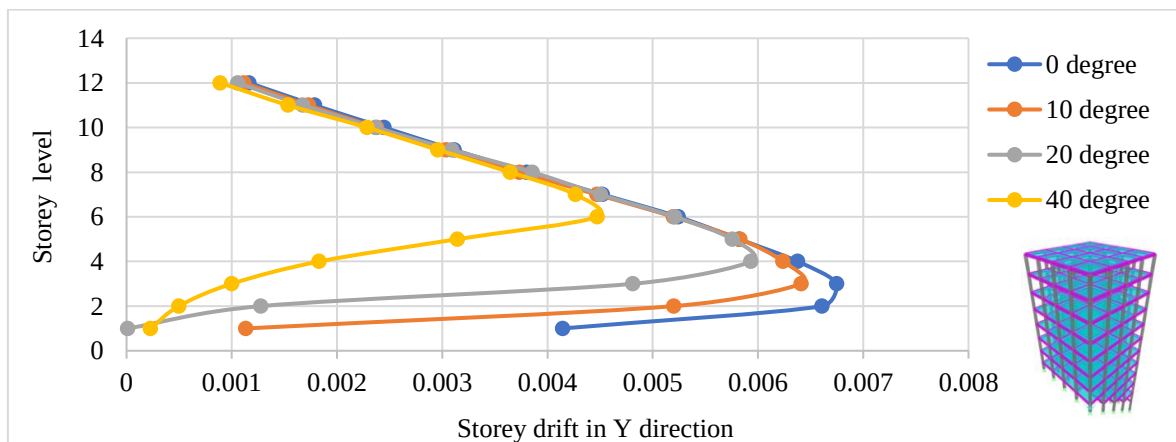


Figure 4.42: Storey Drift in Y Direction When the No. of Storeys were 12 (case I).

Case II:

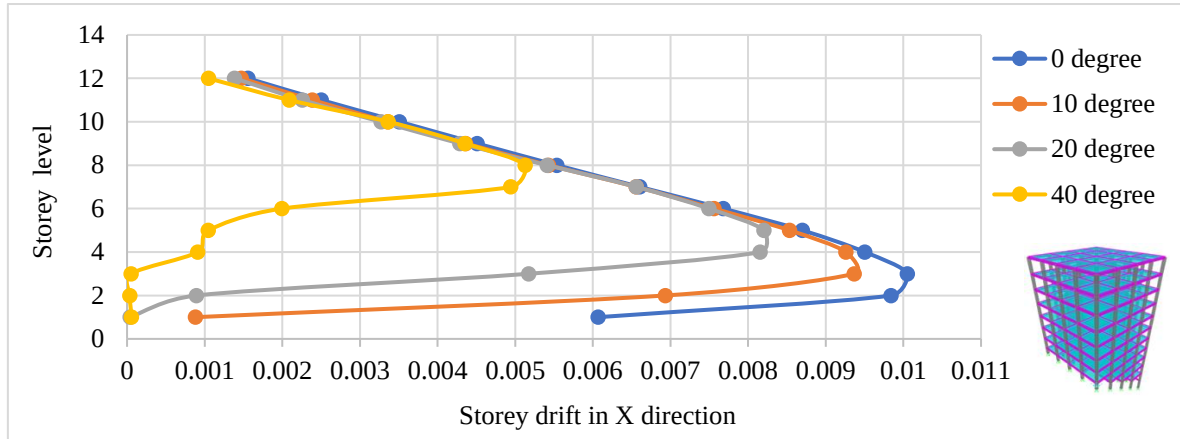


Figure 4.43: Storey Drift in X Direction When the No. of Storeys were 12 (case II).

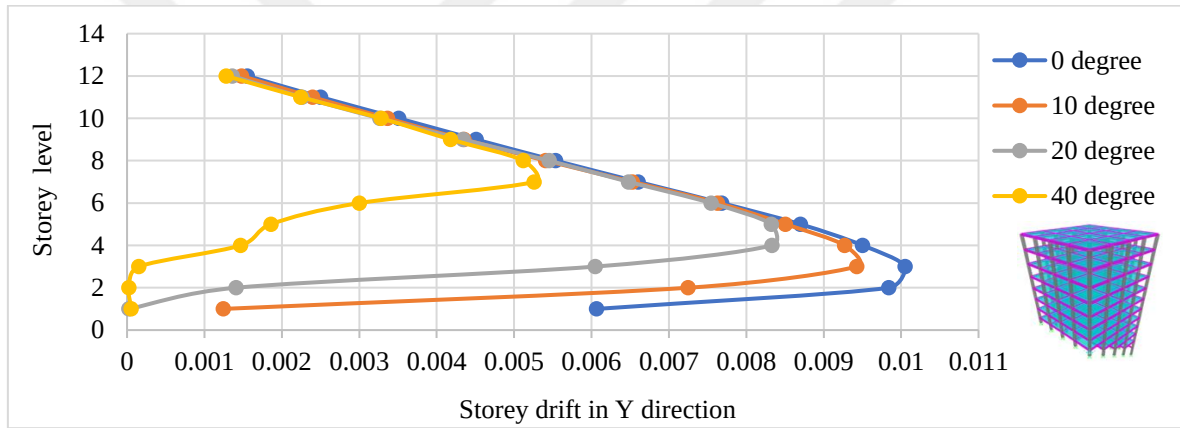


Figure 4.44: Storey Drift in Y Direction When the No. of Storeys were 12 (case II).

Case III:

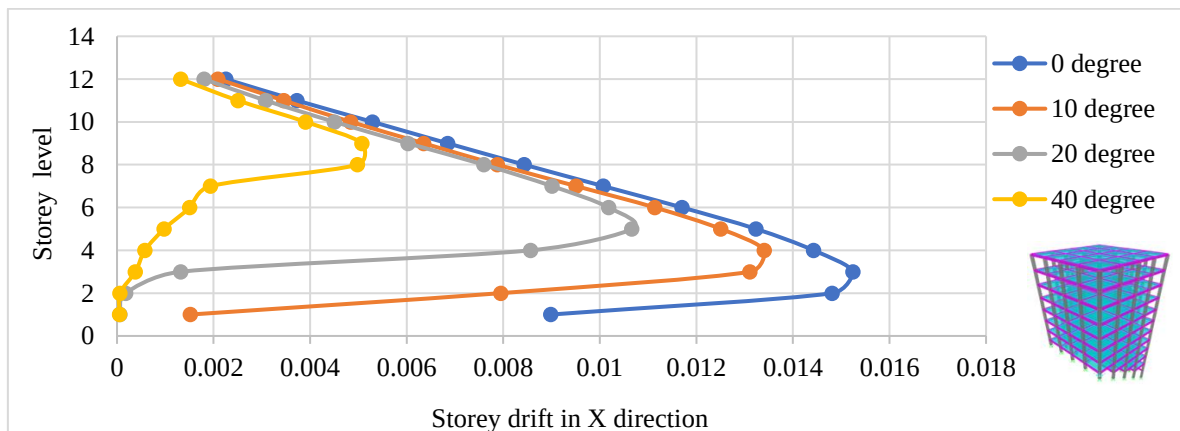


Figure 4.45: Storey Drift in X Direction When the No. of Storeys were 12 (case III).

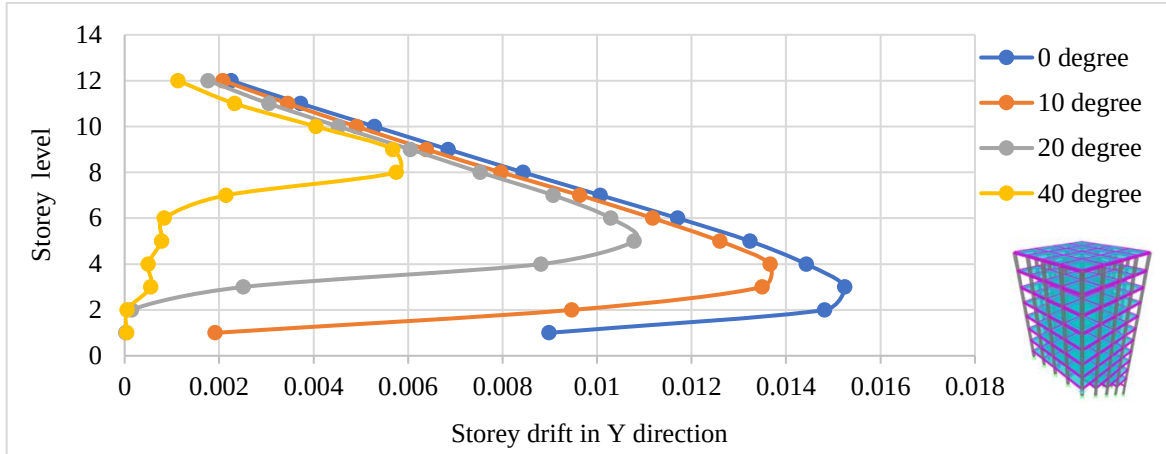


Figure 4.46: Storey Drift in Y Direction When the No. of Storeys were 12 (case III).

Case IV:

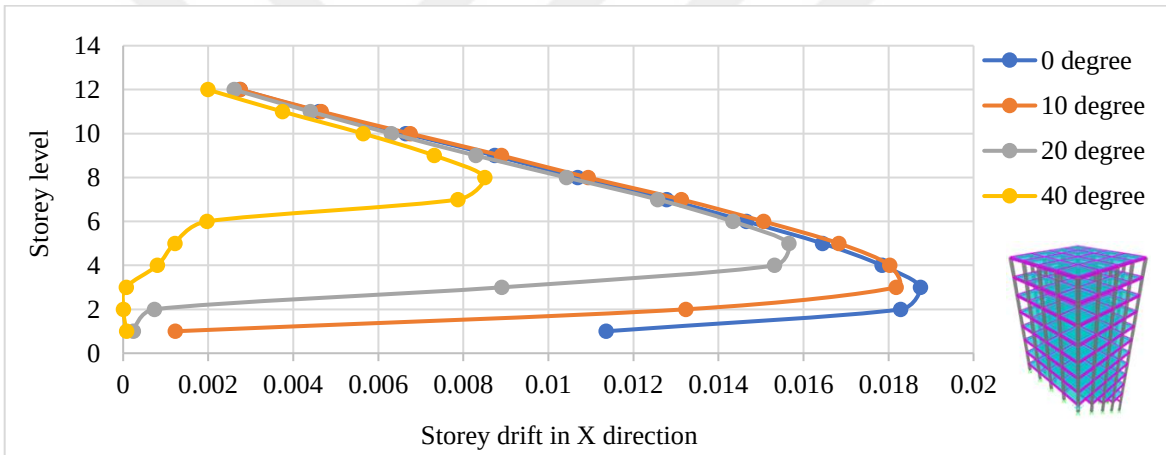


Figure 4.47: Storey Drift in X Direction When the No. of Storeys were 12 (case IV).

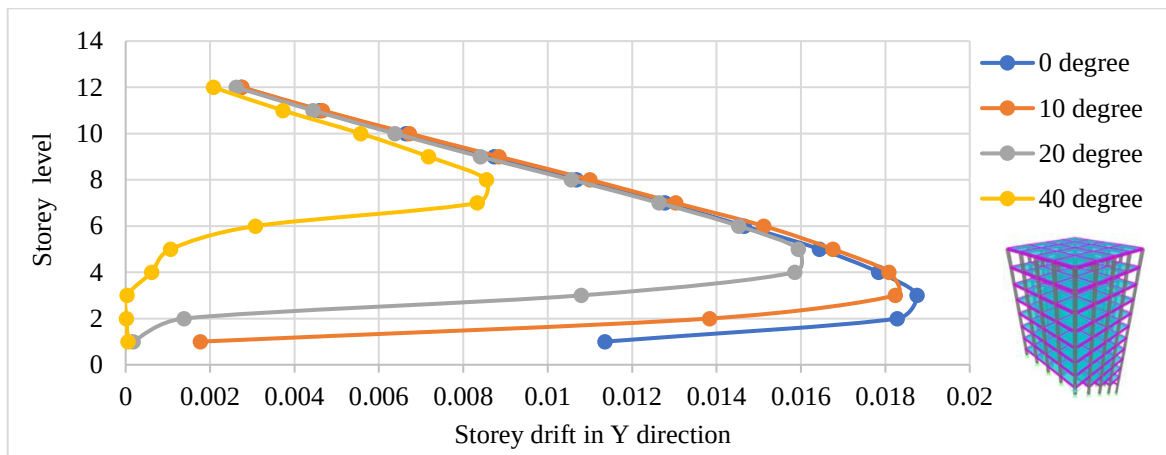


Figure 4.48: Storey Drift in Y Direction When the No. of Storeys were 12 (case IV).

Case V:

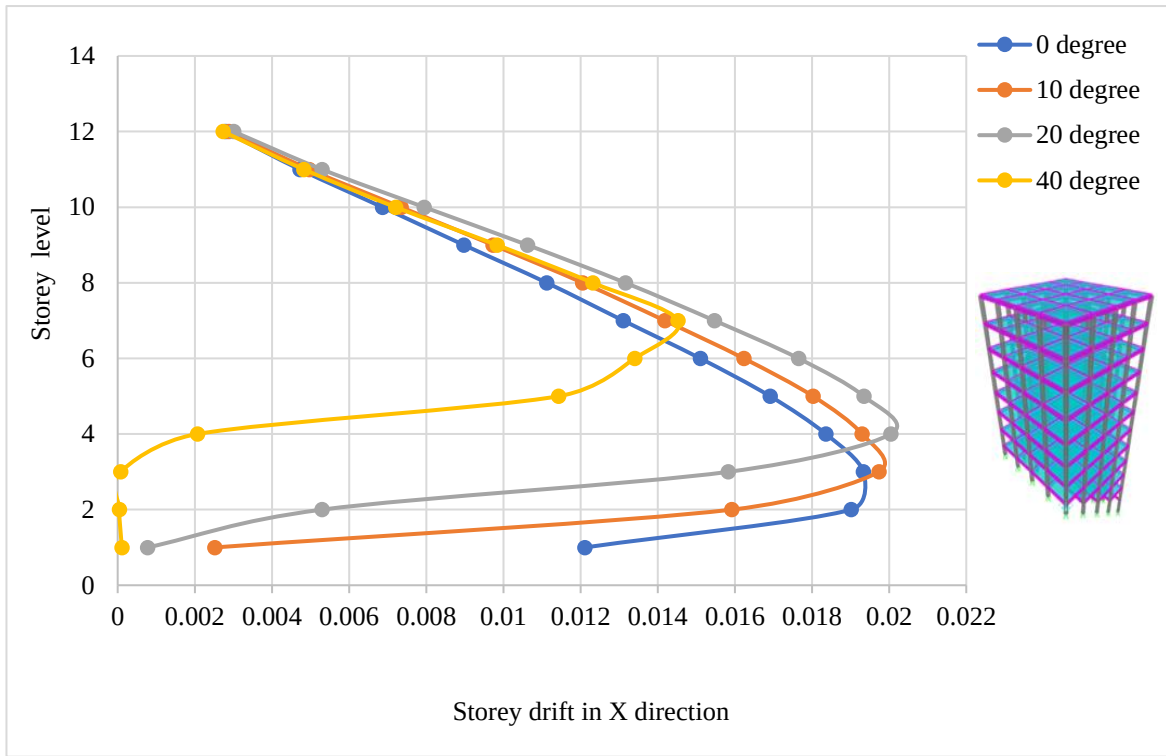


Figure 4.49: Storey Drift in X Direction When the No. of Storeys were 12 (case V).

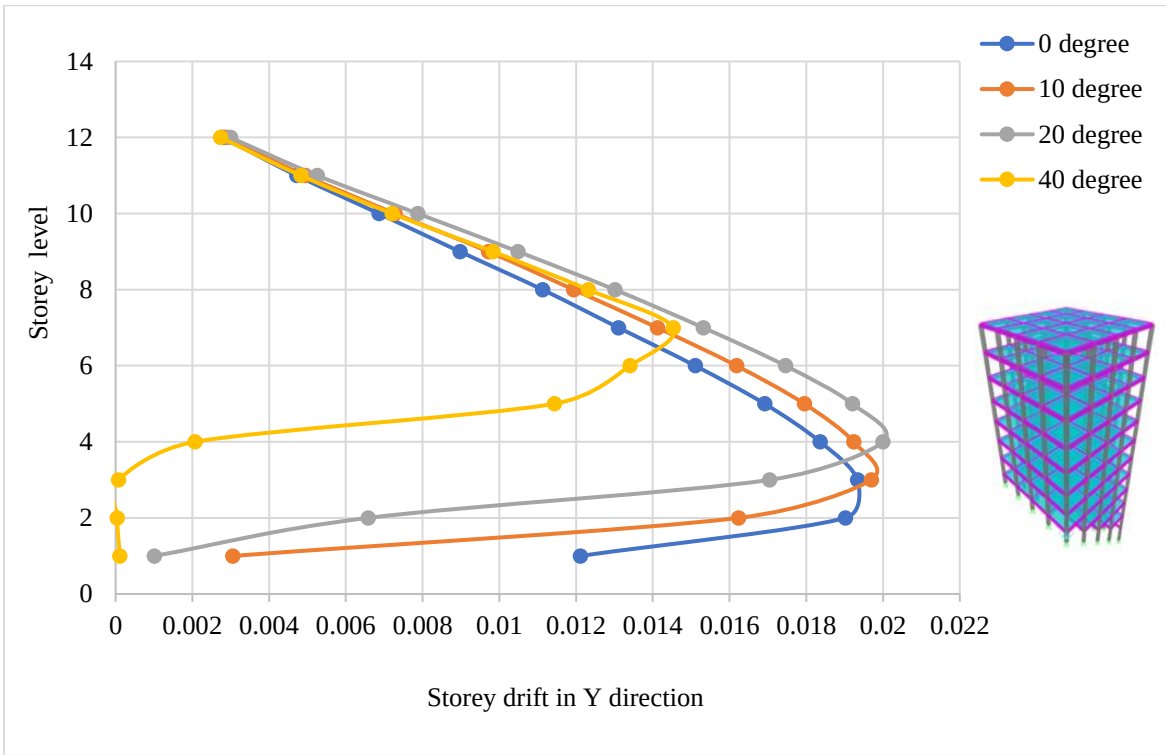


Figure 4.50: Storey Drift in Y Direction When the No. of Storeys were 12 (case V).

The Results of Storey Drift When the No. of Storeys were 16:

Case I:

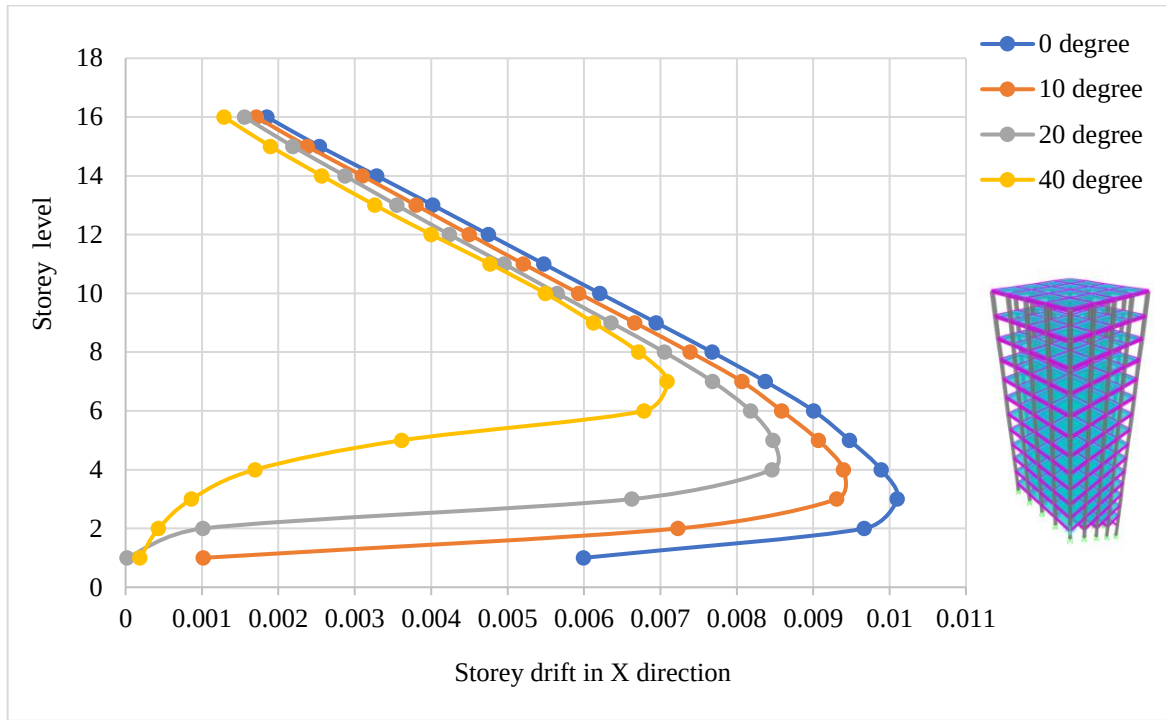


Figure 4.51: Storey Drift in X Direction When the No. of Storeys were 16 (case I).

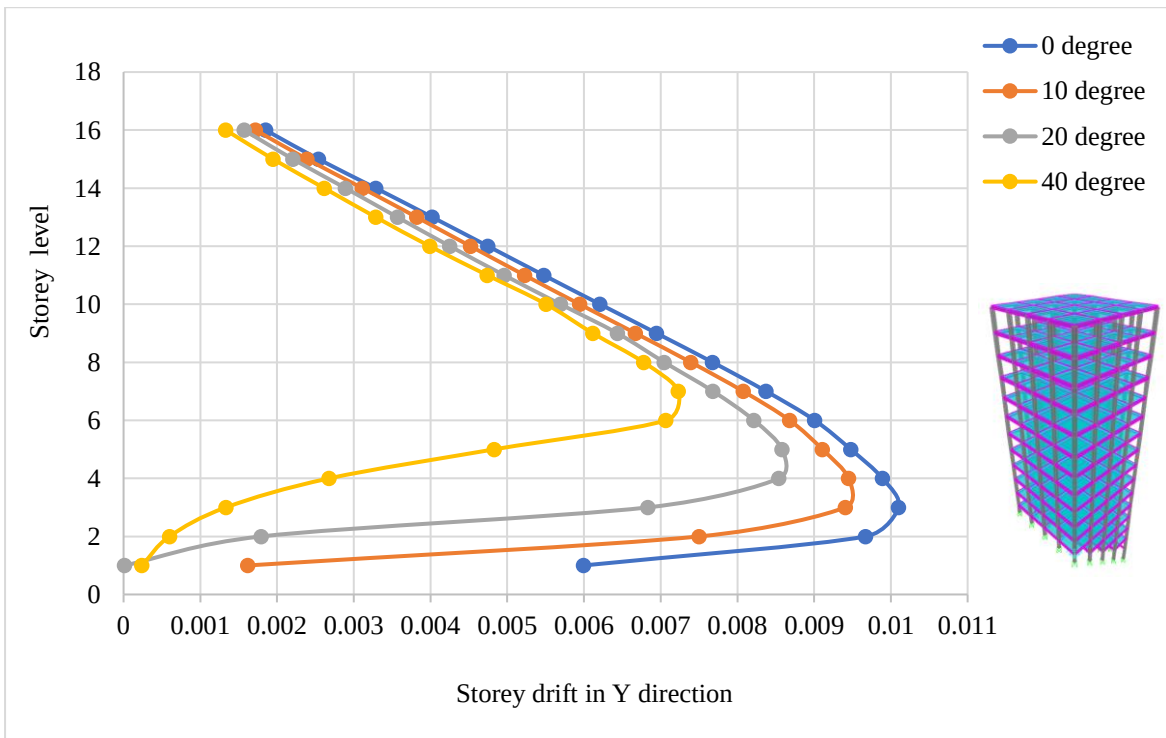


Figure 4.52: Storey Drift in Y Direction When the No. of Storeys were 16 (case I).

Case II:

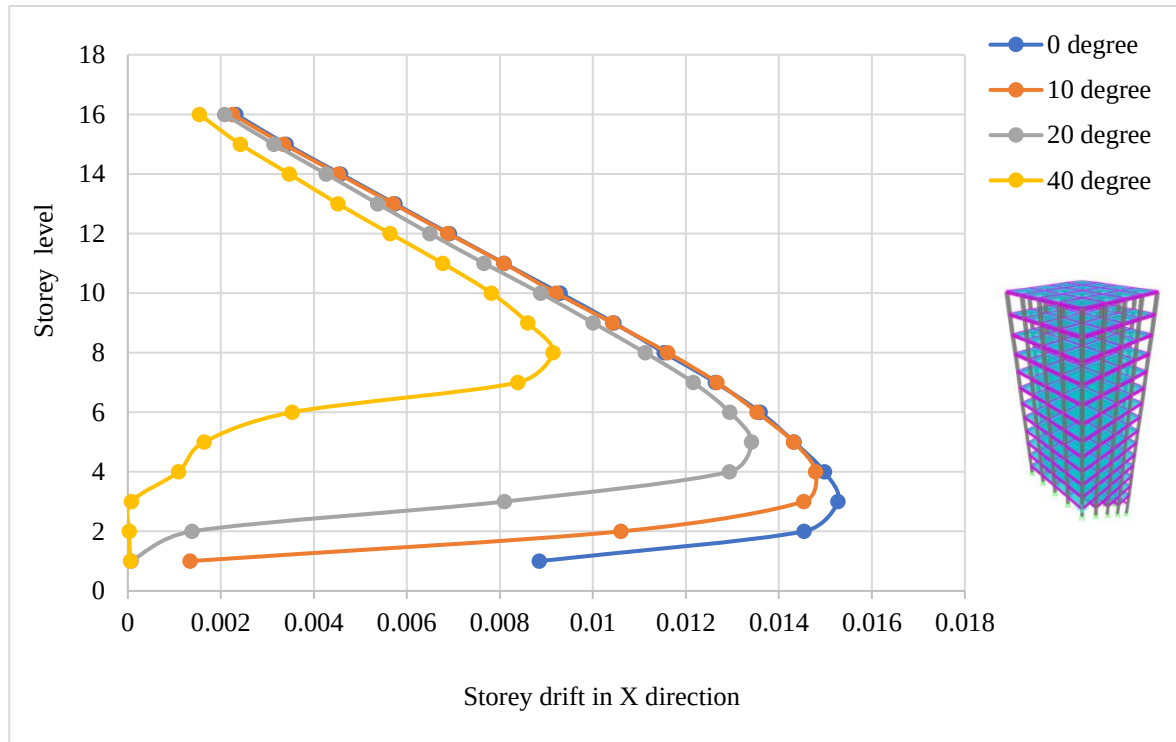


Figure 4.53: Storey Drift in X Direction When the No. of Storeys were 16 (case II).

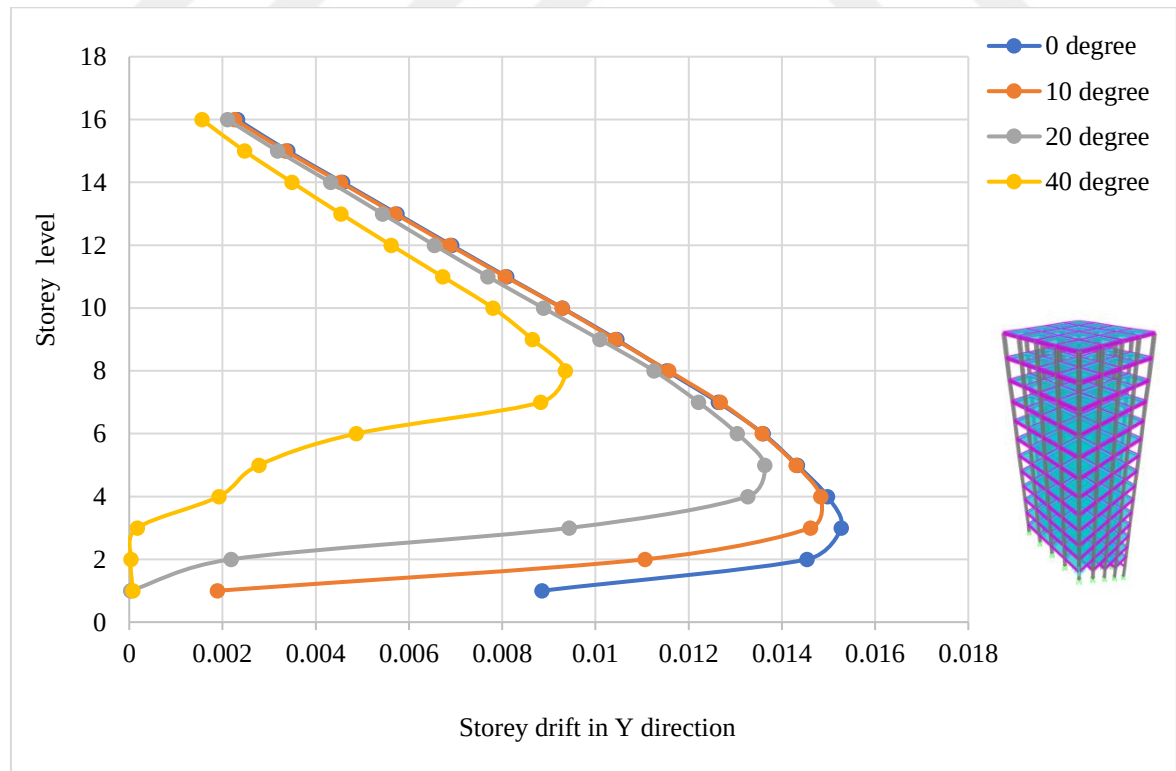


Figure 4.54: Storey Drift in Y Direction When the No. of Storeys were 16 (case II).

Case III:

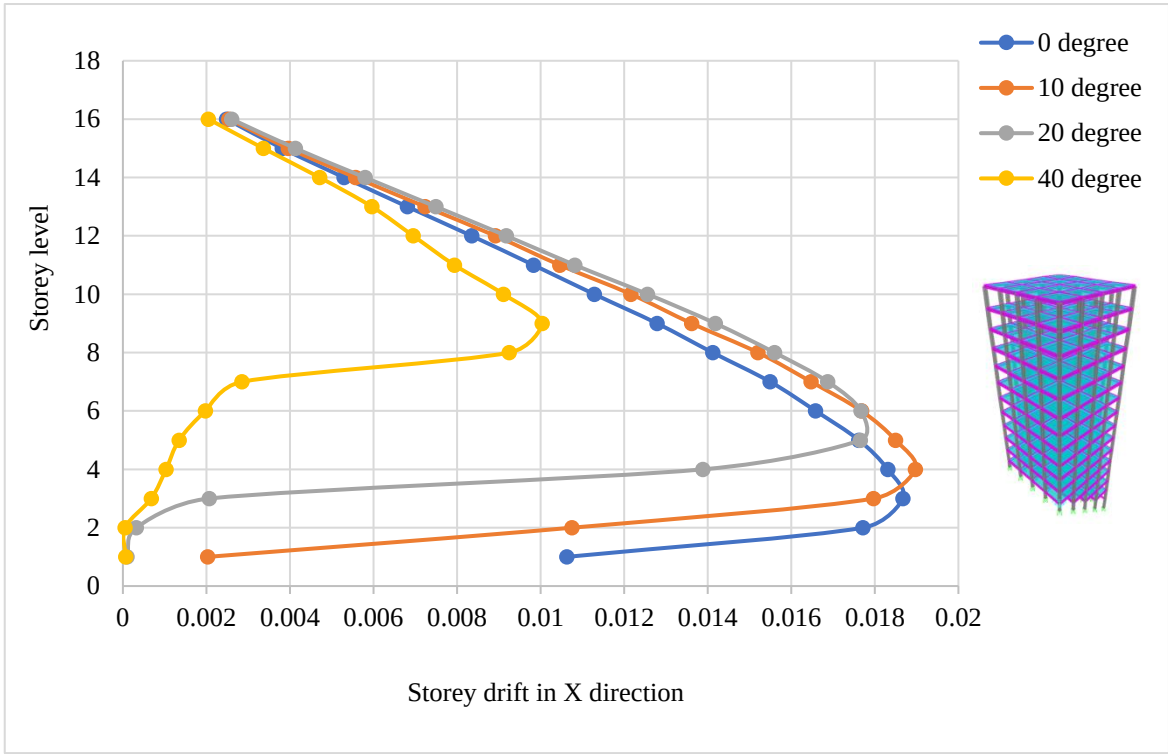


Figure 4.55: Storey Drift in X Direction When the No. of Storeys were 16(case III).

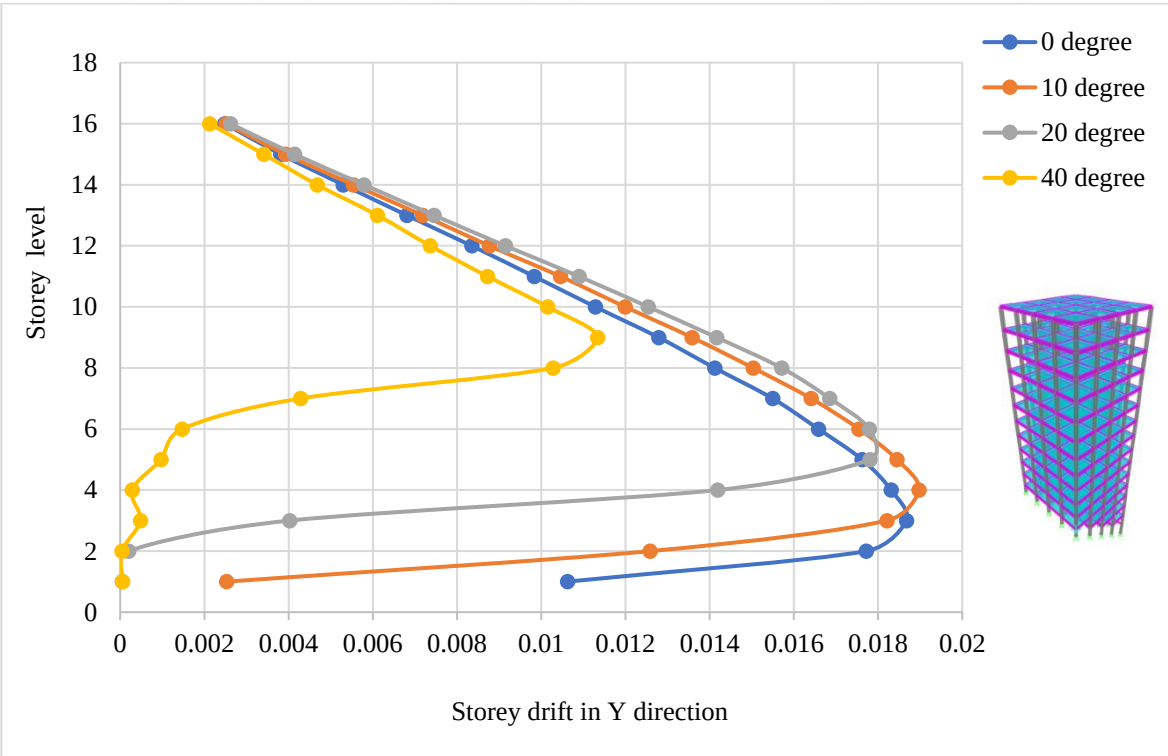


Figure 4.56: Storey Drift in Y Direction When the No. of Storeys were 16 (case III).

Case IV:

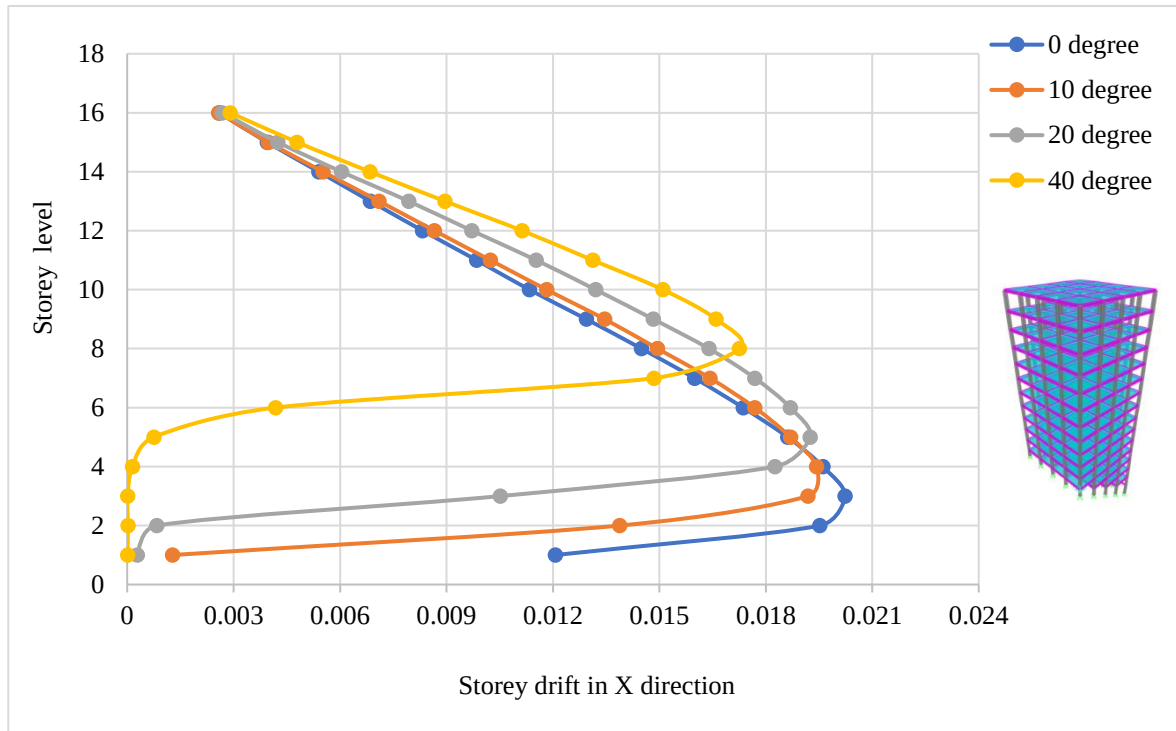


Figure 4.57: Storey Drift in X Direction When the No. of Storeys were 16 (case IV).

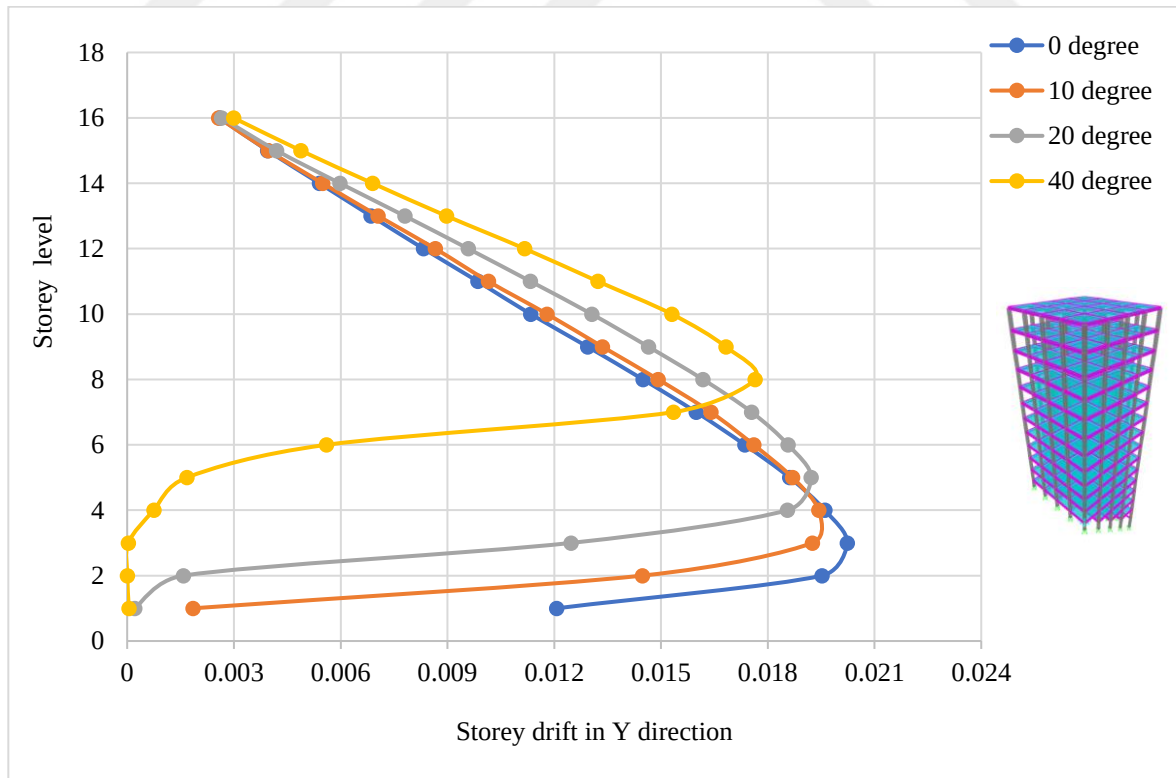


Figure 4.58: Storey Drift in Y Direction When the No. of Storeys were 16 (case IV).

Case V:

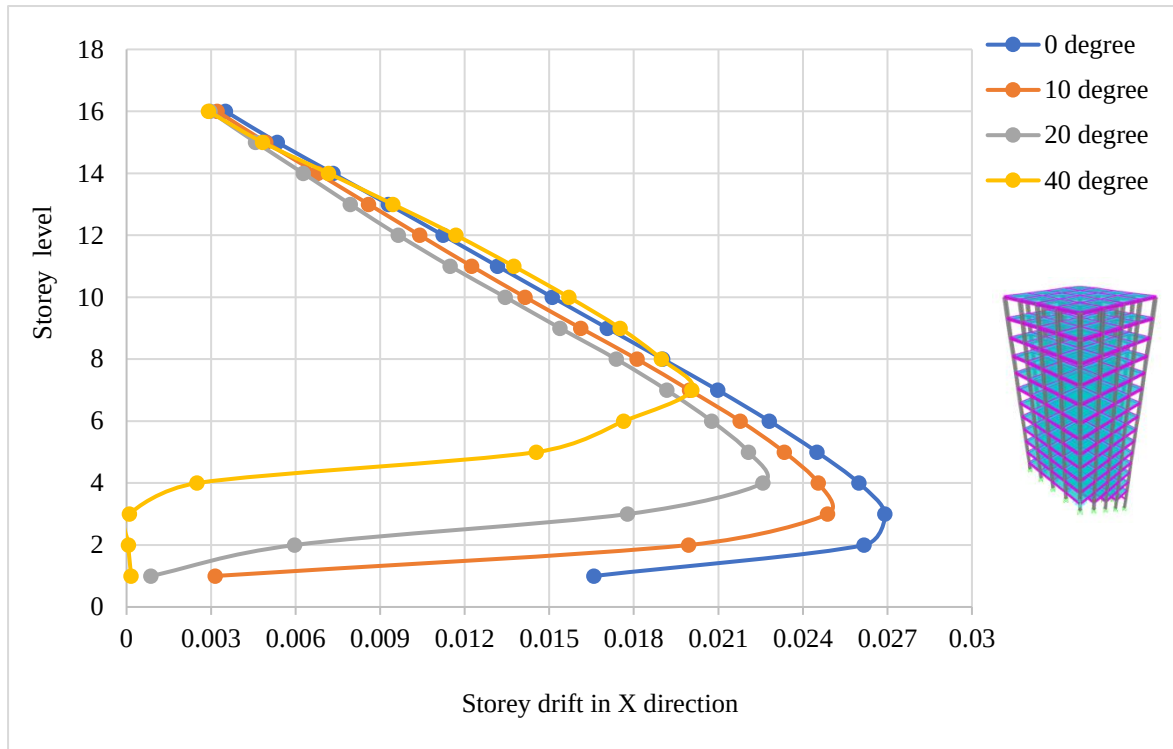


Figure 4.59: Storey Drift in X Direction When the No. of Storeys were 16 (case V).

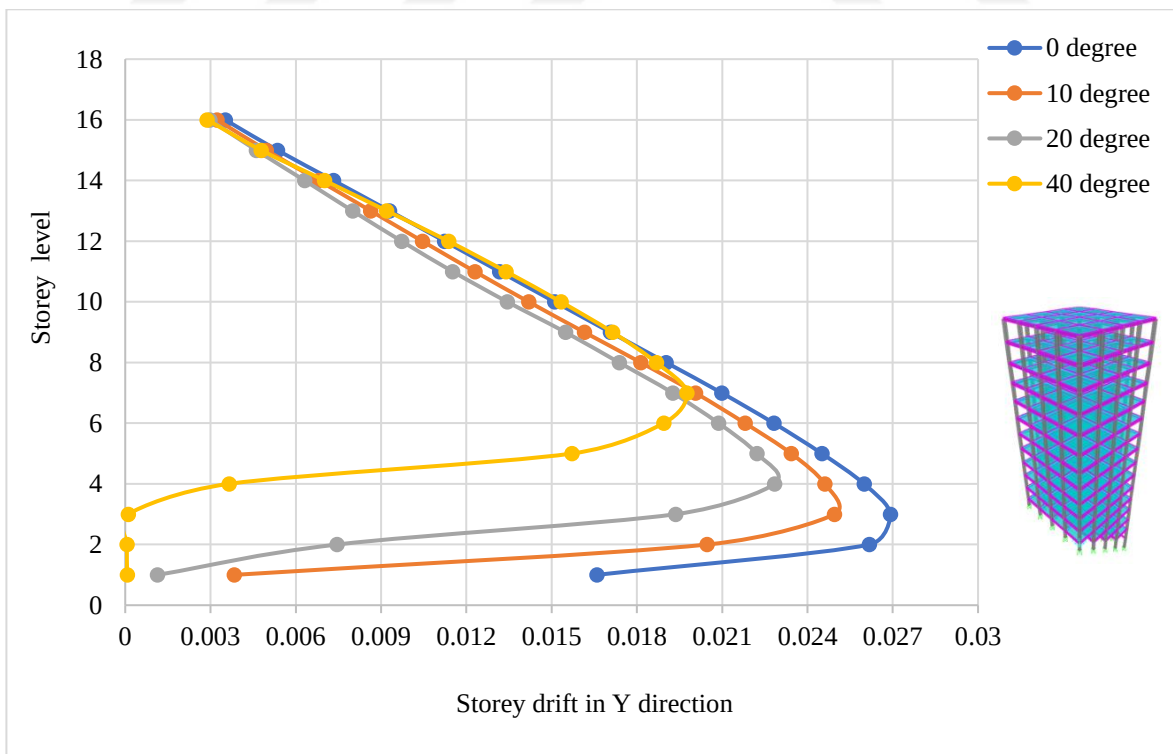


Figure 4.60: Storey Drift in Y Direction When the No. of Storeys were 16 (case V).

The Results of Storey Drift When the No. of Storeys were 20:

Case I:

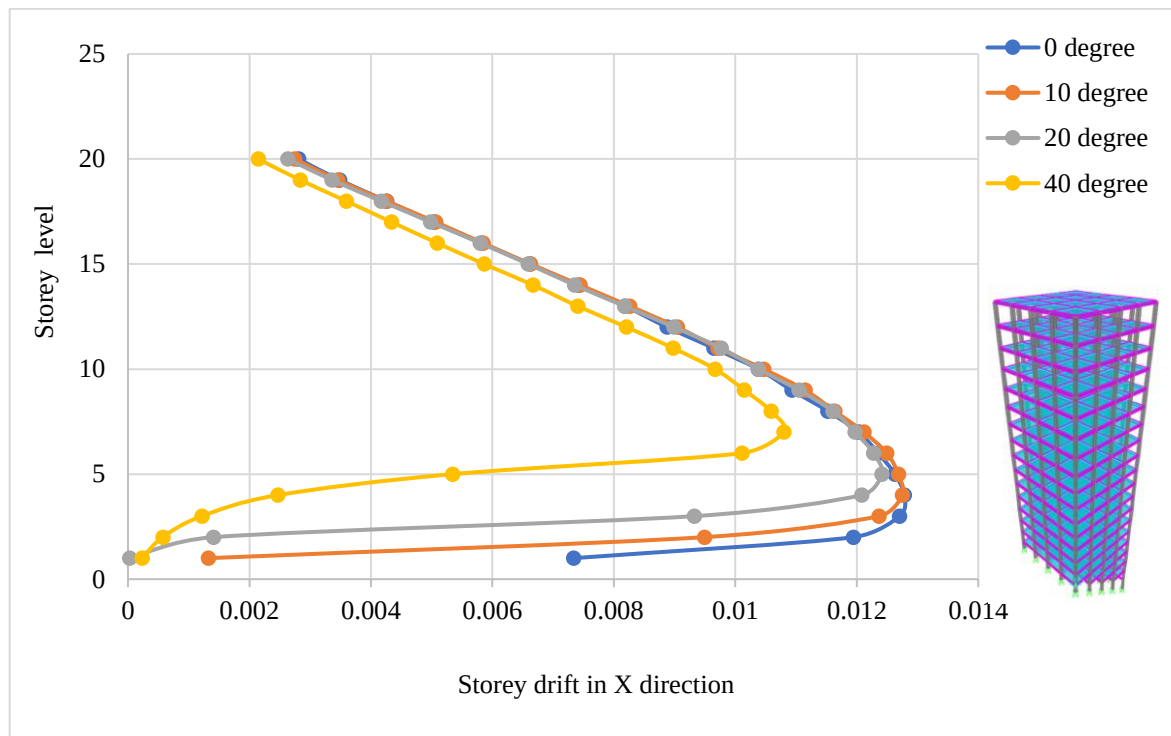


Figure 4.61: Storey Drift in X Direction When the No. of Storeys were 20 (case I).

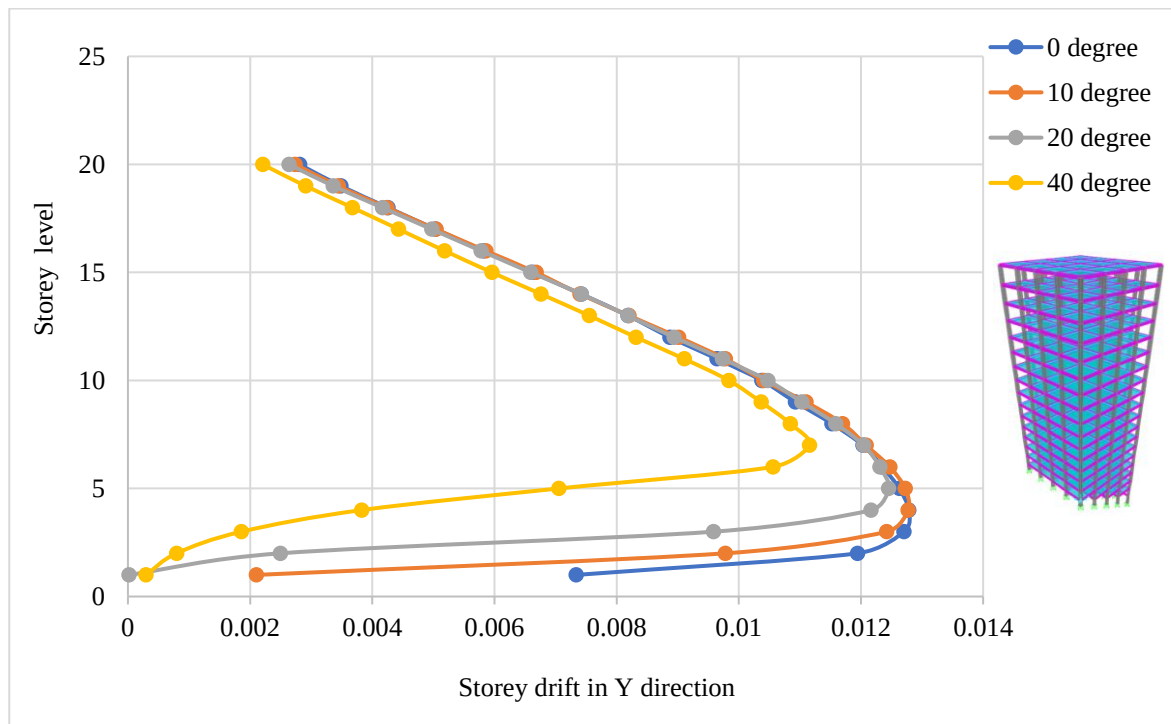


Figure 4.62: Storey Drift in Y Direction When the No. of Storeys were 20 (case I).

Case II:

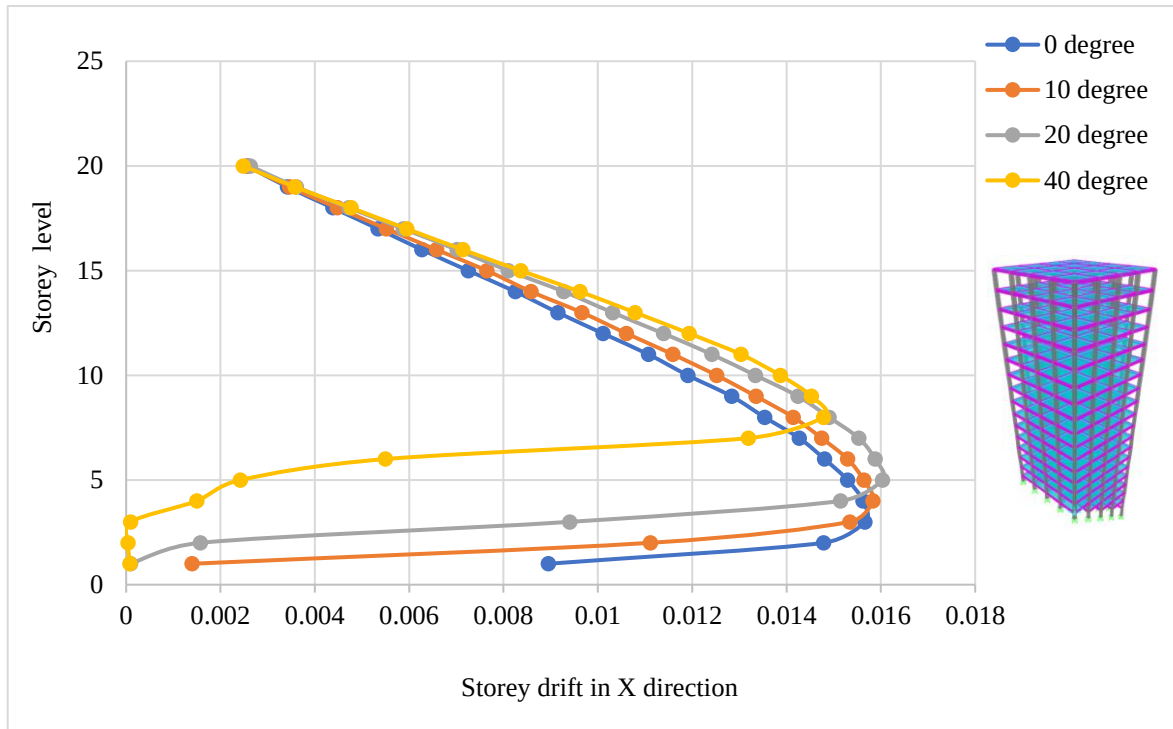


Figure 4.63: Storey Drift in X Direction When the No. of Storeys were 20 (case II).

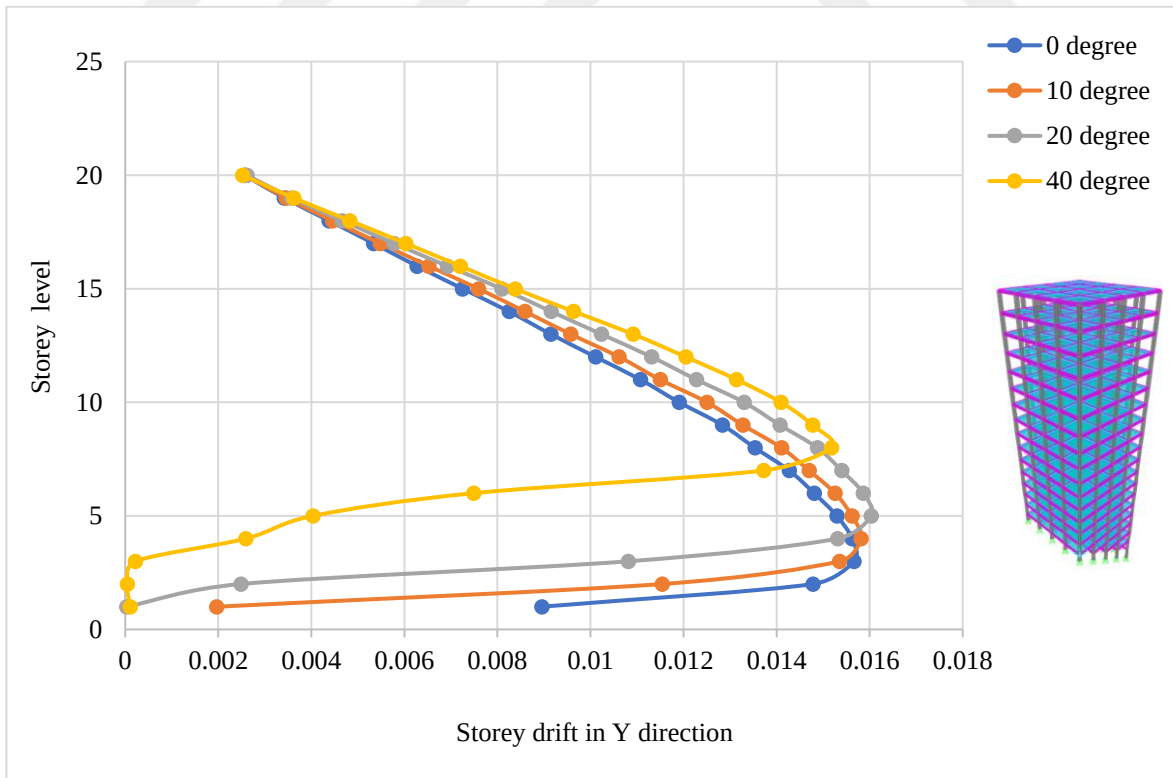


Figure 4.64: Storey Drift in Y Direction When the No. of Storeys were 20 (case II).

Case III:

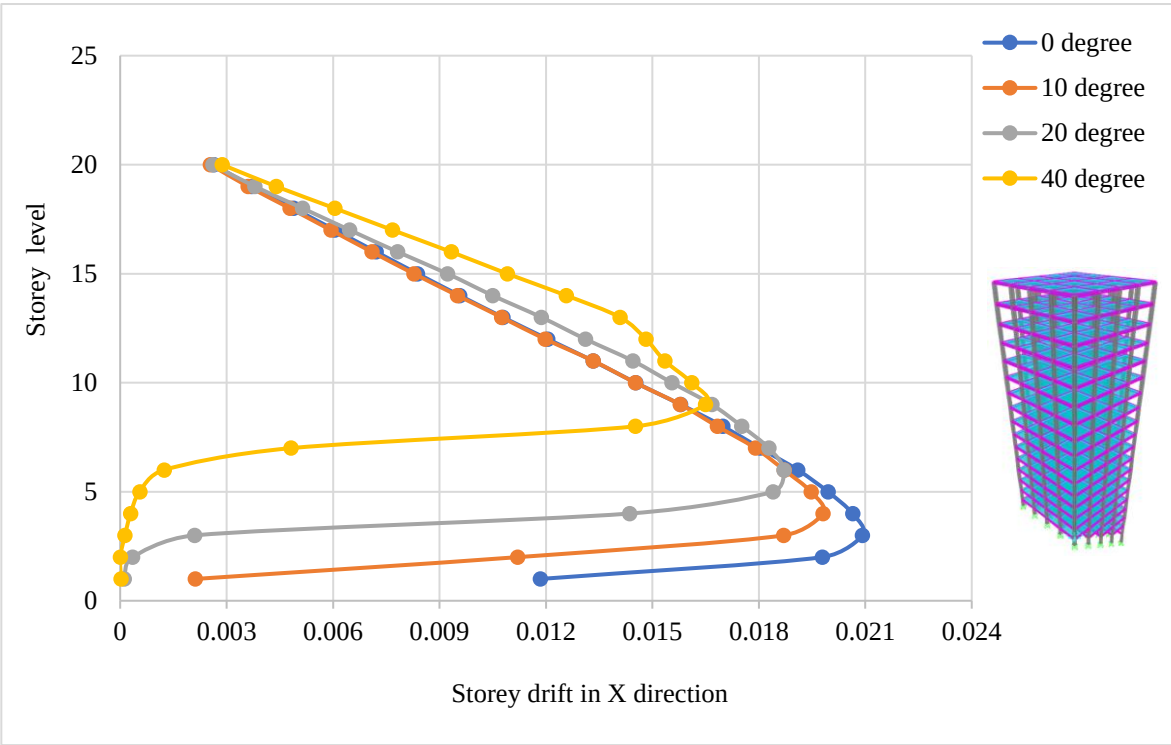


Figure 4.65: Storey Drift in X Direction When the No. of Storeys were 20 (case III).

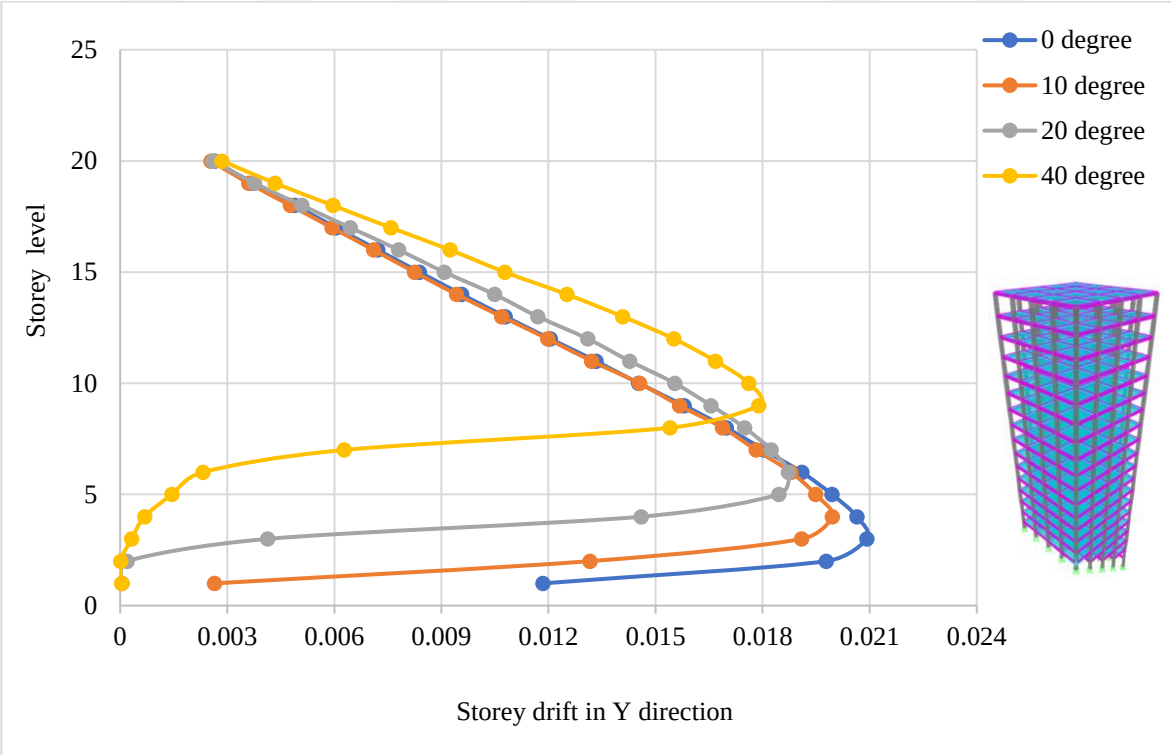


Figure 4.66: Storey Drift in Y Direction When the No. of Storeys were 20 (case III).

Case IV:

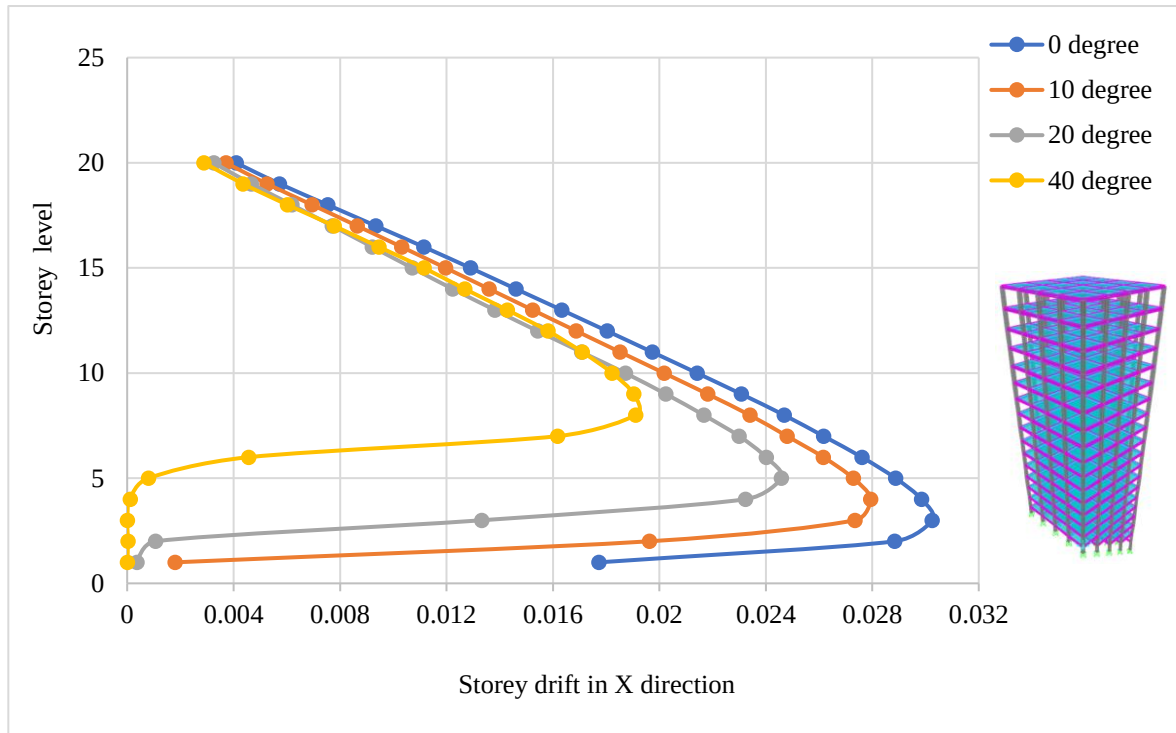


Figure 4.67: Storey Drift in X Direction When the No. of Storeys were 20 (case IV).

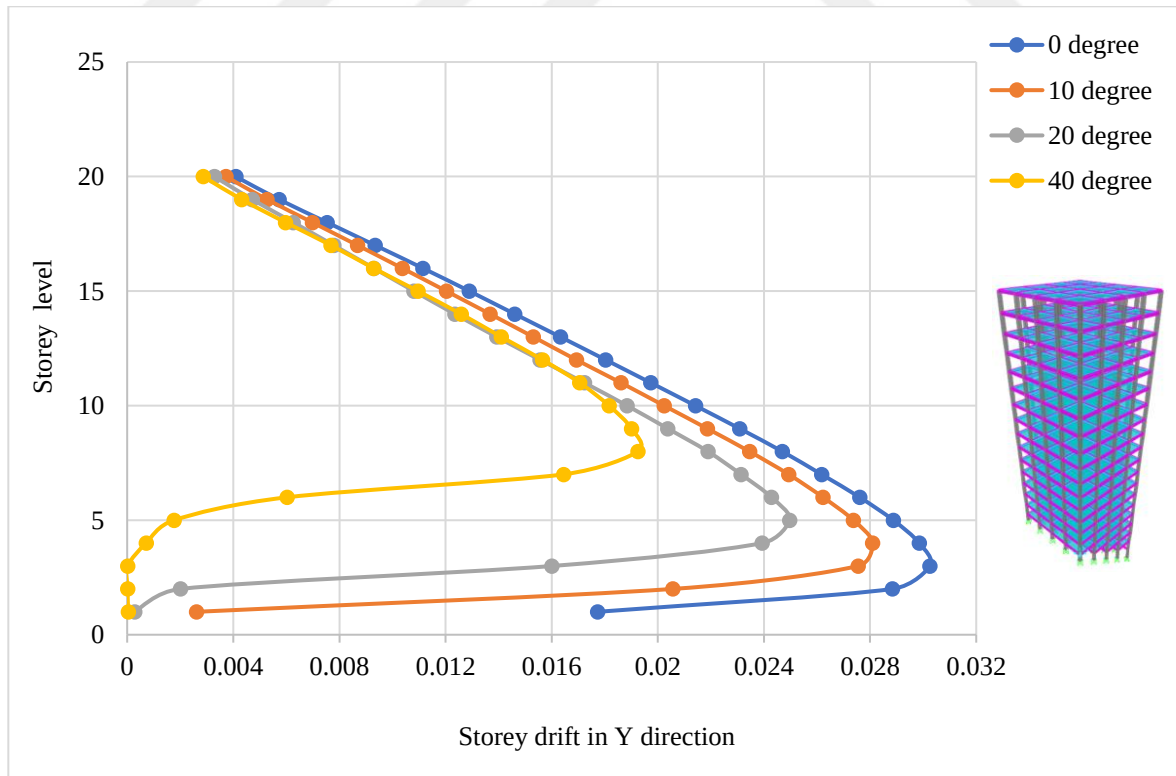


Figure 4.68: Storey Drift in Y Direction When the No. of Storeys were 20 (case IV).

Case V:

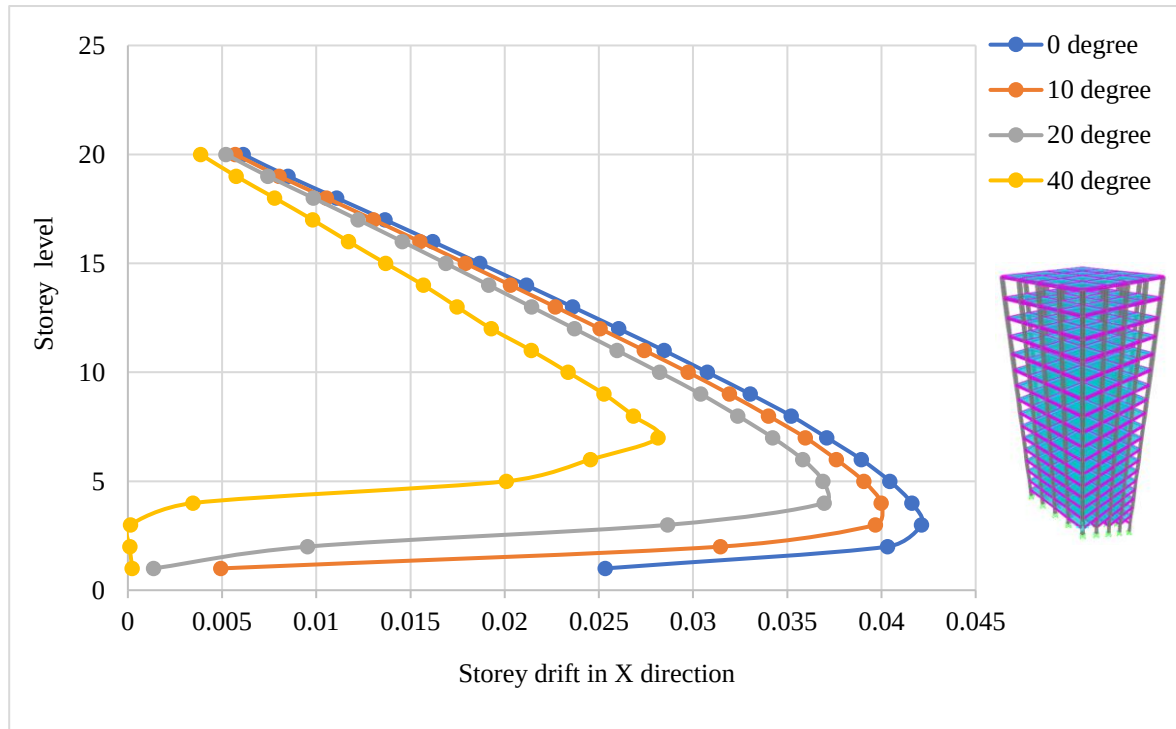


Figure 4.69: Storey Drift in X Direction When the No. of Storeys were 20 (case V).

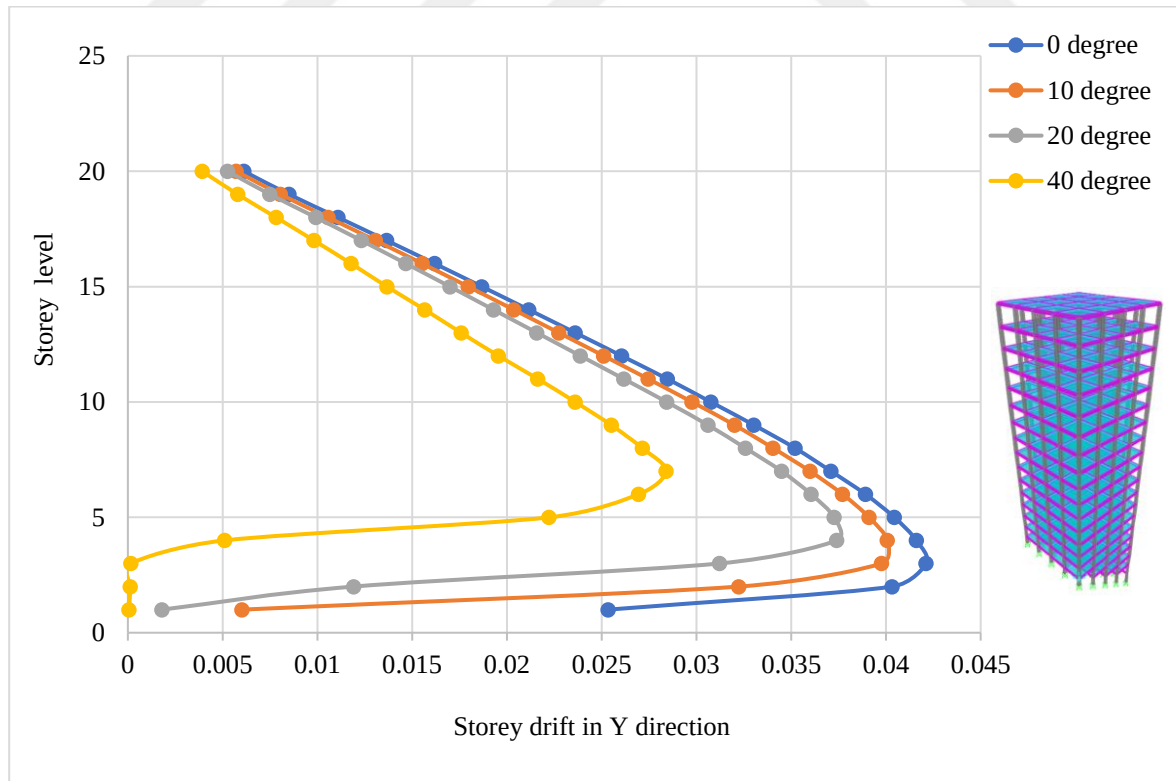


Figure 4.70: Storey Drift in Y Direction When the No. of Storeys were 20 (case V).

4.3.2 Modeling Results of Buildings with Shear Wall

Buildings with shear walls had been analyzed and the results obtained had been compared with the results of buildings without shear walls. The results had been compared for the same building characteristics in terms of foundation inclination angle, number of storeys, span width, and storey height.

The effect of the degree of foundation inclinations with the presence of shear walls:

- a. In the case absence of shear walls as shown in Figure 4.10, when the No. of storeys were 8 the base shear values were (6470, 5561, 4962 and 3748) kN, when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively, and when the No. of storeys were 20 the base shear values were (13770, 13740, 13770 and 12490) kN, when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively. While in the case presence of shear walls as shown in Figure 4.77, when the No. of storeys were 8 the base shear values were (8879, 8473, 8085 and 4142) kN, when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively, and when the No. of storeys were 20 the base shear values were (20960, 20040, 18980 and 15060) kN, when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively.
- b. In the case absence of shear walls as shown in Figure 4.15, when the No. of storeys were 8 the time period values were (1.181, 1.041, 0.786 and 0.287) sec., when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively, and when the No. of storeys were 20 the time period values were (3.065, 2.909, 2.655 and 2.133) sec., when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively. While in the case presence of shear walls as shown in Figure 4.82, when the No. of storeys were 8 the time period values were (0.361, 0.311, 0.251 and 0.1406) sec., when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively, and when the No. of storeys were 20 the time period values were (1.596, 1.501, 1.367 and 0.987) sec., when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively.
- c. In the case absence of shear walls as shown in Figure 4.16, when the No. of storeys were 8 the displacements in X direction values were (133.864, 109.776, 60.056 and 5.99) mm, when the degrees of foundation inclination were (0°, 10°, 20° and 40°) respectively, and when the No. of storeys were 20 the displacements in X direction

values were (768.543, 698.522, 621.058 and 456.716) mm, when the degrees of foundation inclination were (0° , 10° , 20° and 40°) respectively. While in the case presence of shear walls as shown in Figure 4.83, when the No. of storeys were 8 displacements in X direction values were (14.878, 12.465, 8.532 and 1.317) mm, when the degrees of foundation inclination were (0° , 10° , 20° and 40°) respectively, and when the No. of storeys were 20 the displacements in X direction values were (301.141, 278.915, 242.157 and 141.686) mm, when the degrees of foundation inclination were (0° , 10° , 20° and 40°) respectively.

The effect of the No. of storeys with the presence of shear walls:

- a. In the case absence of shear walls as shown in Figure 4.10, when the degree of foundation inclination was 0° the base shear values were (6470, 9463, 13480 and 13770) kN, when the No. of storeys were (8, 12, 16 and 20) respectively, and when the degree of foundation inclination was 40° the base shear values were (3748, 6805, 8446 and 12490) kN, when the No. of storeys were (8, 12, 16 and 20) respectively. While in the case presence of shear walls as shown in Figure 4.77, when the degree of foundation inclination was 0° the base shear values were (8879, 12030, 16120 and 20960) kN, when the No. of storeys were (8, 12, 16 and 20) respectively, and when the degree of foundation inclination was 40° the base shear values were (4142, 9812, 11960 and 15060) kN, when the No. of storeys were (8, 12, 16 and 20) respectively.
- b. In the case absence of shear walls as shown in Figure 4.15, when the degree of foundation inclination was 0° the time period values were (1.181, 1.796, 2.423 and 3.065) sec., when the No. of storeys were (8, 12, 16 and 20) respectively, and when the degree of foundation inclination was 40° the time period values were (0.287, 0.857, 1.494 and 2.133) sec., when the No. of storeys were (8, 12, 16 and 20) respectively. While in the case presence of shear walls as shown in Figure 4.82, the degree of foundation inclination was 0° the time period values were (0.361, 0.696, 1.115 and 1.596) sec., when the No. of storeys were (8, 12, 16 and 20) respectively, and when the degree of foundation inclination was 40° the time period values were (0.140, 0.312, 0.603 and 0.987) sec., when the No. of storeys were (8, 12, 16 and 20) respectively.
- c. In the case absence of shear walls as shown in Figure 4.16, when the degree of foundation inclination was 0° the displacements in X direction values were (133.864,

345.129, 569.387 and 768.543) mm, when the No. of storeys were (8, 12, 16 and 20) respectively, and when the degree of foundation inclination was 40° the displacements in X direction values were (5.99, 62.078, 192.118 and 456.716) mm, when the No. of storeys were (8, 12, 16 and 20) respectively. While in the case presence of shear walls as shown in Figure 4.83, when the degree of foundation inclination was 0° the displacements in X direction values were (14.878, 56.096, 142.084 and 301.141) mm, when the No. of storeys were (8, 12, 16 and 20) respectively, and when the degree of foundation inclination was 40° the displacements in X direction values were (1.317, 12.83, 53.33 and 141.686) mm, when the No. of storeys were (8, 12, 16 and 20) respectively.

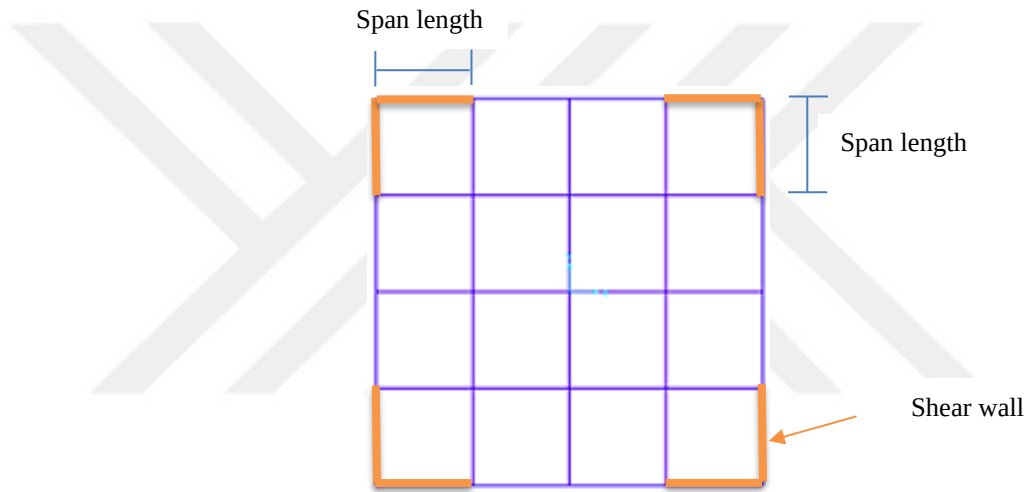


Figure 4.71: Plan of the Building (Shows the Location of the Shear Walls).

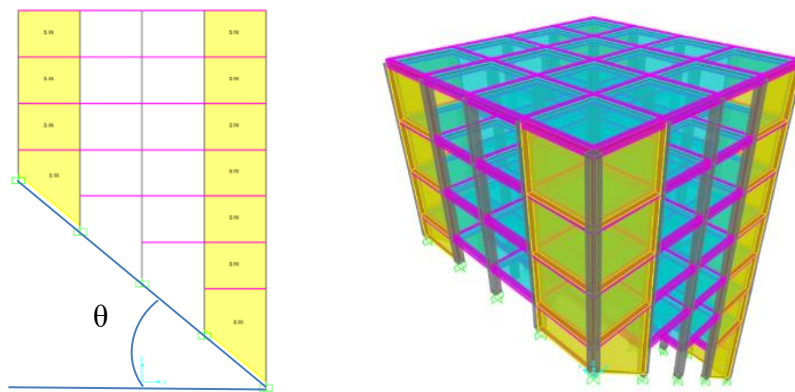


Figure 4.72: 3D & 2D Model of 8 Storey Stepback Building Inclined with an Angle of θ with Shear Wall.

Where θ equal to (0° , 10° , 20° and 40°).

4.3.2.1 Modeling results based on the no. of storeys and span length with shear wall

The effect of the span length with the presence of shear walls:

- a. (Figure 4.6, Figure 4.10 & Figure 4.14) and (Figure 4.73, Figure 4.77 & Figure 4.81), had been compared to evaluate the effect of the presence of shear walls on the base shear values. The value of base shear increased by (61%, 37.2% & 14.3%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 0°), while its value increased by (67.5%, 115% & 39.6%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 40°). Also, the value of base shear increased by (30.9%, 52% & 42.3%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 0°), while its value increased by (32%, 20.5% & 94%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).
- b. (Figure 4.7, Figure 4.11 & Figure 4.15) and (Figure 4.74, Figure 4.78 & Figure 4.82), had been compared to evaluate the effect of the presence of shear walls on the time period values. The value of time period decreased by (53%, 72.7% & 69.4%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 0°), while its value decreased by (58.4%, 61.3% & 51%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 40°). Also, the value of time period decreased by (16.6%, 28% & 39%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 0°), while its value decreased by (34%, 43.6% & 53.7%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).
- c. (Figure 4.7, Figure 4.11 & Figure 4.15) and (Figure 4.74, Figure 4.78 & Figure 4.82), had been compared to evaluate the effect of the presence of shear walls on the displacements in X direction values. The value of displacements in X direction decreased by (73.3%, 83.5% & 89%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 0°), while its value decreased by (77.5%, 80% & 78%) when the span length was (4, 5

& 6) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 40°). Also, the value of displacements in X direction decreased by (47%, 51.7% & 61%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 0°), while its value decreased by (47.8%, 61% & 69%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).

The Results When the Storey Height (3 m) and Span Length (4 m):

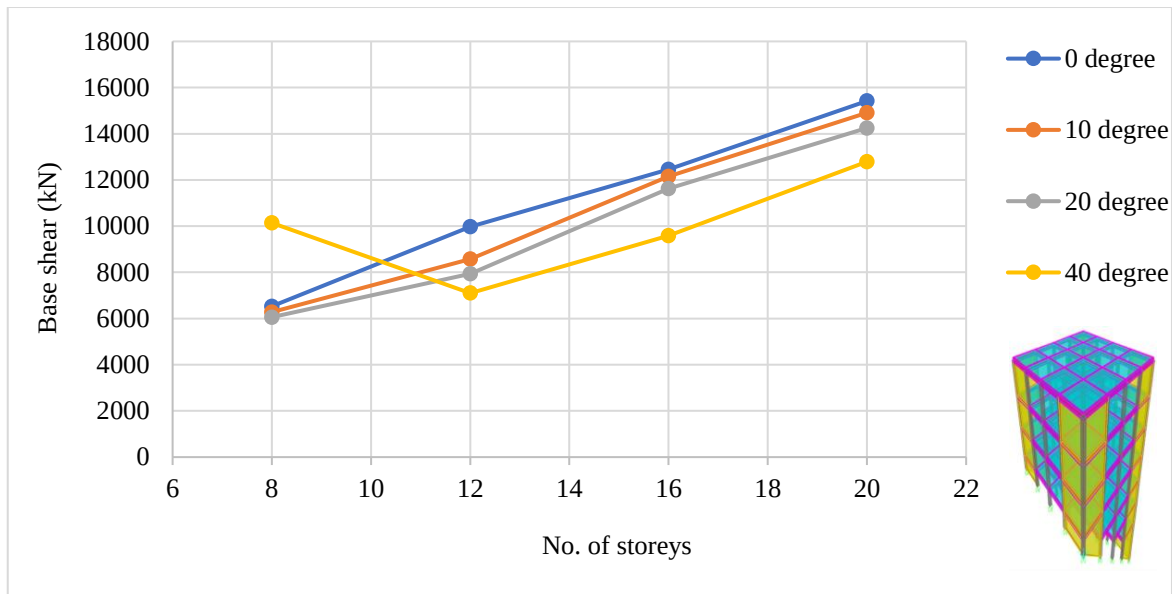


Figure 4.73: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

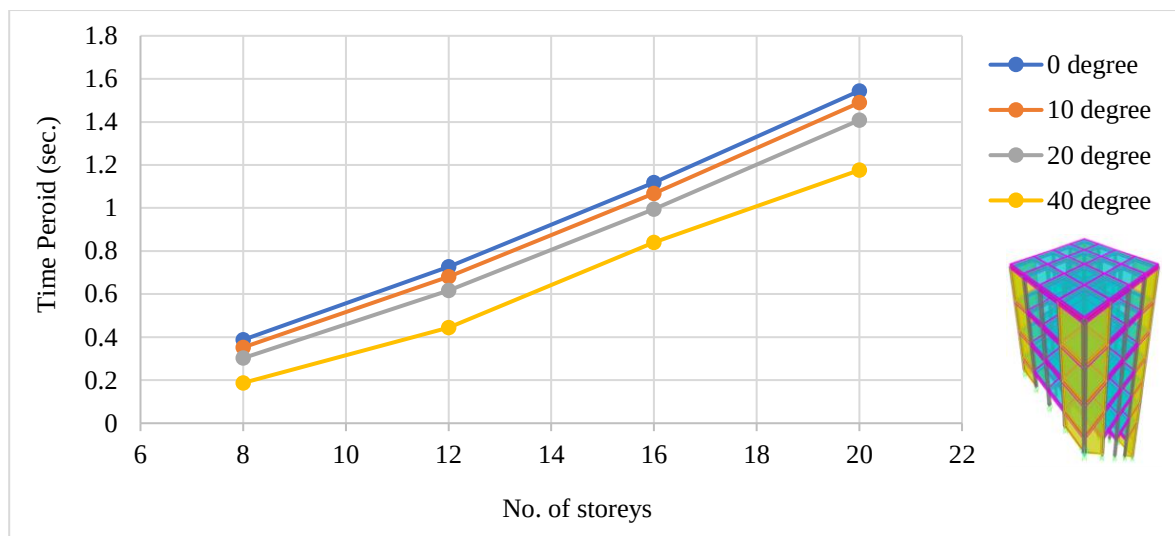


Figure 4.74: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

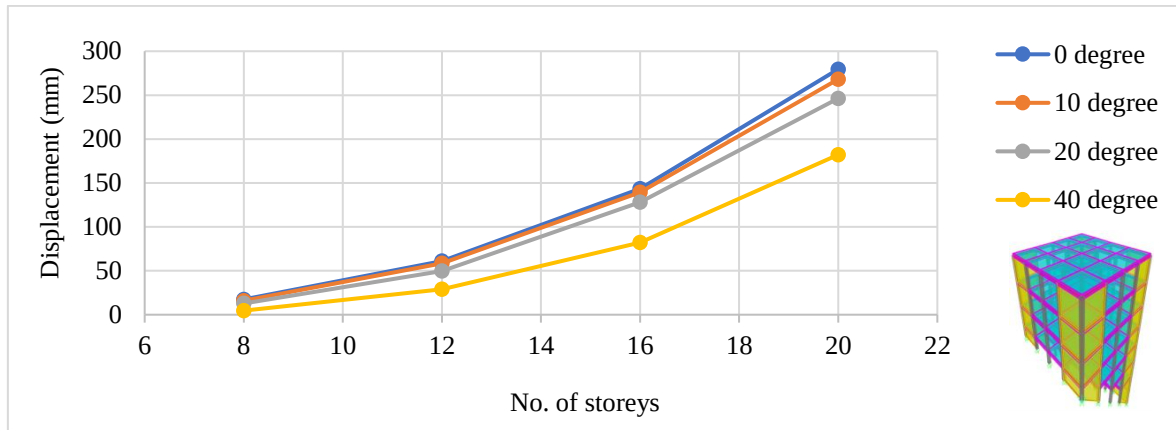


Figure 4.75: Roof Displacements in X Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

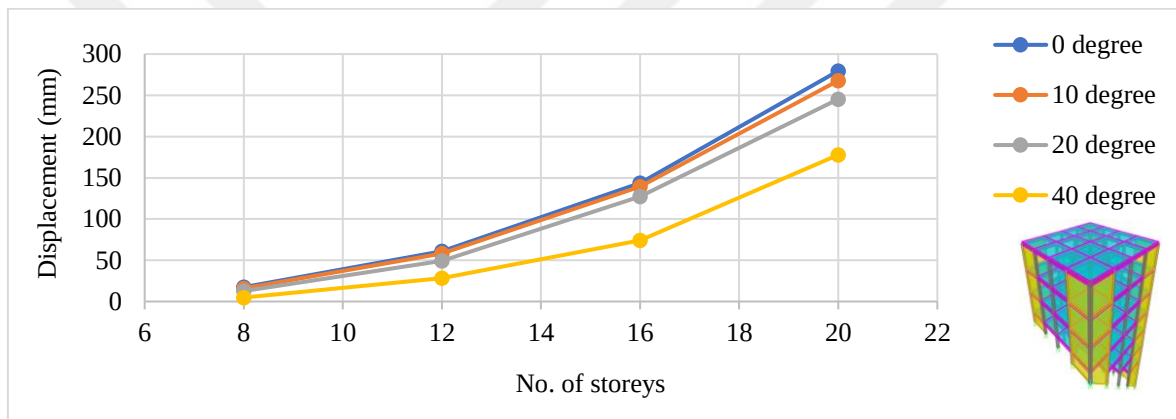


Figure 4.76: Roof Displacements in Y Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

The Results When the Storey Height (3 m) and Span Length (5 m):

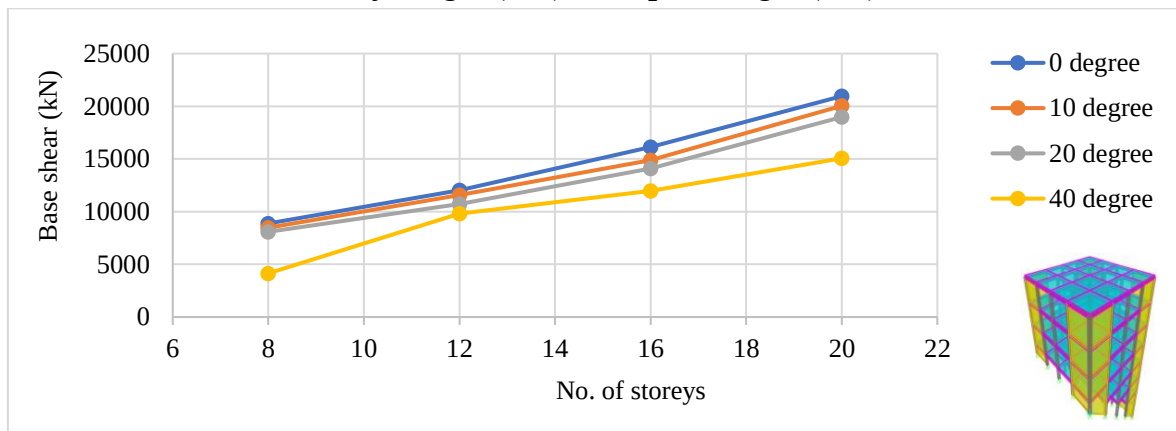


Figure 4.77: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

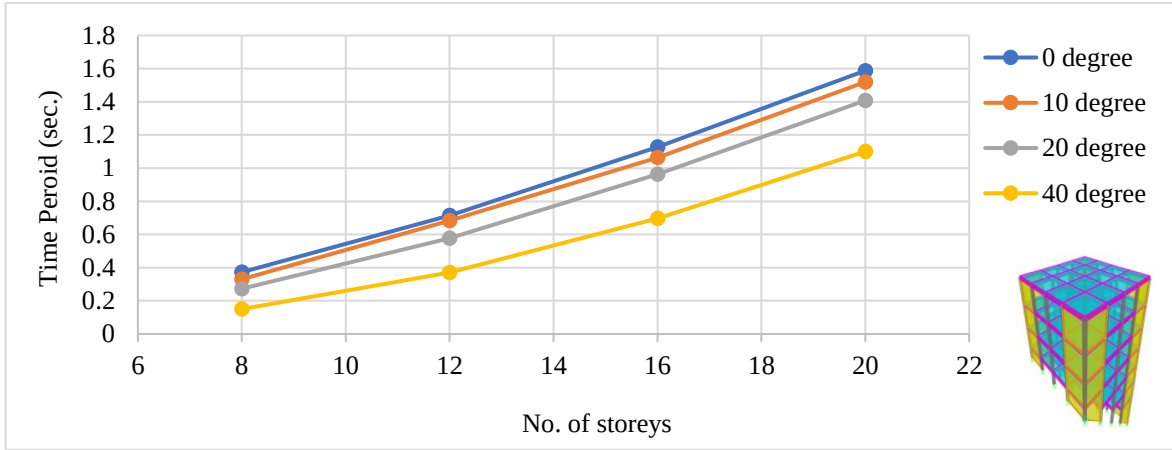


Figure 4.78: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

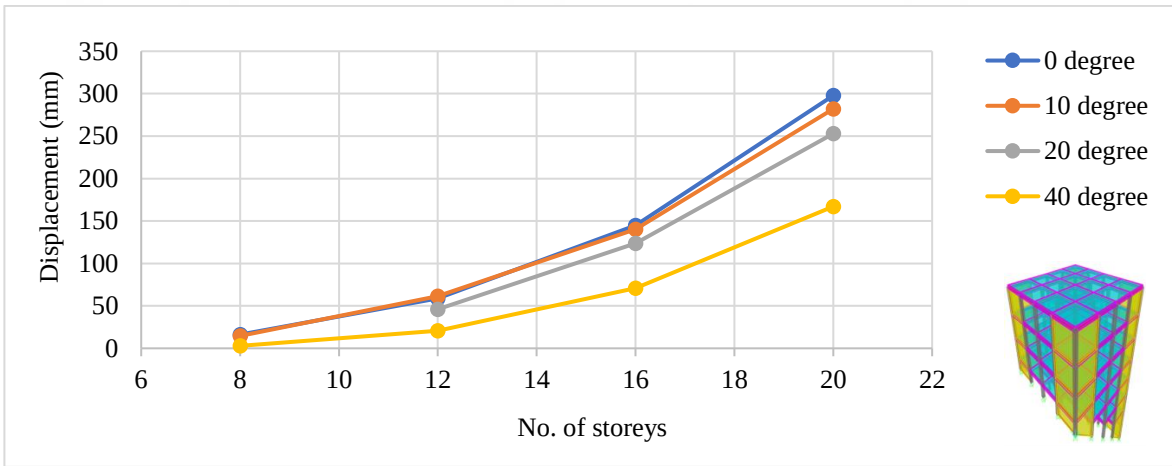


Figure 4.79: Roof Displacements in X Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

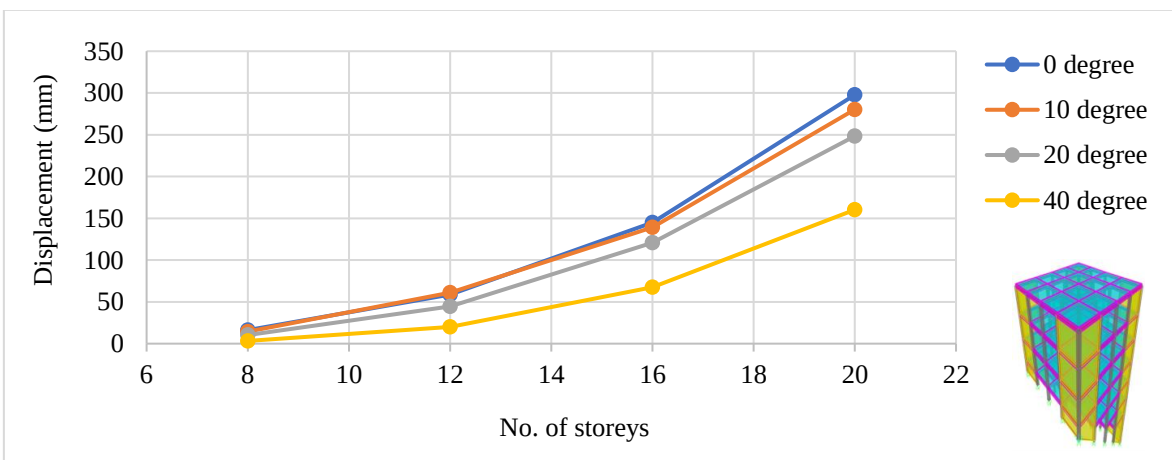


Figure 4.80: Roof Displacements in Y Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

The Results When the Storey Height (3 m) and Span Length (6 m):

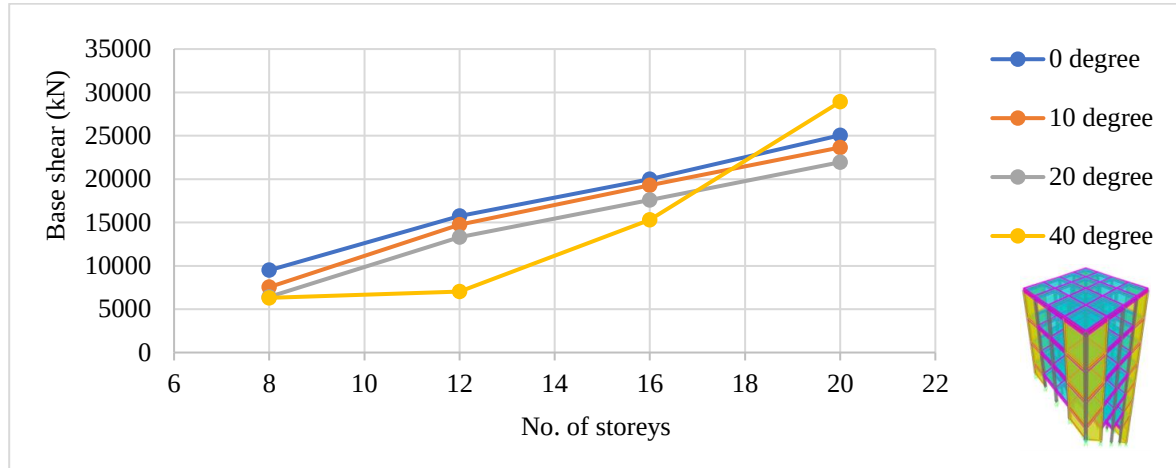


Figure 4.81: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

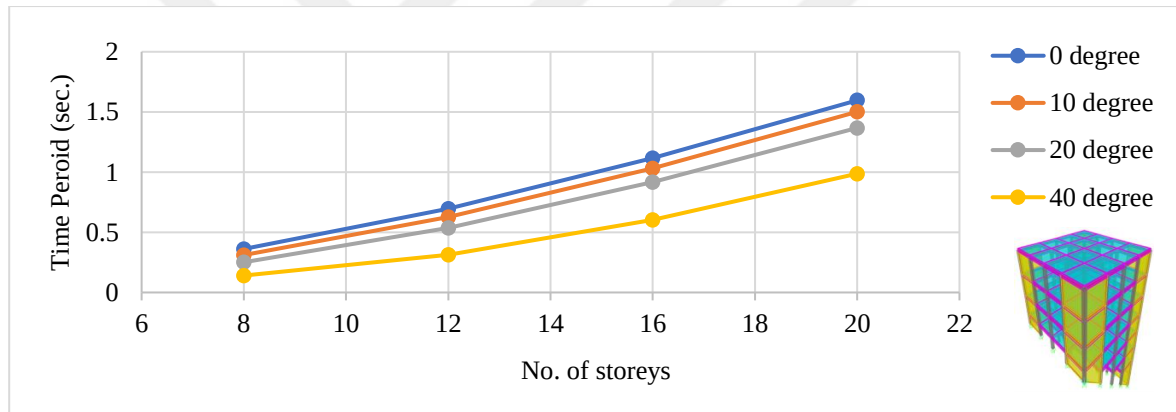


Figure 4.82: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

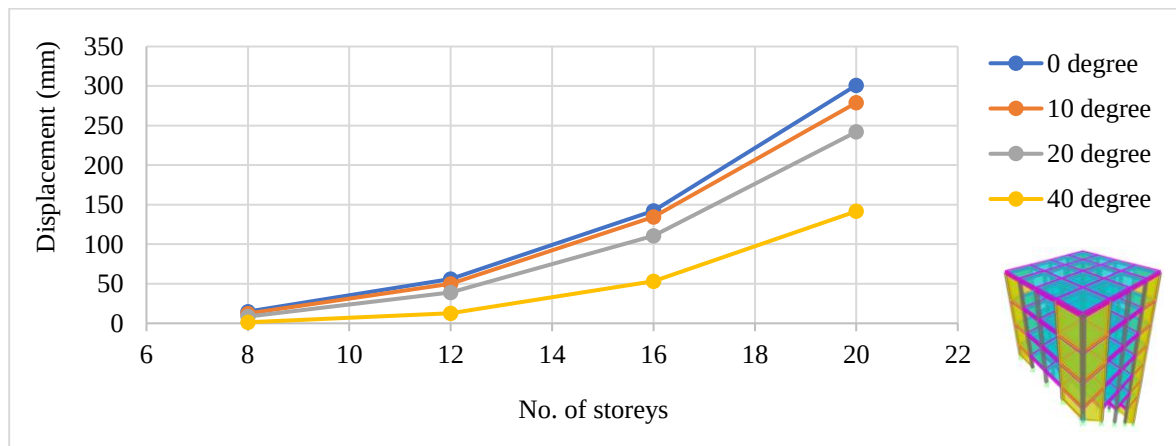


Figure 4.83: Roof Displacements in X Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

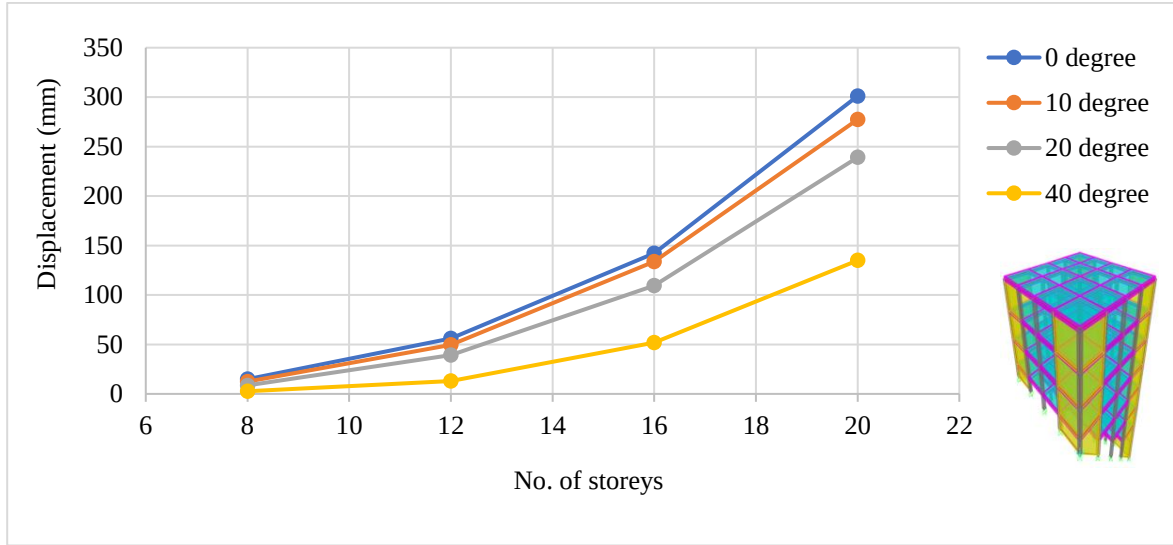


Figure 4.84: Roof Displacements in Y Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

4.3.2.2 Modeling results based on the no. of storeys and storey height with shear wall

The effect of the storey height with the presence of shear walls:

- (Figure 4.18, Figure 4.22 & Figure 4.26) and (Figure 4.85, Figure 4.89 & Figure 4.93), had been compared to evaluate the effect of the presence of shear walls on the base shear values. The value of base shear increased by (14.3%, 34.6% & 29.7%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 0°), while its value increased by (37%, 10% & 2%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 40°). Also, the value of base shear increased by (42.3%, 47% & 19%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 0°), while its value increased by (94%, 50.7% & 46%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).
- (Figure 4.19, Figure 4.23 & Figure 4.27) and (Figure 4.86, Figure 4.90 & Figure 4.94), had been compared to evaluate the effect of the presence of shear walls on the time period values. The value of time period decreased by (69.4%, 68.8% & 68%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 0°), while its value decreased by (51%, 62.8% &

72.8%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 40°). Also, the value of time period decreased by (48%, 46% & 48%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 0°), while its value decreased by (53.7%, 50% & 50%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).

- c. (Figure 4.20, Figure 4.24 & Figure 4.28) and (Figure 4.87, Figure 4.91 & Figure 4.95), had been compared to evaluate the effect of the presence of shear walls on the displacements in X direction values. The value of displacements in X direction decreased by (89%, 88% & 89%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 0°), while its value decreased by (78%, 85% & 91%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 8 and the degree of foundation inclination 40°). Also, the value of displacements in X direction decreased by (61%, 61% & 69%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 0°), while its value decreased by (69%, 60% & 60%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).

The Results When the Storey Height (3 m) and Span Length (6 m):

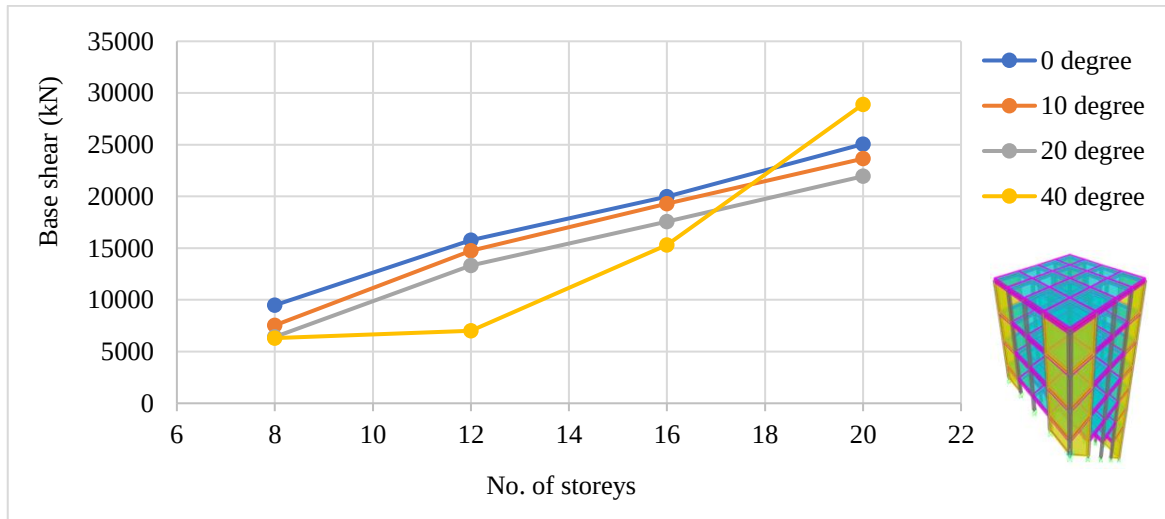


Figure 4.85: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

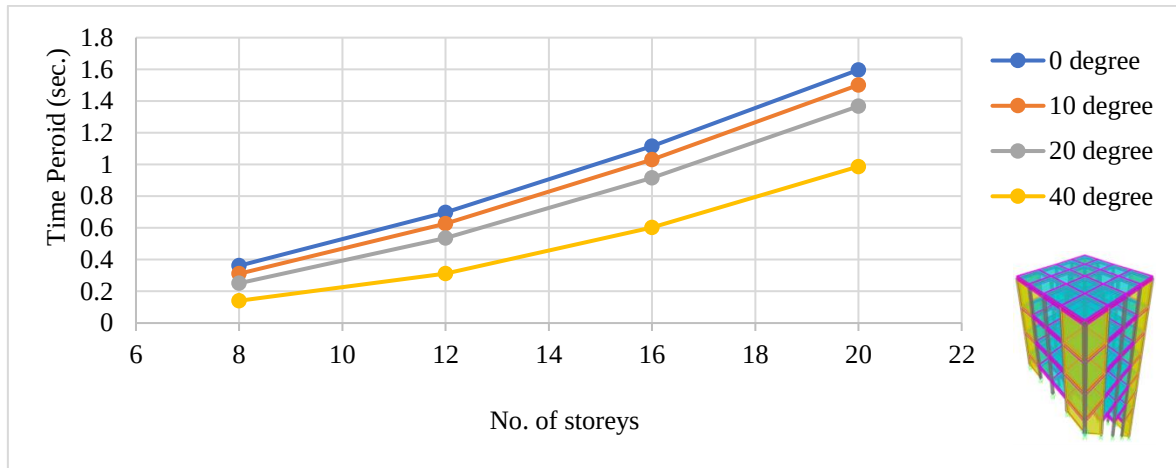


Figure 4.86: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

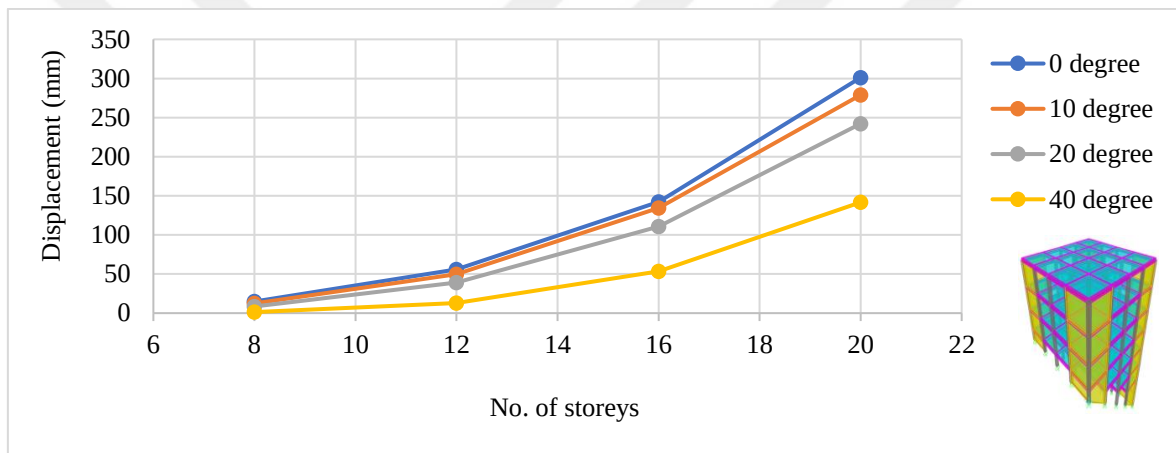


Figure 4.87: Roof Displacements in X Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

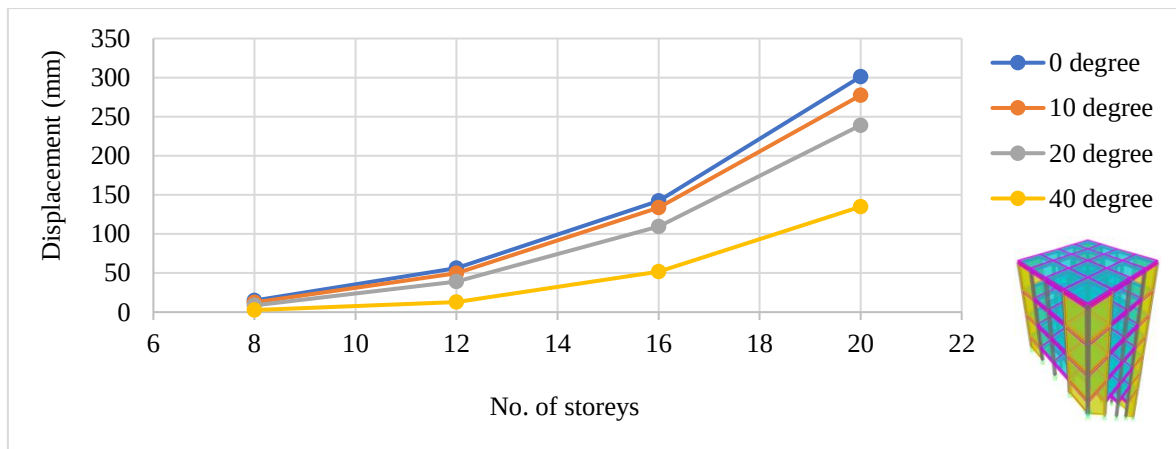


Figure 4.88: Roof Displacements in Y Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

The Results When the Storey Height (3.5 m) and Span Length (6 m):

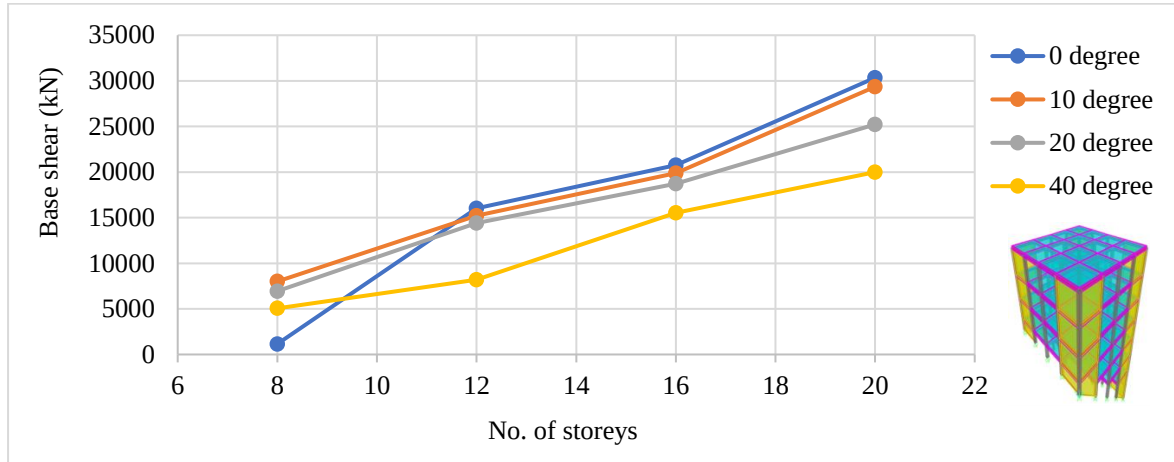


Figure 4.89: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

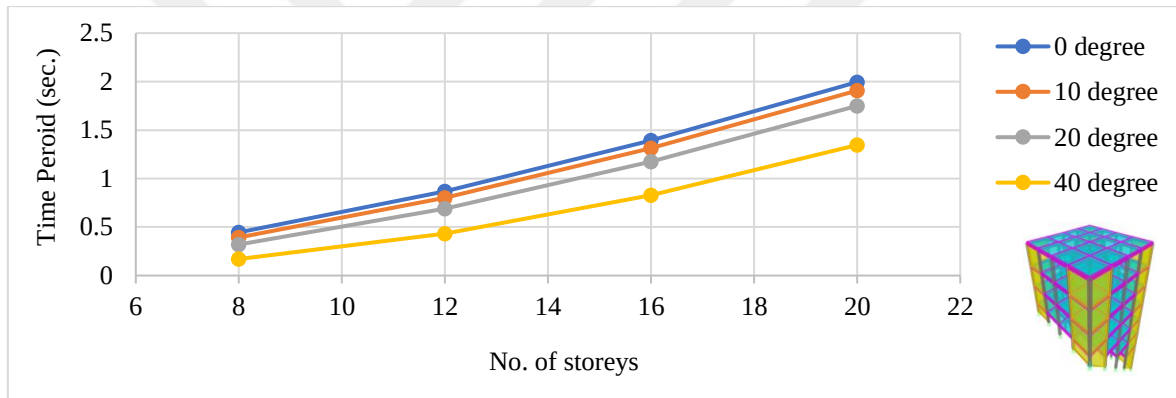


Figure 4.90: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

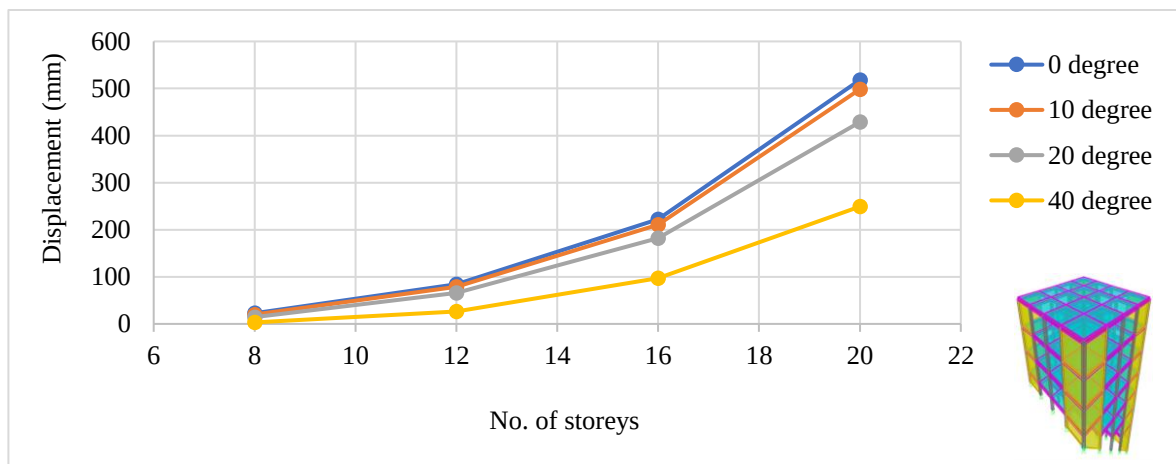


Figure 4.91: Roof Displacements in X Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

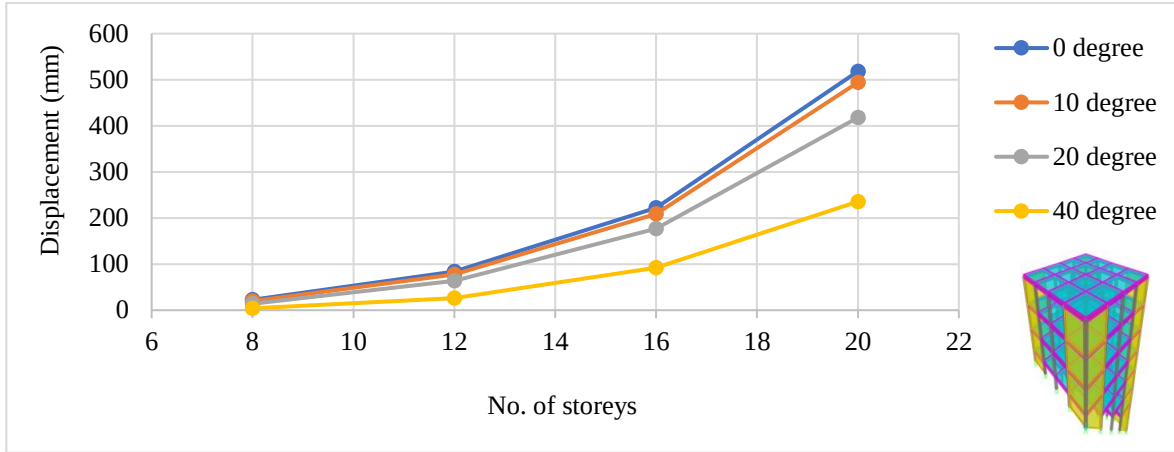


Figure 4.92: Roof Displacements in Y Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

The Results When the Storey Height (4 m) and Span Length (6 m):

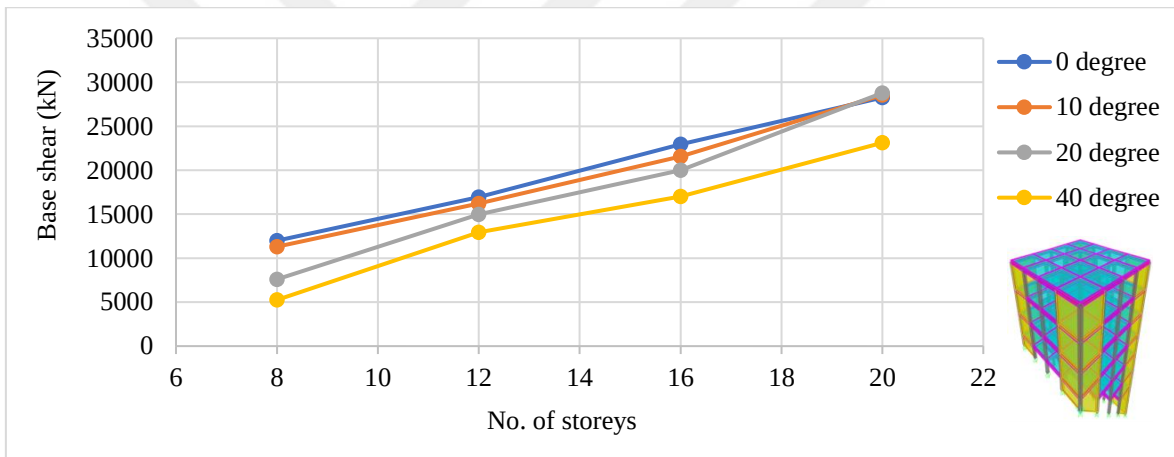


Figure 4.93: Maximum Base Shear Based on the No. of Storeys and the Degree of Inclined Foundation.

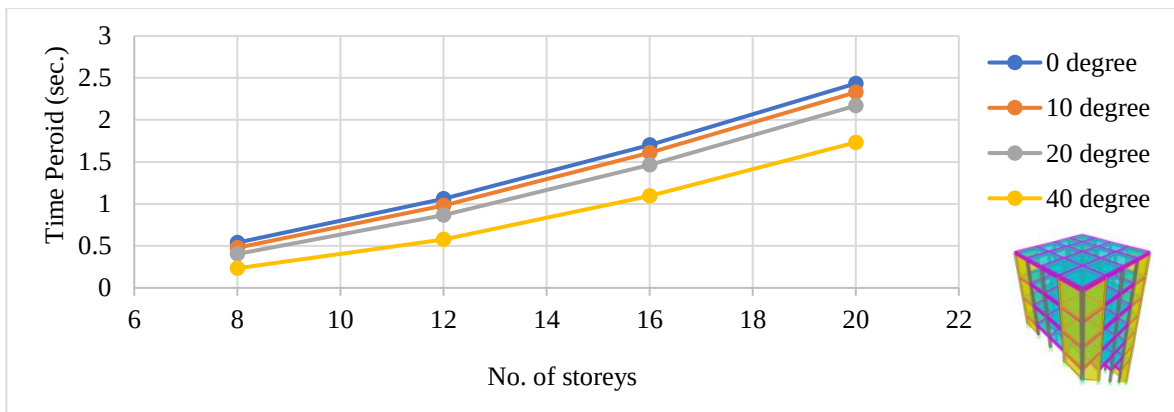


Figure 4.94: Time Period Based on the No. of Storeys and the Degree of Inclined Foundation.

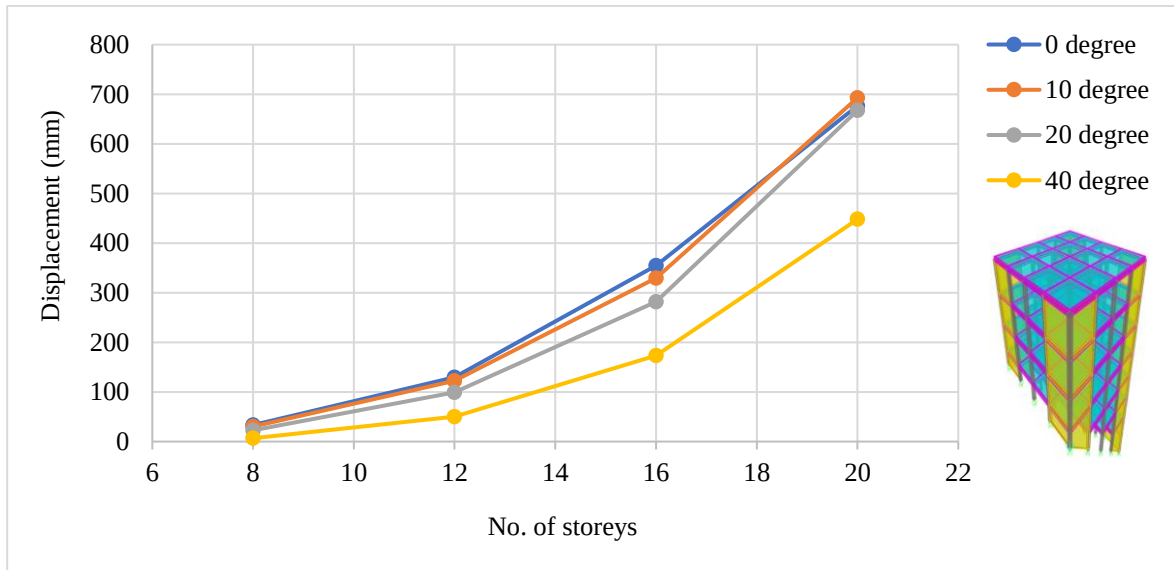


Figure 4.95: Roof Displacements in X Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

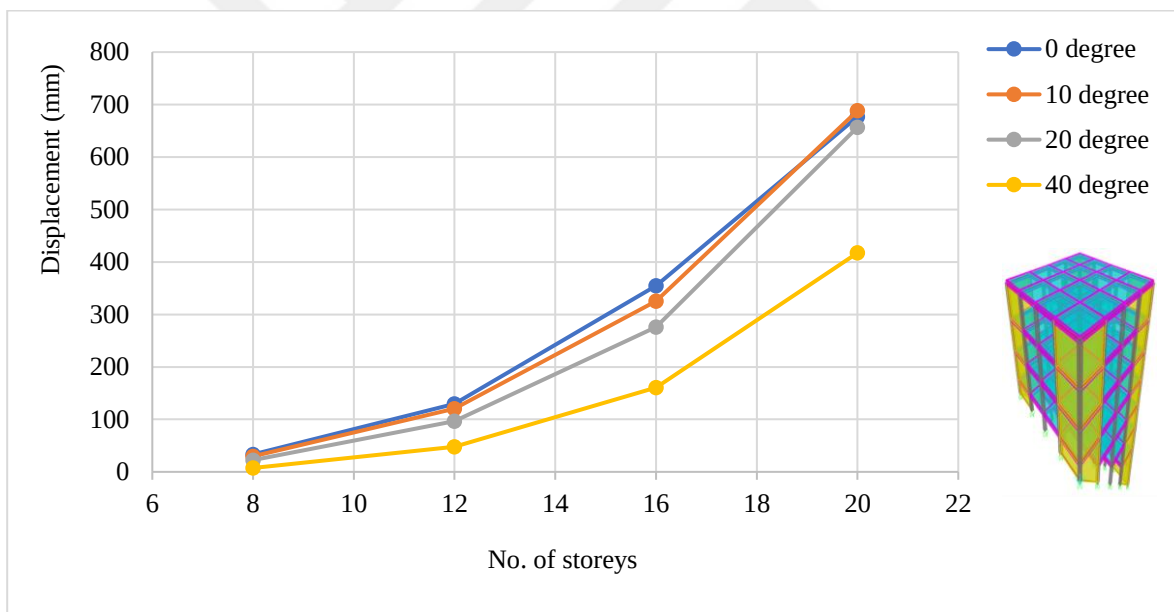


Figure 4.96: Roof Displacements in Y Direction Based on the No. of Storeys and the Degree of Inclined Foundation.

4.3.2.3 Storey drift of the buildings with shear wall

As shown in Figure 4.97 all buildings had been modeled in the case presence of shear walls, where the values of storey drift obtained in this case had been compared with the values of storey drift in the case absence of shear walls. The value of the storey drift

decreased by 40-70% in the case presence of shear walls compared to its value in the absence of shear walls, as shown in (Figure 4.98 to Figure 4.137).

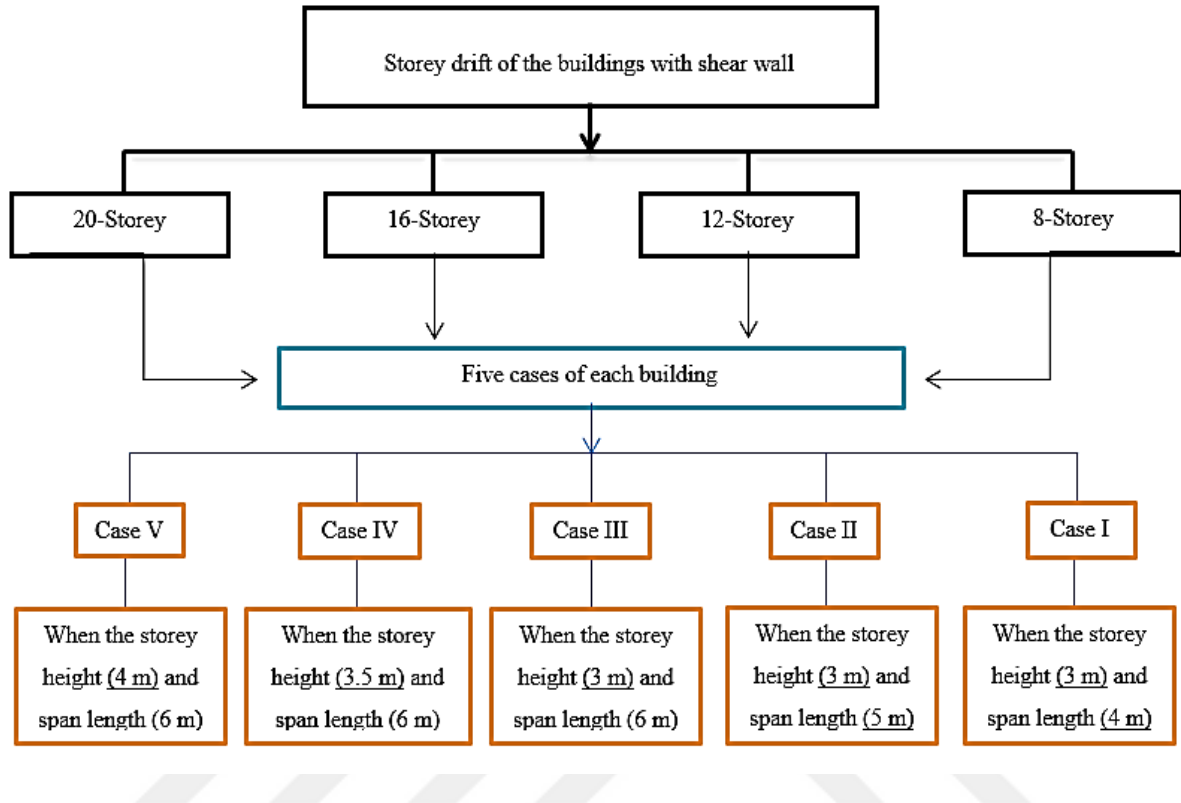


Figure 4.97: Storey Drift of the Buildings with Shear Wall.

The value of the storey drift decreased when the degree of foundation inclination of the building increased. As shown in Figure 4.118, the value of storey drift decreased by (43.7%, 86% & 88%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 1st storey level. While its value decreased by (1%, 5% & 27%) at the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 16th storey level.

The value of the storey drift increased when the span length increased. As shown in (Figure 4.118, Figure 4.120 & Figure 4.122), the value of storey drift increased by (5% & 10%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 1st storey level and the degree of the foundation inclination was 0°). The value of storey drift increased by (4% & 2.6%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 16th storey level and the degree of the foundation inclination was 0°). While its value increased by (35% & 57%) when the span length increased from 4 m to (5

& 6) m respectively, (at the 1st storey level and the degree of the foundation inclination was 40°). Also, its value decreased by (8% & 25%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 16th storey level and the degree of the foundation inclination was 40°).

The value of the storey drift increased when the storey height increased. As shown in (Figure 4.122, Figure 4.124 & Figure 4.126), the value of storey drift increased by (18% & 52%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 1st storey level and the degree of the foundation inclination was 0°). The value of storey drift increased by (35% & 90%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 16th storey level and the degree of the foundation inclination was 0°). While its value decreased by (41% & 59%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 1st storey level and the degree of the foundation inclination was 40°). Also, its value increased by (49% & 126%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 16th storey level and the degree of the foundation inclination was 40°).

The Results of Storey Drift When the No. of Storeys were 8:

Case I:

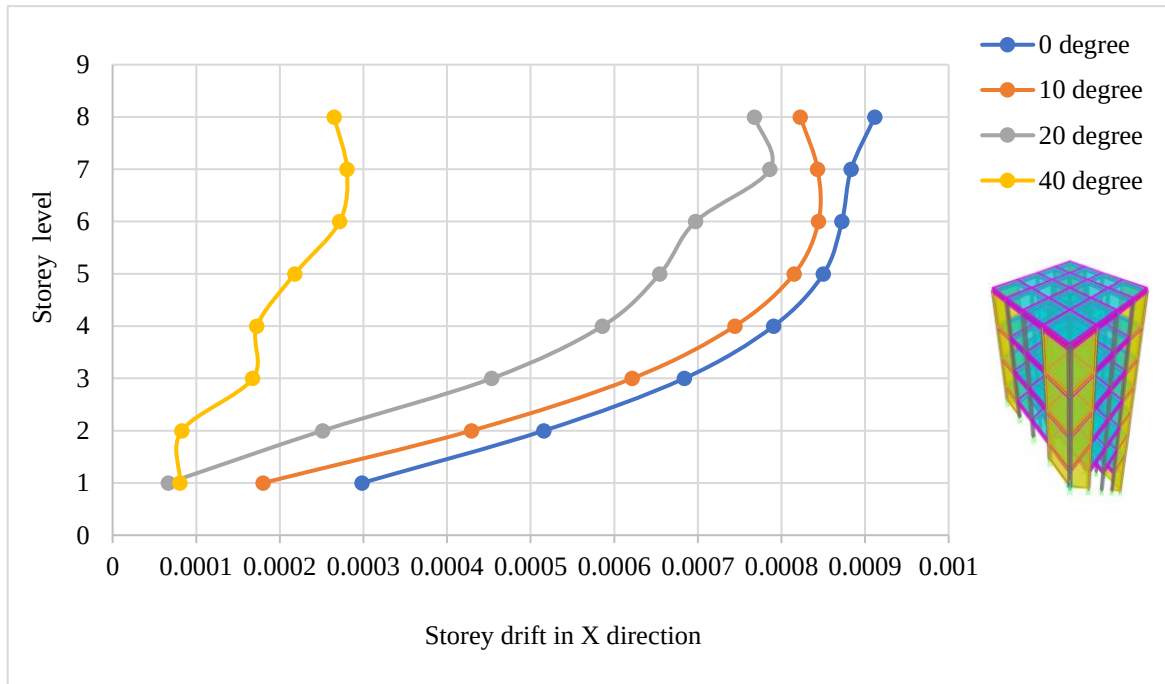


Figure 4.98: Storey Drift in X Direction When the No. of Storeys were 8 (case I).

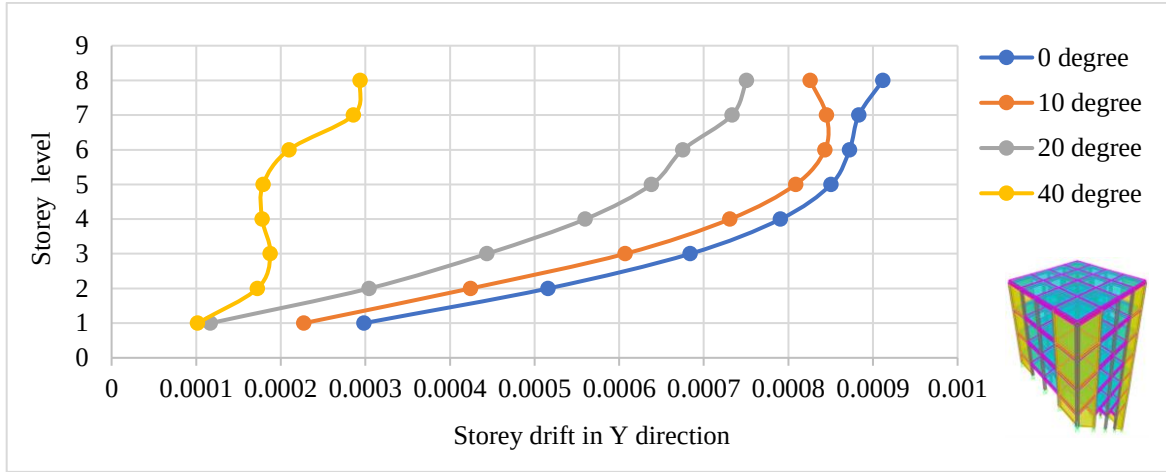


Figure 4.99: Storey Drift in Y Direction When the No. of Storeys were 8 (case I).

Case II:

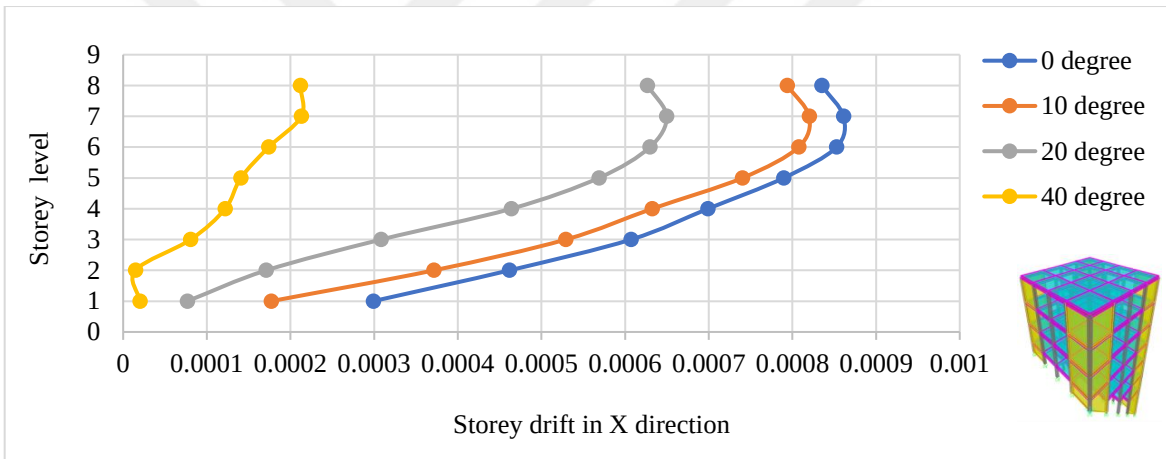


Figure 4.100: Storey Drift in X Direction When the No. of Storeys were 8 (case II).

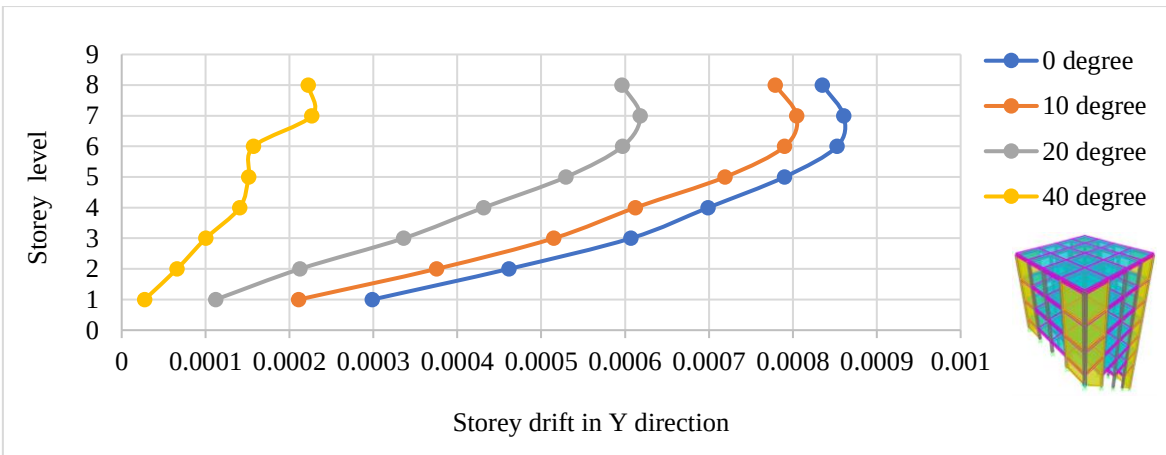


Figure 4.101: Storey Drift in Y Direction When the No. of Storeys were 8 (case II).

Case III:

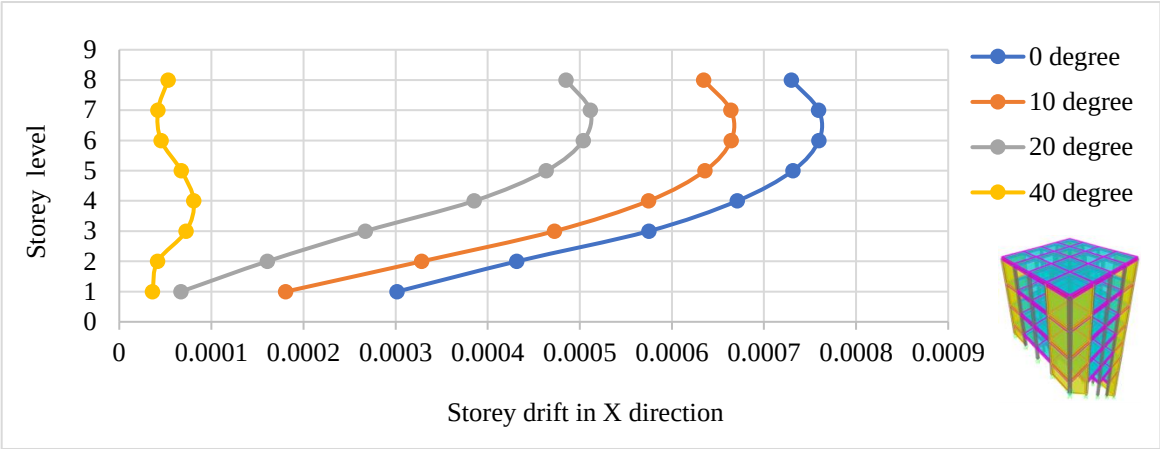


Figure 4.102: Storey Drift in X Direction When the No. of Storeys were 8 (case III).

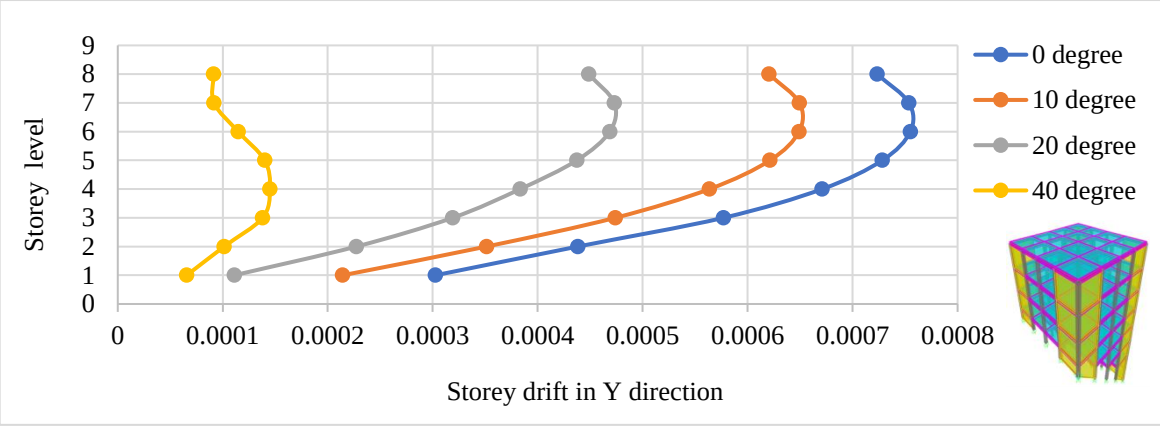


Figure 4.103: Storey Drift in Y Direction When the No. of Storeys were 8 (case III).

Case IV:

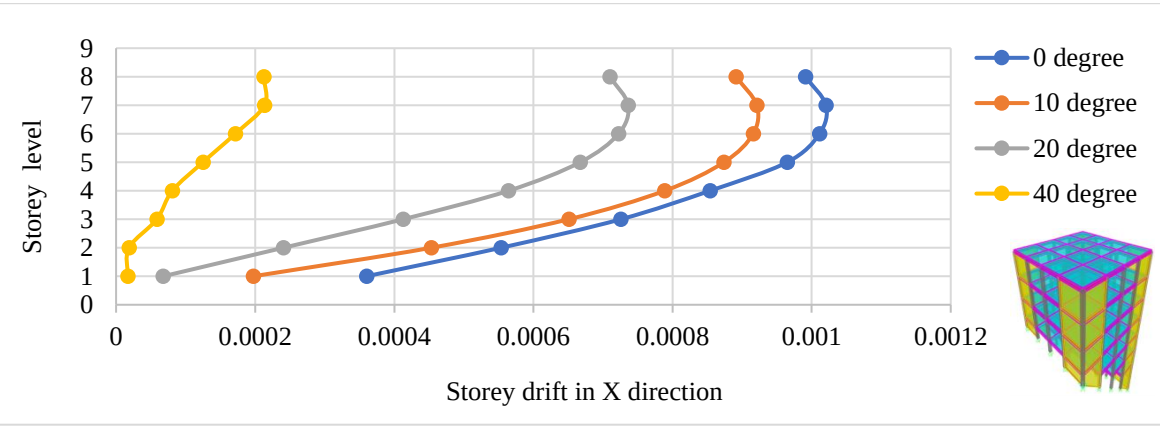


Figure 4.104: Storey Drift in X Direction When the No. of Storeys were 8 (case IV).

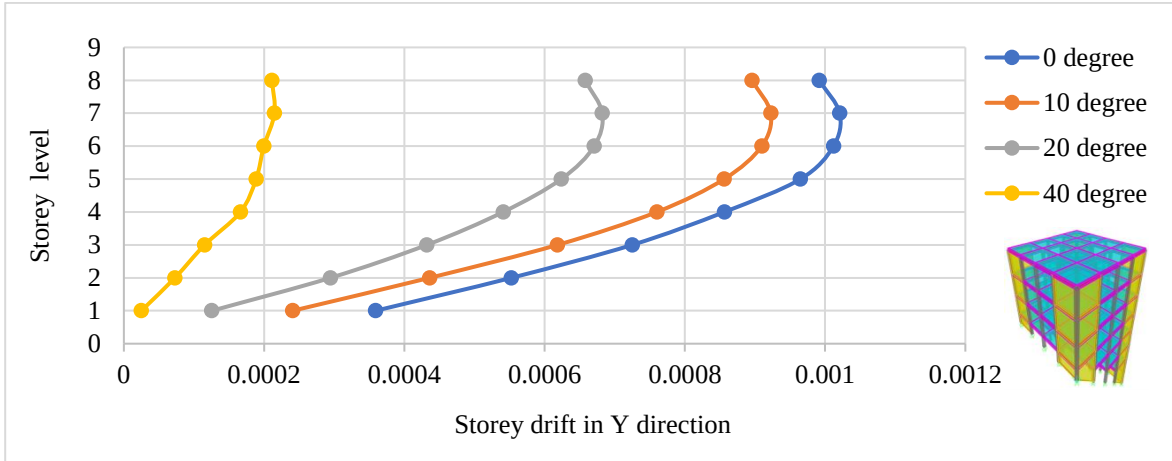


Figure 4.105: Storey Drift in Y Direction When the No. of Storeys were 8 (case IV).

Case V:

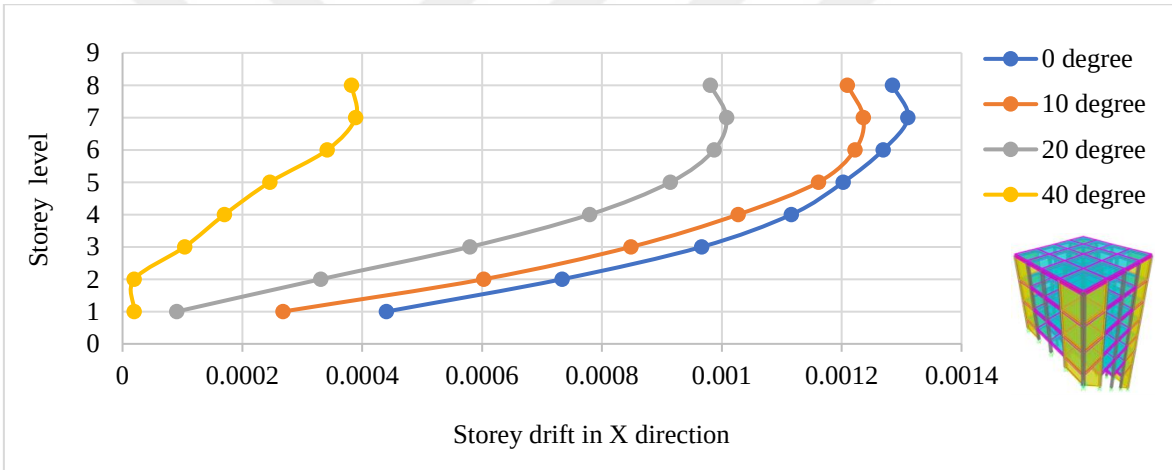


Figure 4.106: Storey Drift in X Direction When the No. of Storeys were 8 (case V).

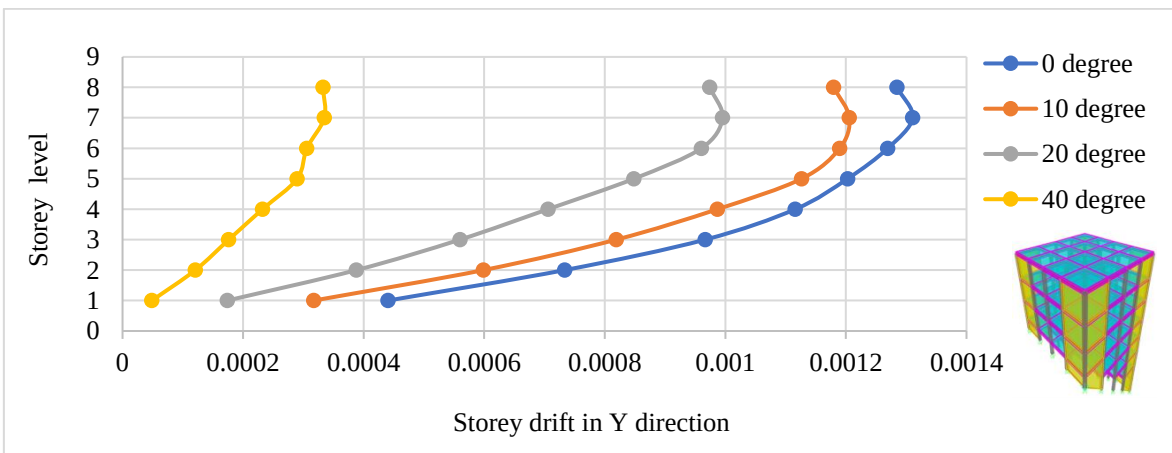


Figure 4.107: Storey Drift in Y Direction When the No. of Storeys were 8 (case V).

The Results of Storey Drift When the No. of Storeys were 12:

Case I:

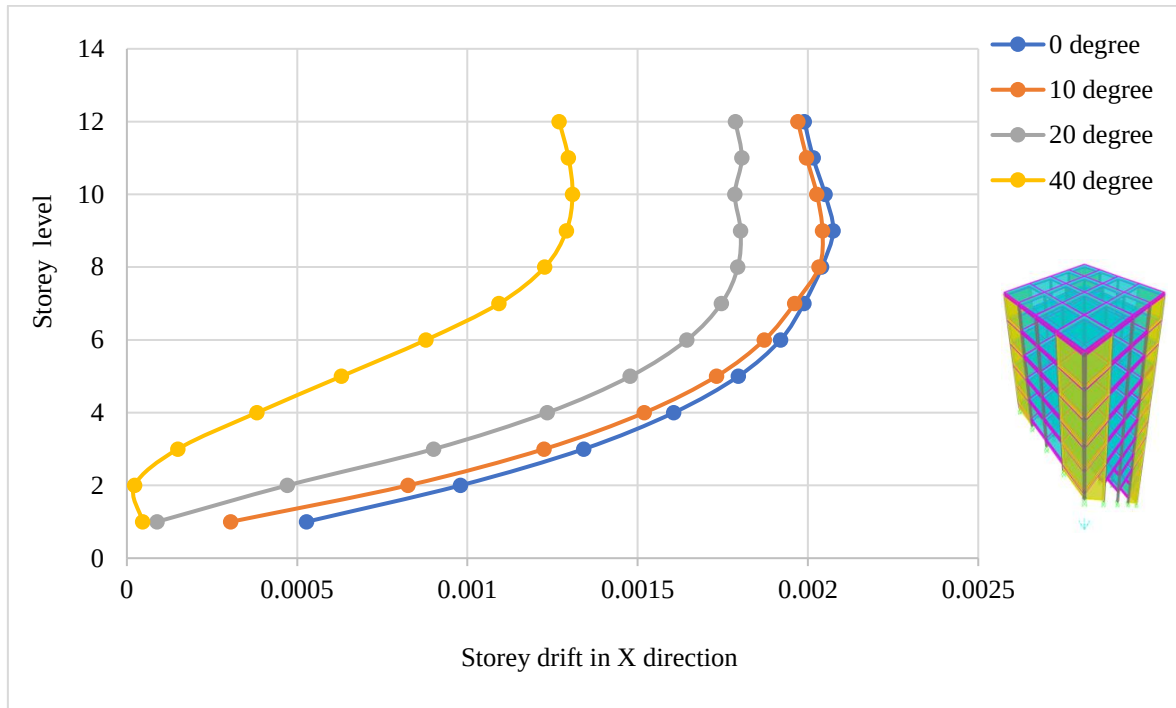


Figure 4.108: Storey Drift in X Direction When the No. of Storeys were 12 (case I).

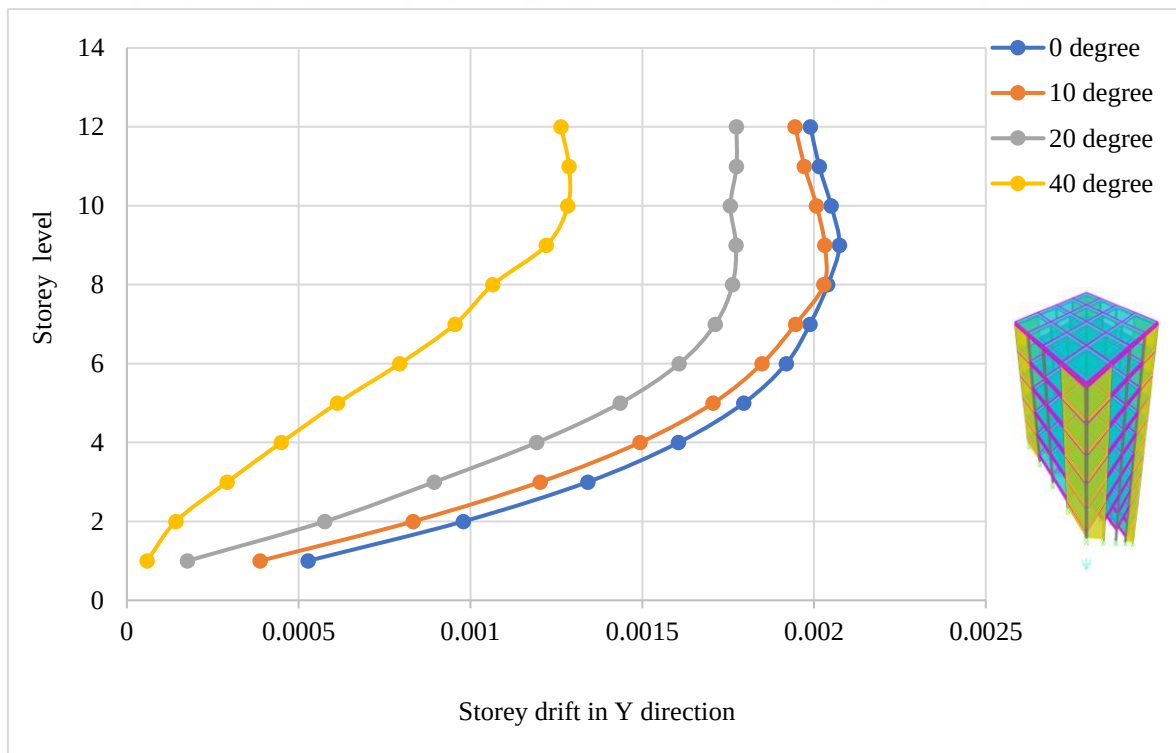


Figure 4.109: Storey Drift in Y Direction When the No. of Storeys were 12 (case I).

Case II:

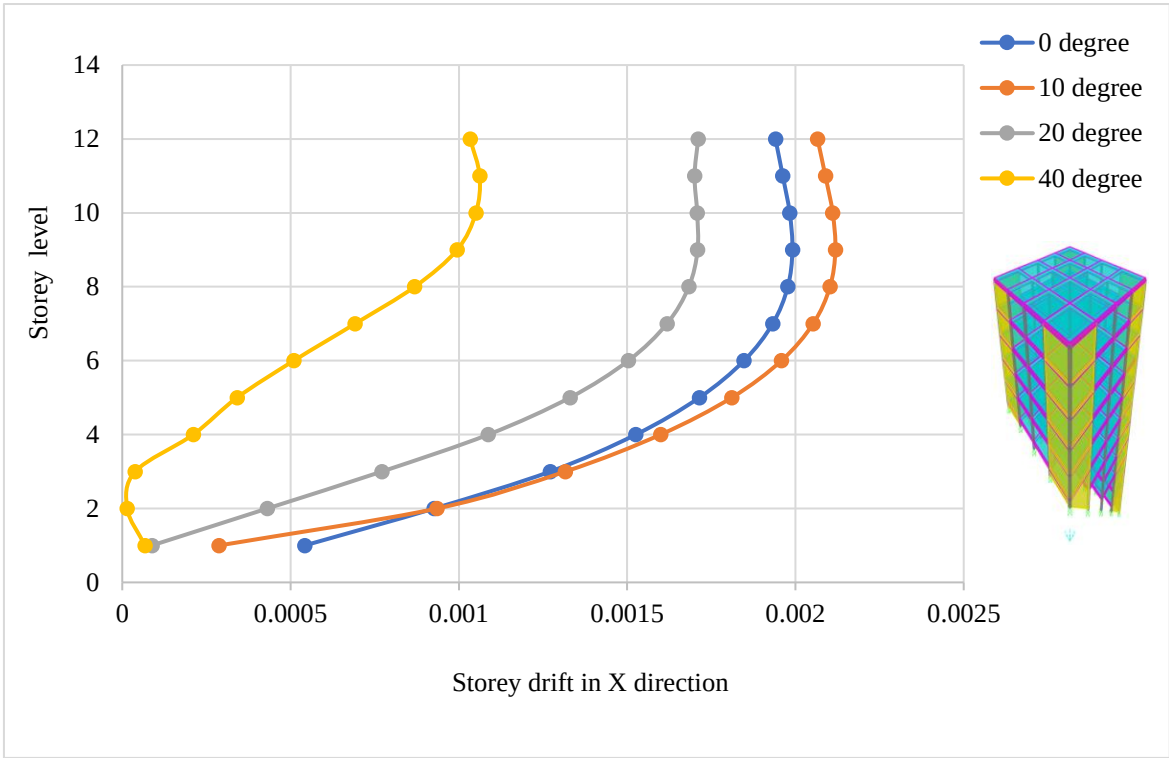


Figure 4.110: Storey Drift in X Direction When the No. of Storeys were 12 (case II).

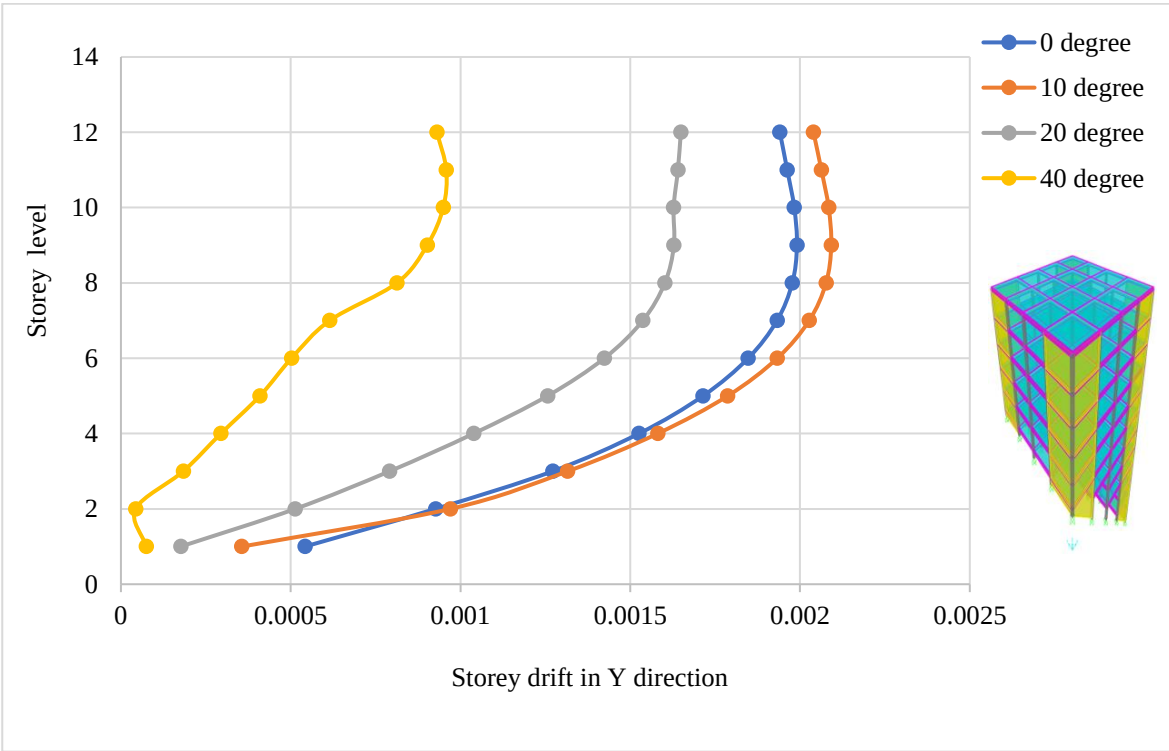


Figure 4.111: Storey Drift in Y Direction When the No. of Storeys were 12 (case II).

Case III:

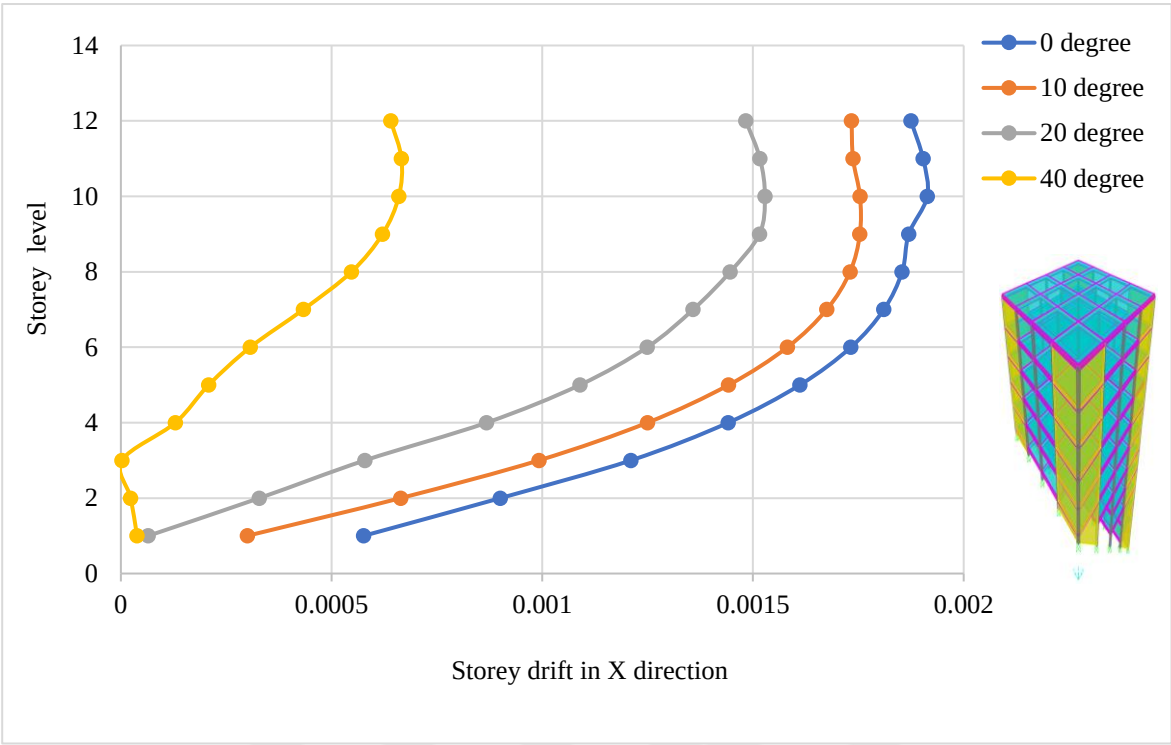


Figure 4.112: Storey Drift in X Direction When the No. of Storeys were 12 (case III).

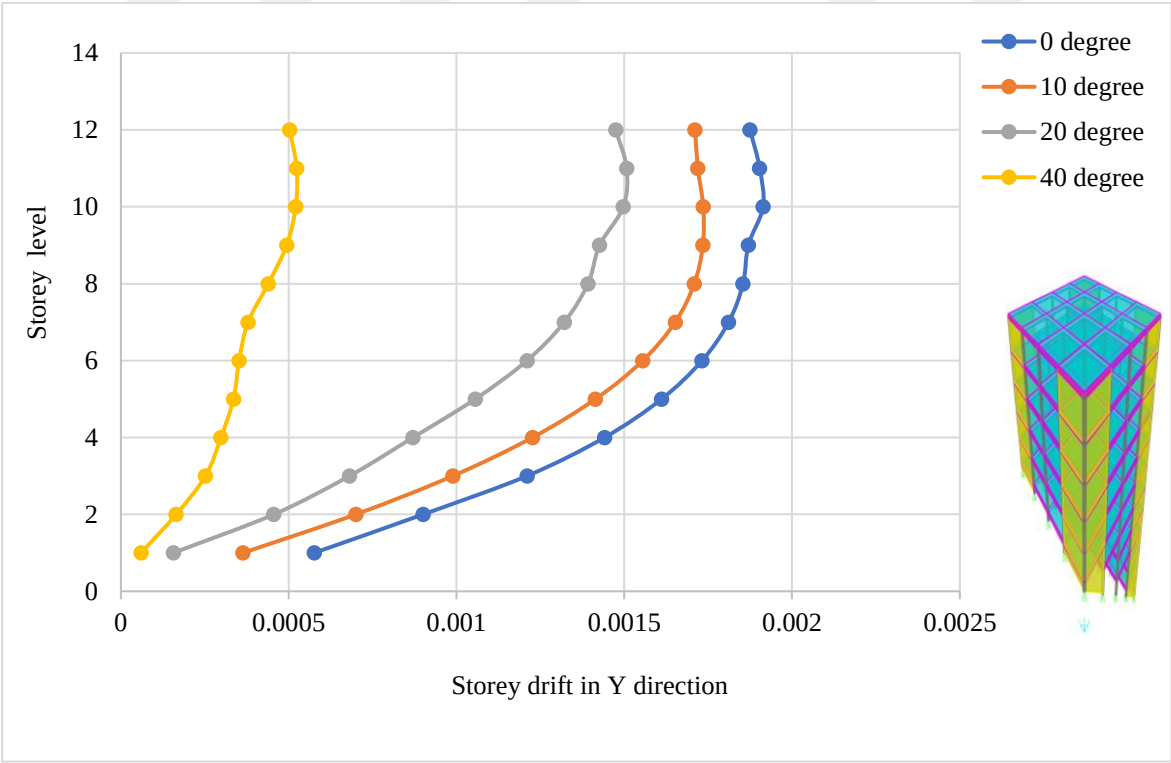


Figure 4.113: Storey Drift in Y Direction When the No. of Storeys were 12 (case III).

Case IV:

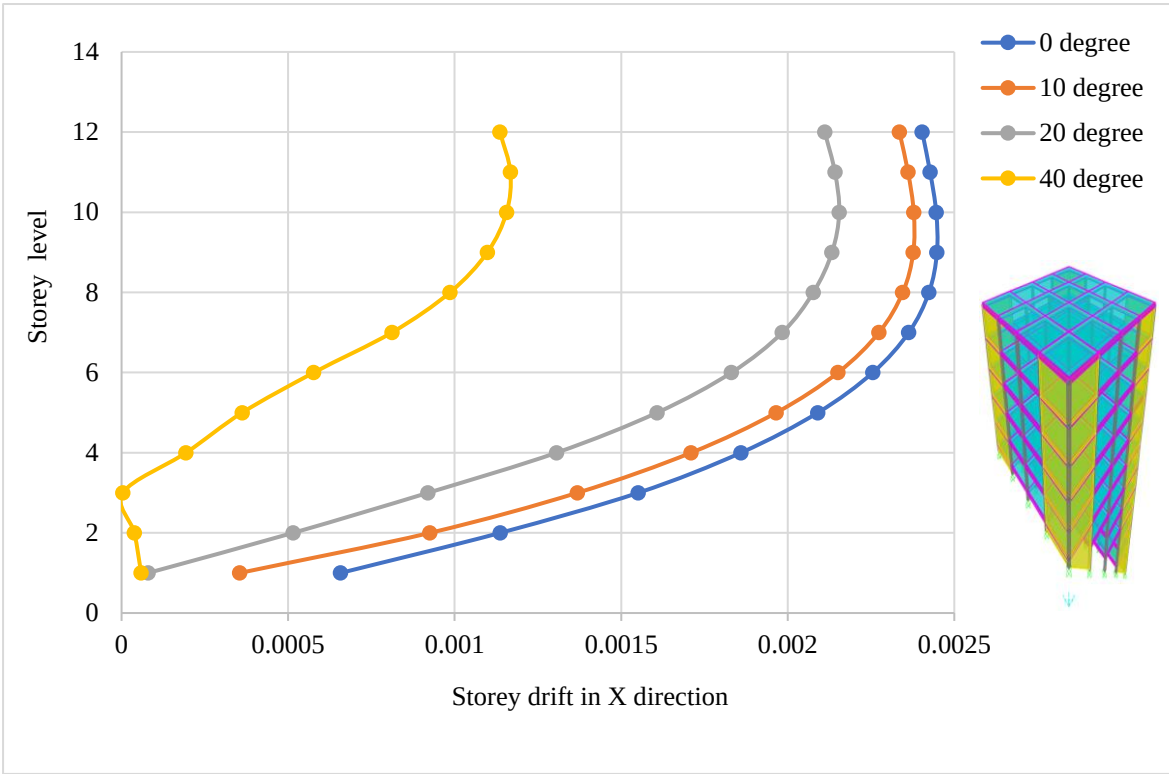


Figure 4.114: Storey Drift in X Direction When the No. of Storeys were 12 (case IV).

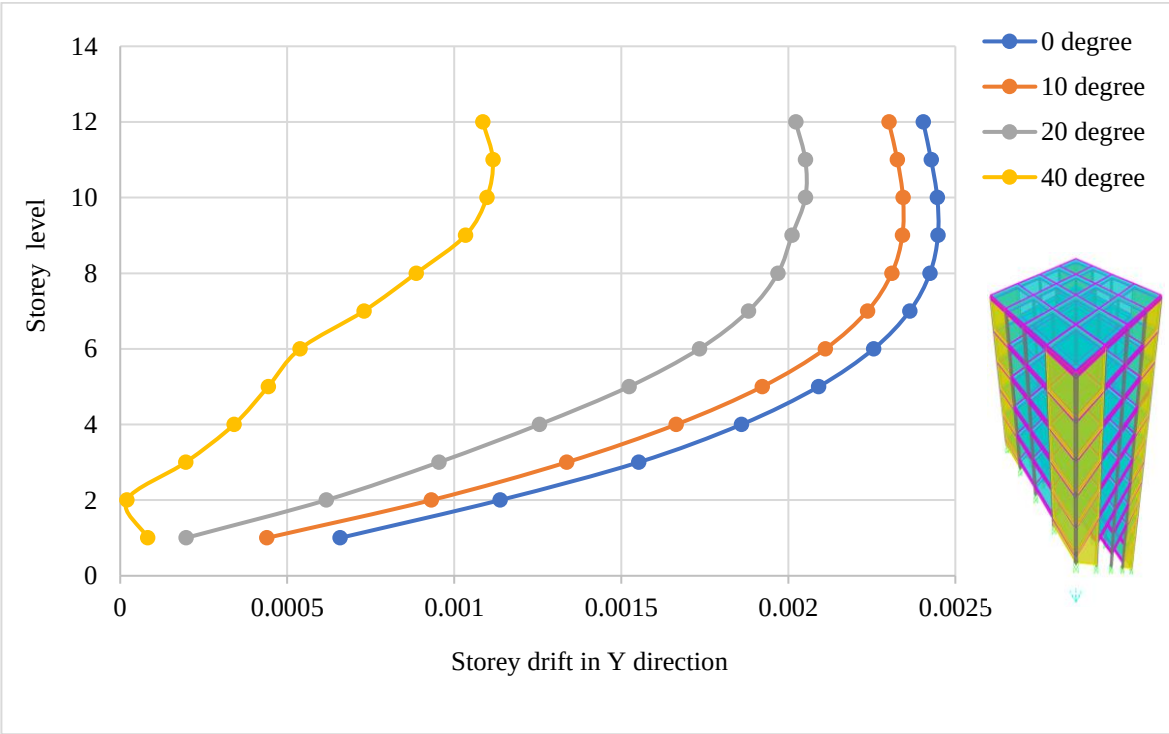


Figure 4.115: Storey Drift in Y Direction When the No. of Storeys were 12 (case IV).

Case V:

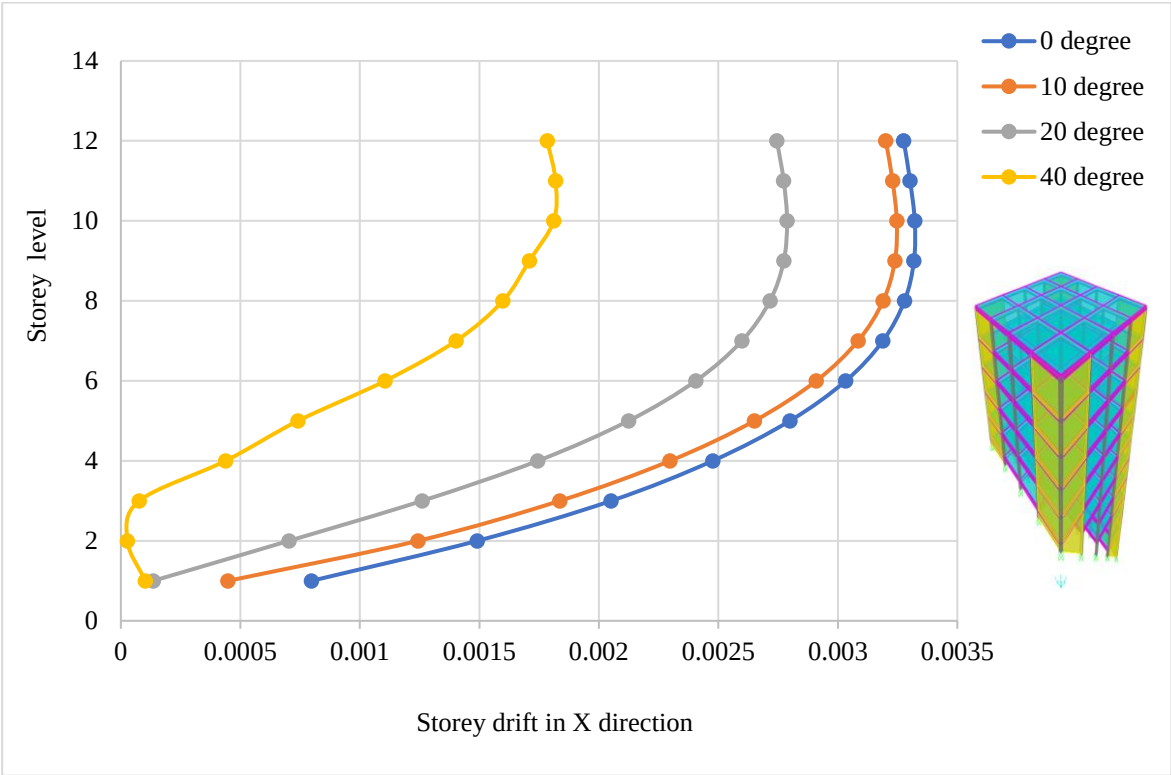


Figure 4.116: Storey Drift in X Direction When the No. of Storeys were 12 (case V).

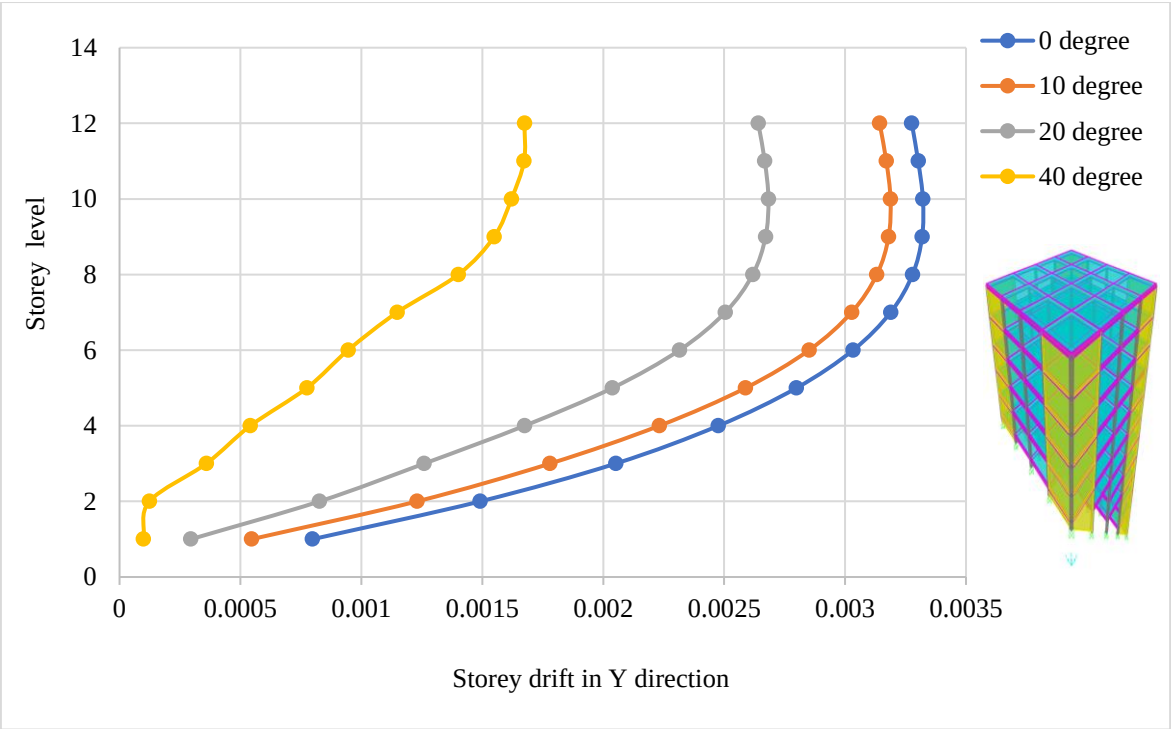


Figure 4.117: Storey Drift in Y Direction When the No. of Storeys were 12 (case V).

The Results of Storey Drift When the No. of Storeys were 16:

Case I:

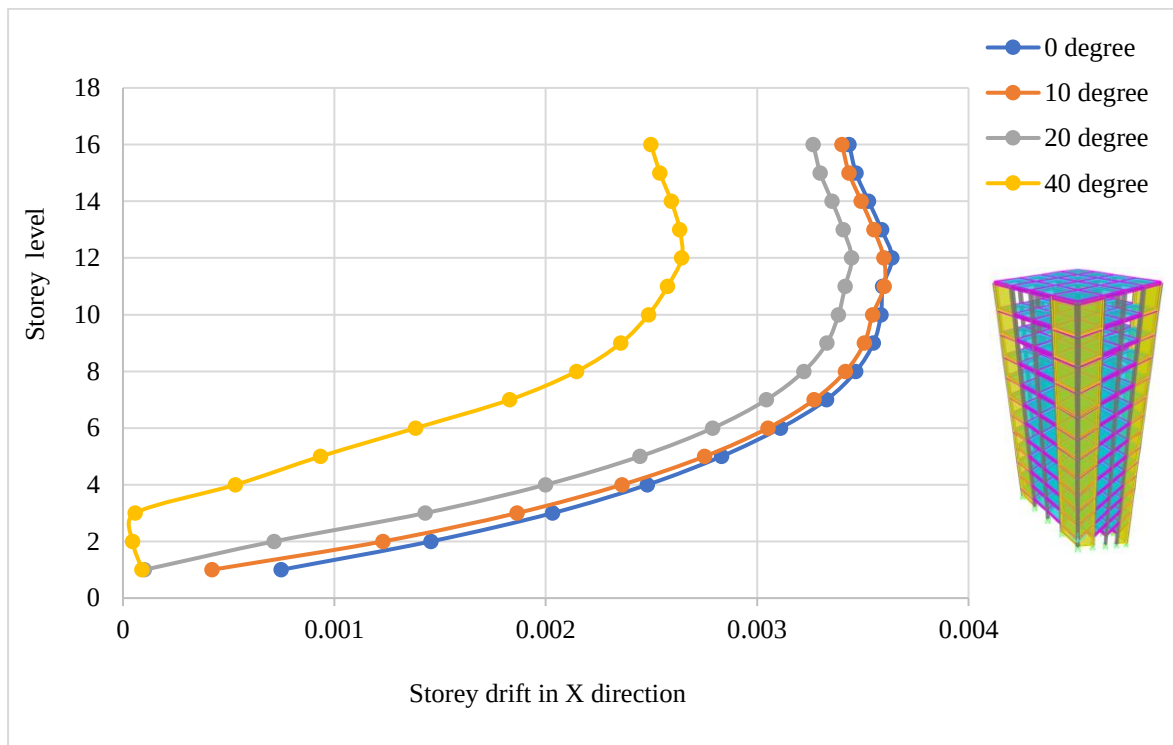


Figure 4.118: Storey Drift in X Direction When the No. of Storeys were 16 (case I).

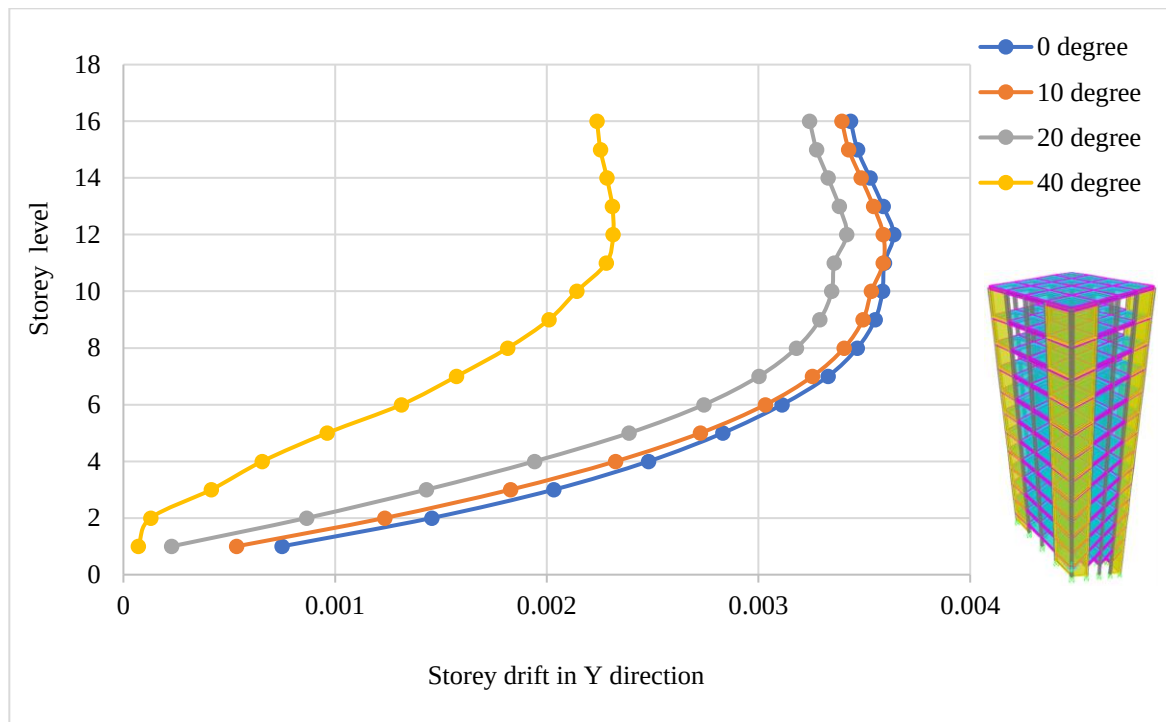


Figure 4.119: Storey Drift in Y Direction When the No. of Storeys were 16 (case I).

Case II:

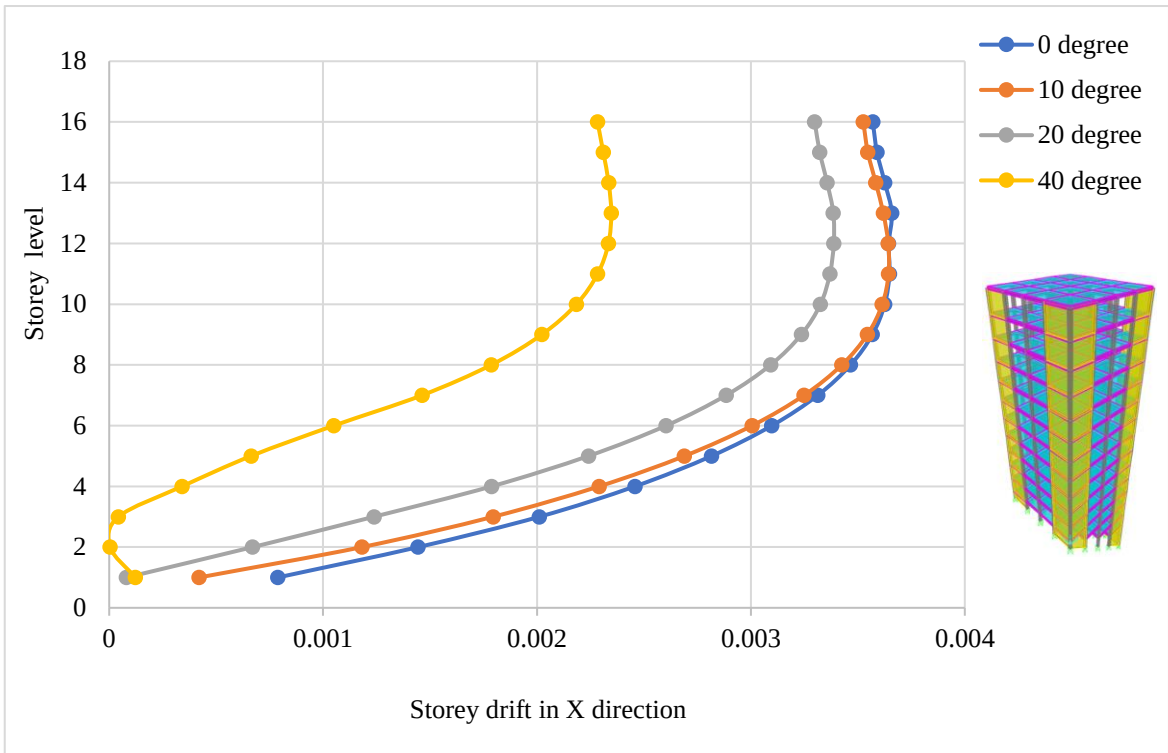


Figure 4.120: Storey Drift in X Direction When the No. of Storeys were 16 (case II).

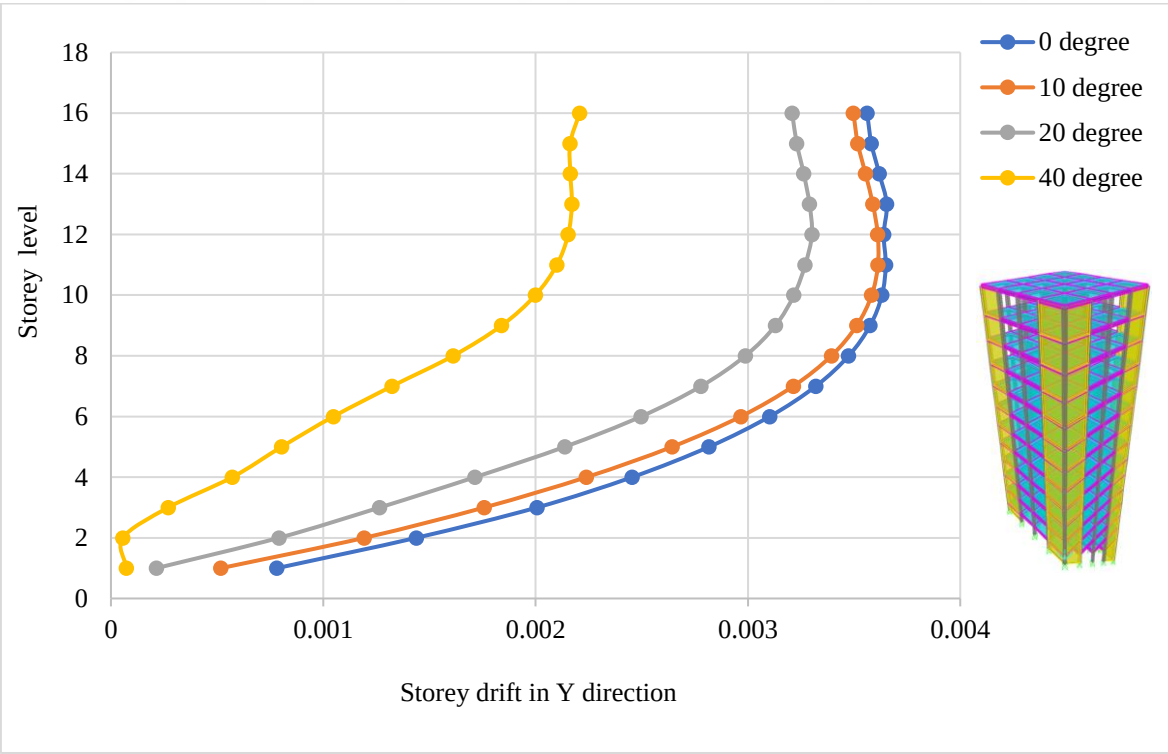


Figure 4.121: Storey Drift in Y Direction When the No. of Storeys were 16 (case II).

Case III:

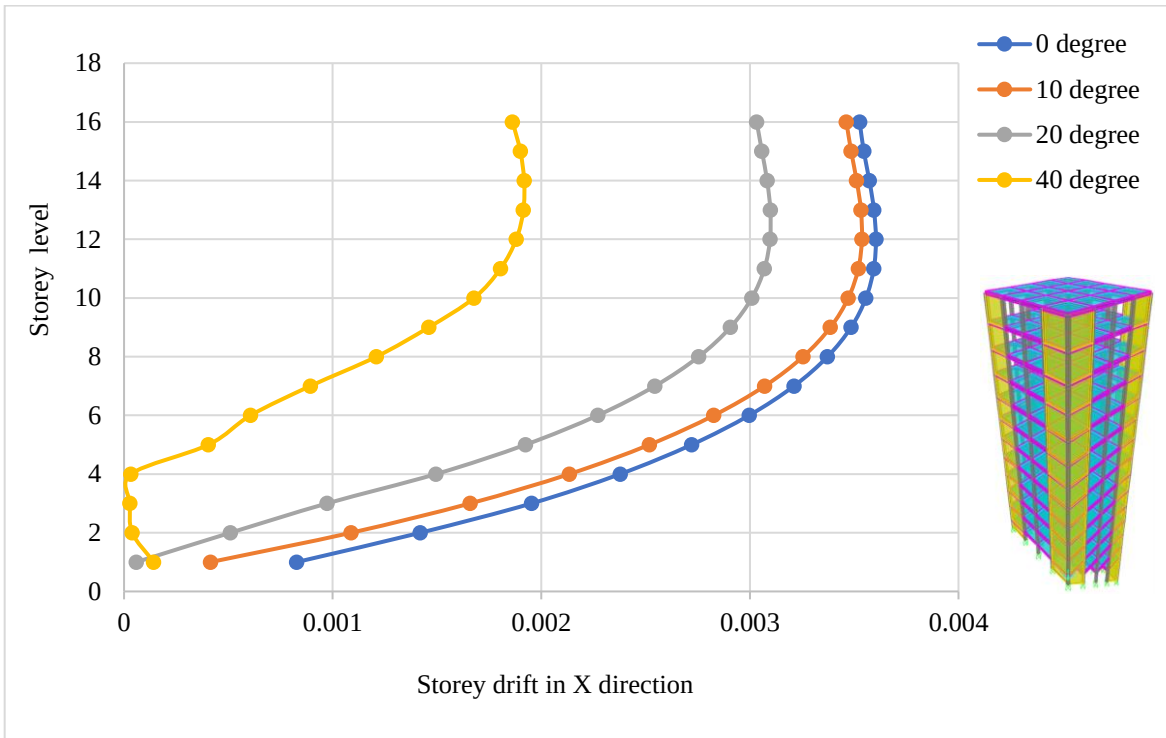


Figure 4.122: Storey Drift in X Direction When the No. of Storeys were 16 (case III).

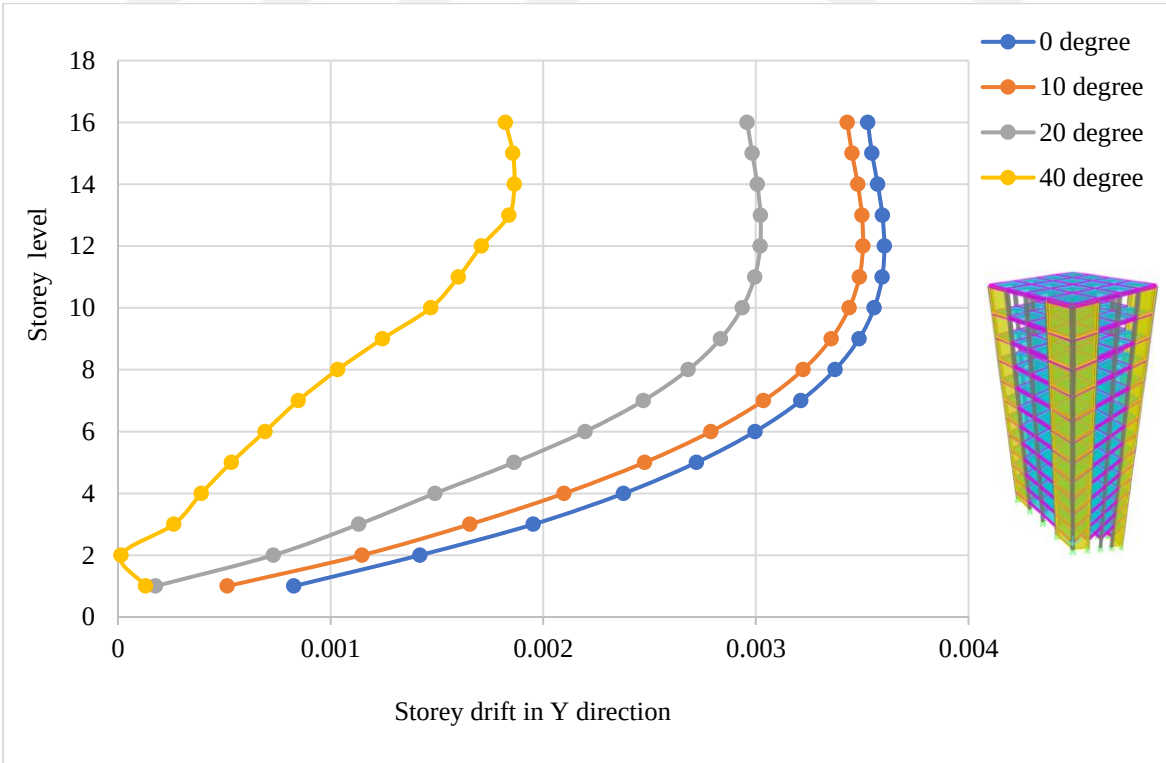


Figure 4.123: Storey Drift in Y Direction When the No. of Storeys were 16 (case III).

Case IV:

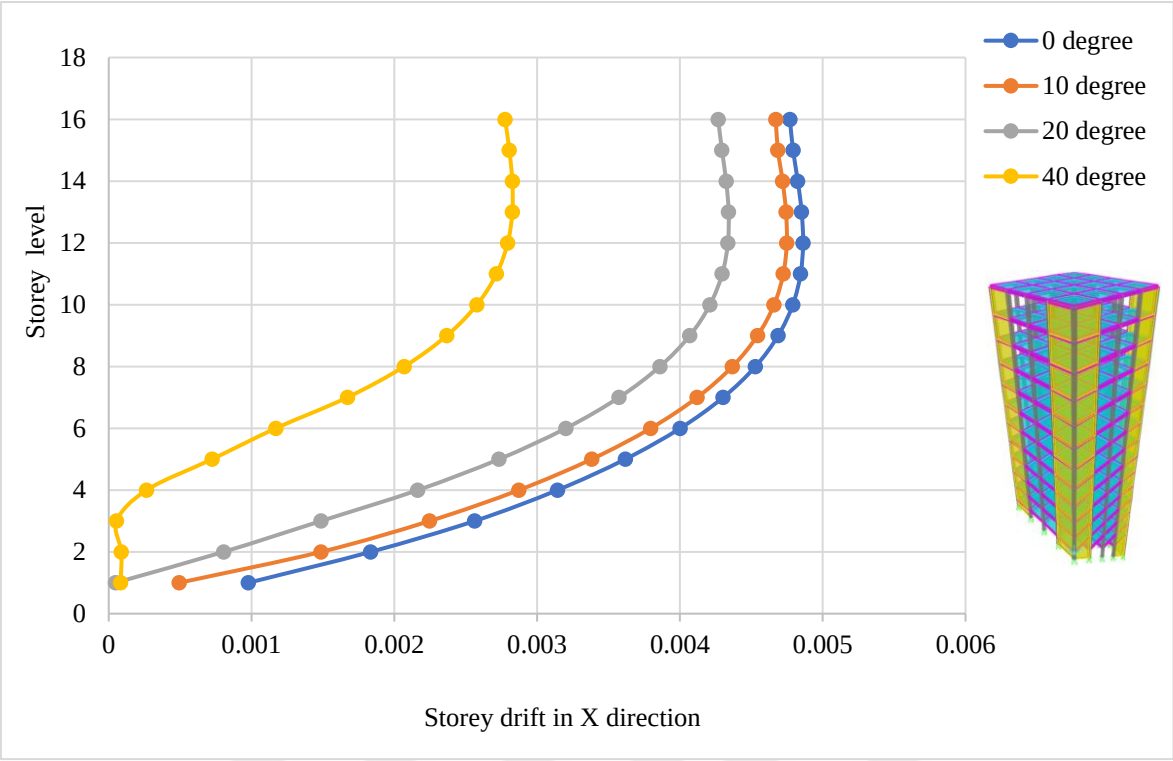


Figure 4.124: Storey Drift in X Direction When the No. of Storeys were 16 (case IV).

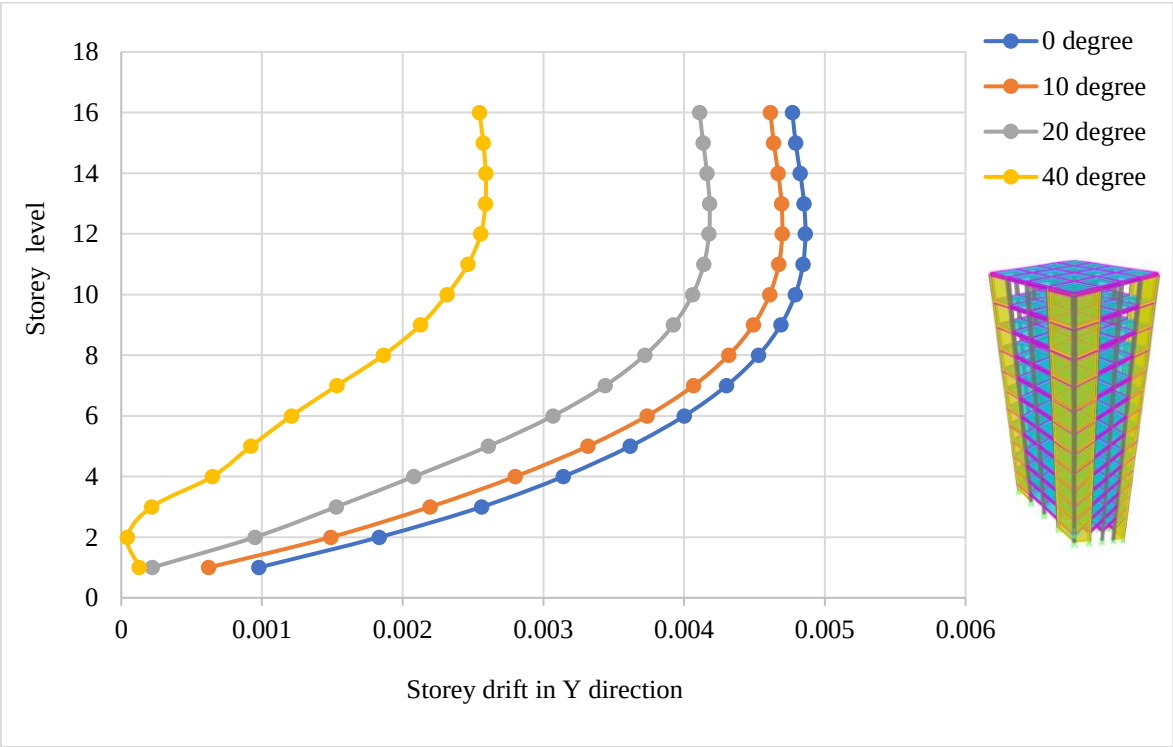


Figure 4.125: Storey Drift in Y Direction When the No. of Storeys were 16 (case IV).

Case V:

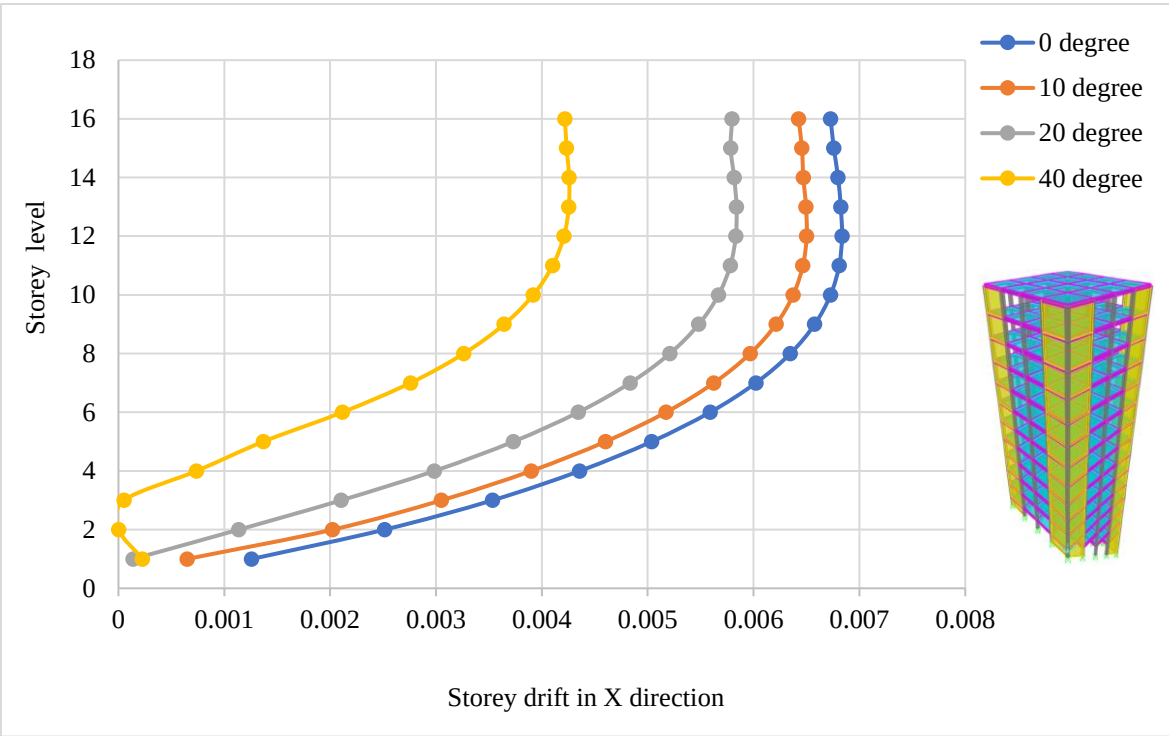


Figure 4.126: Storey Drift in X Direction When the No. of Storeys were 16 (case V).

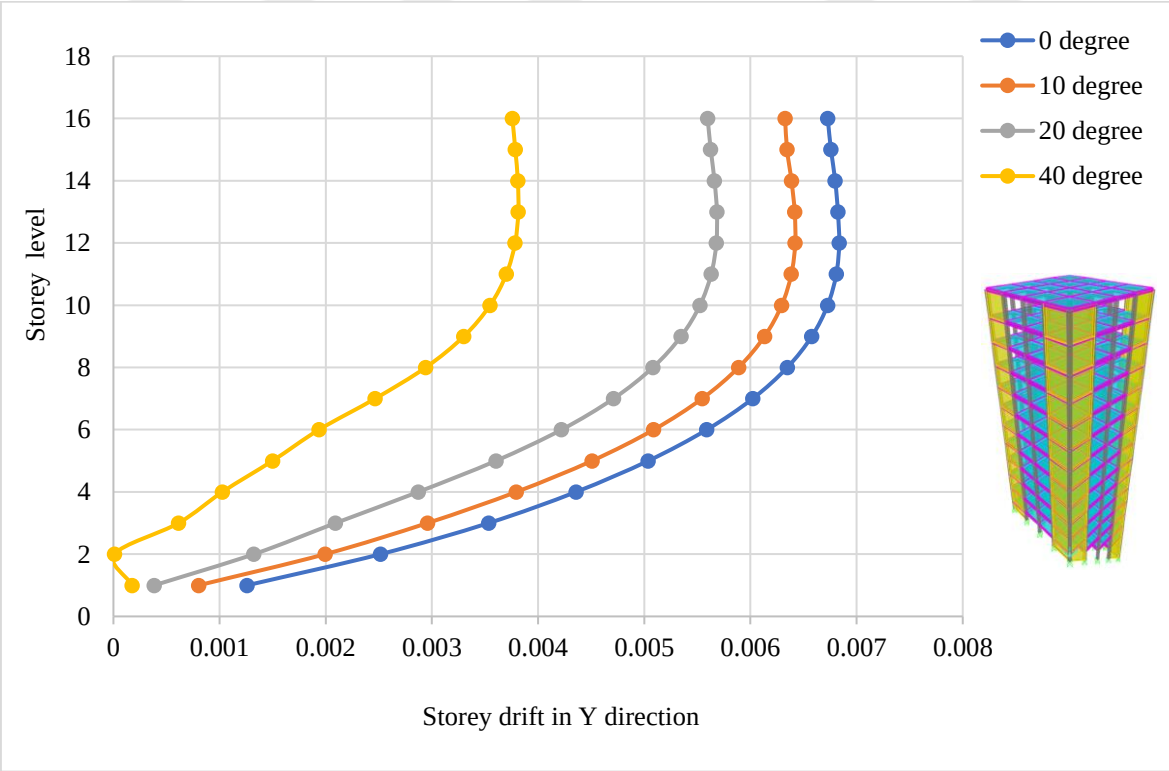


Figure 4.127: Storey Drift in Y Direction When the No. of Storeys were 16 (case V).

The Results of Storey Drift When the No. of Storeys were 20:

Case I:

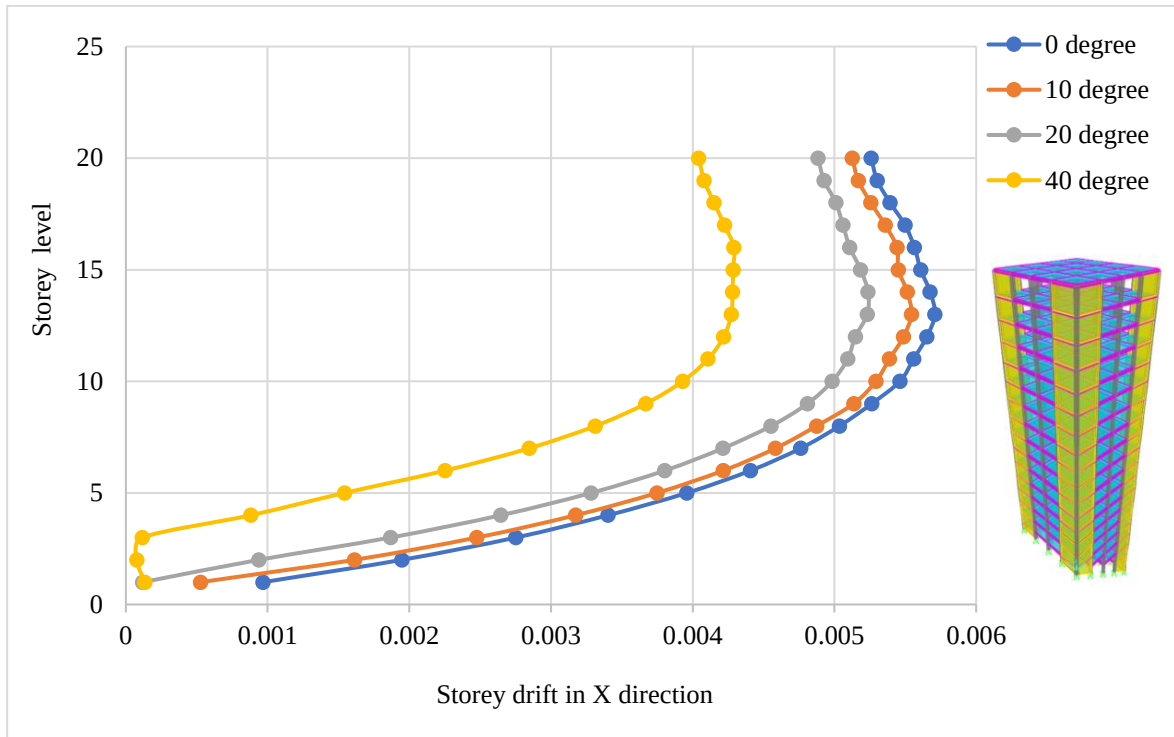


Figure 4.128: Storey Drift in X Direction When the No. of Storeys were 20 (case I).

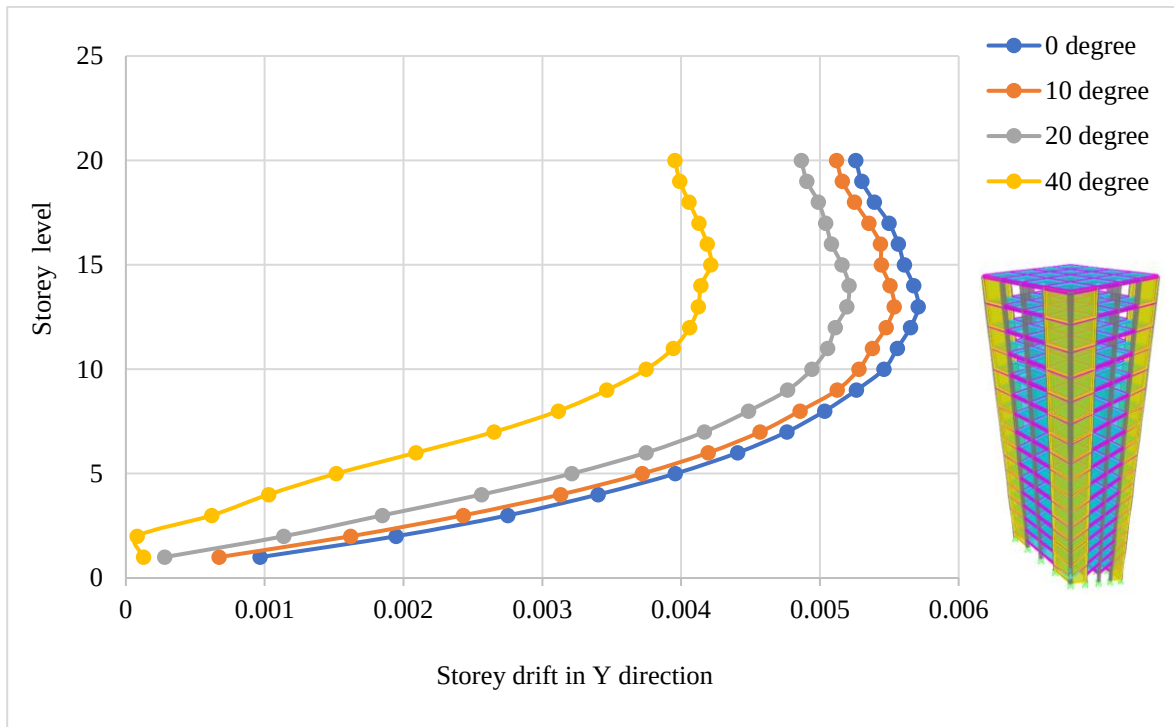


Figure 4.129: Storey Drift in Y Direction When the No. of Storeys were 20 (case I).

Case II:

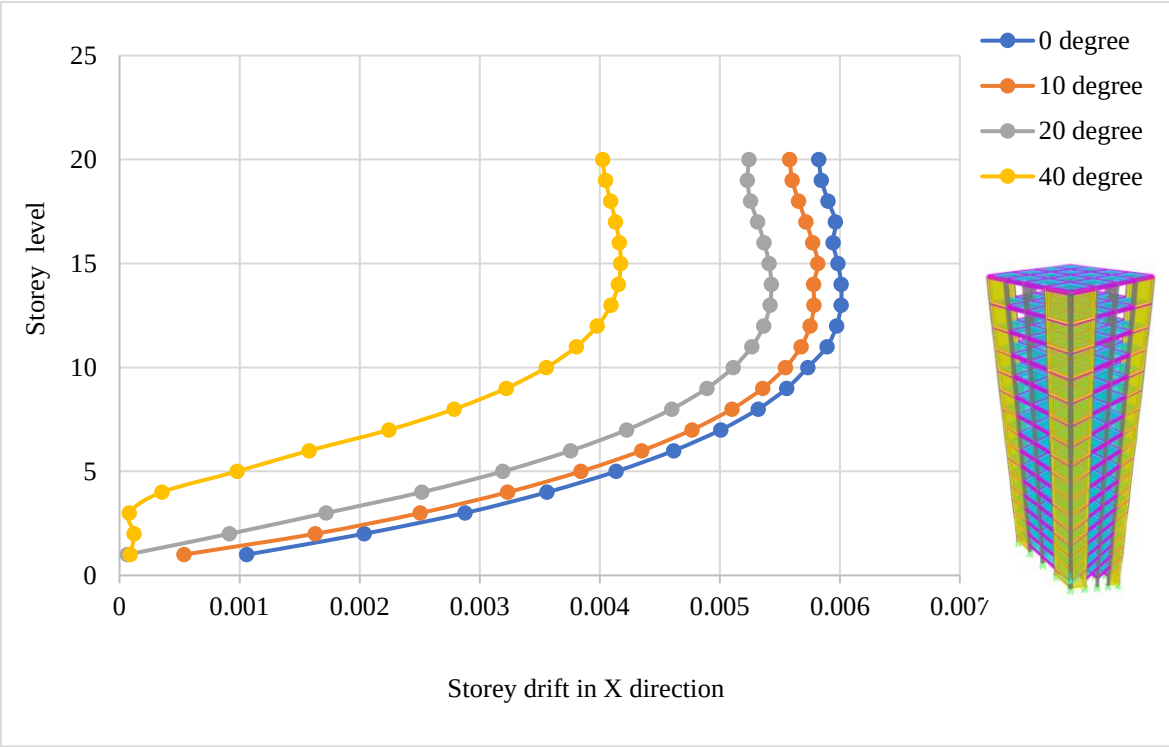


Figure 4.130: Storey Drift in X Direction When the No. of Storeys were 20 (case II).

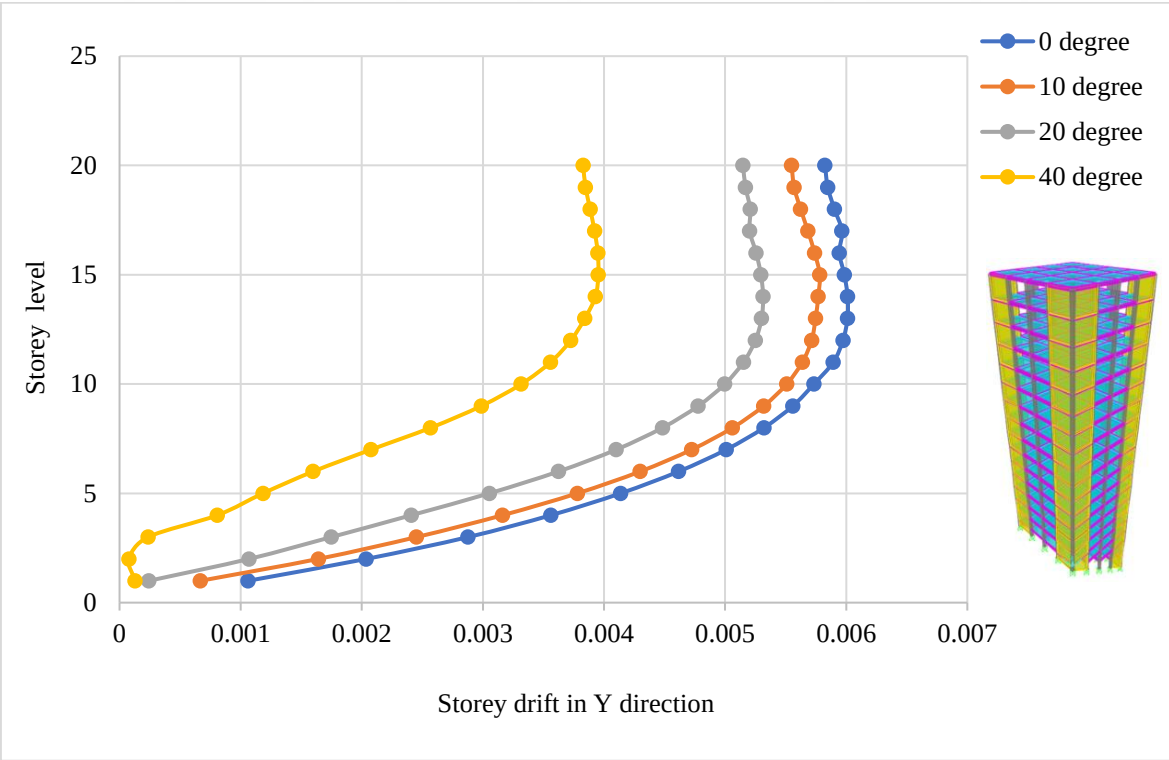


Figure 4.131: Storey Drift in Y Direction When the No. of Storeys were 20 (case II).

Case III:

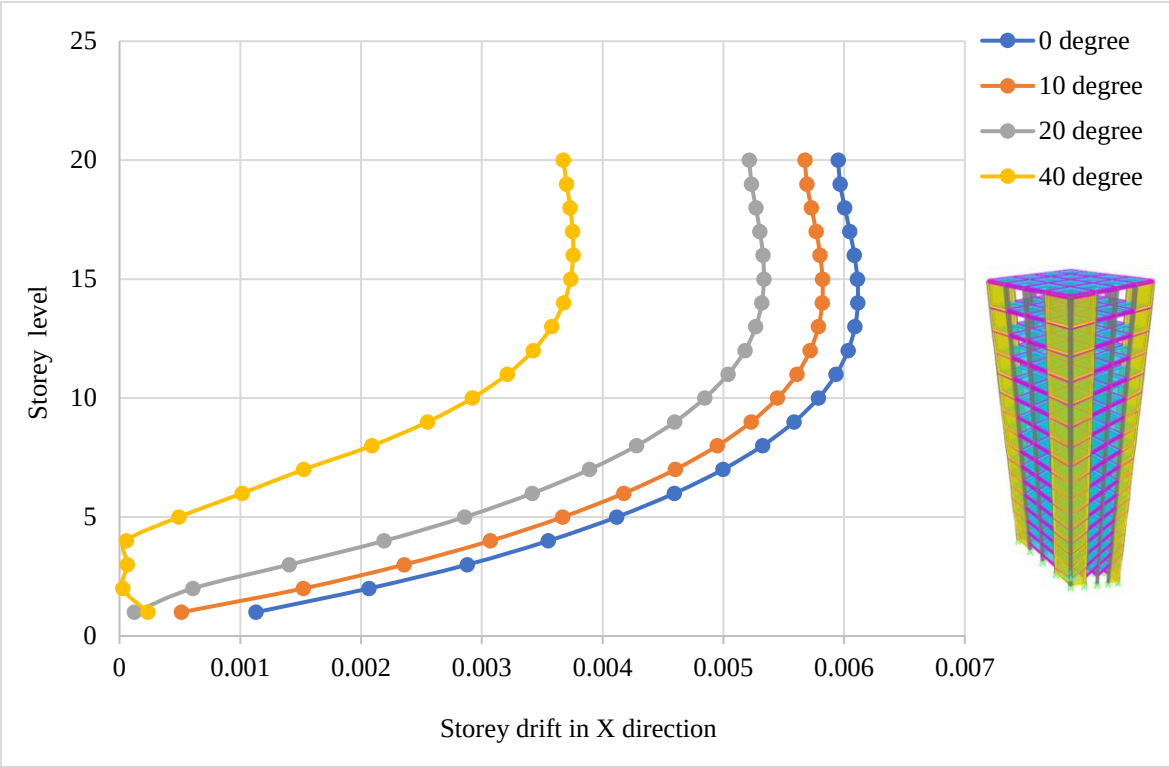


Figure 4.132: Storey Drift in X Direction When the No. of Storeys were 20 (case III).

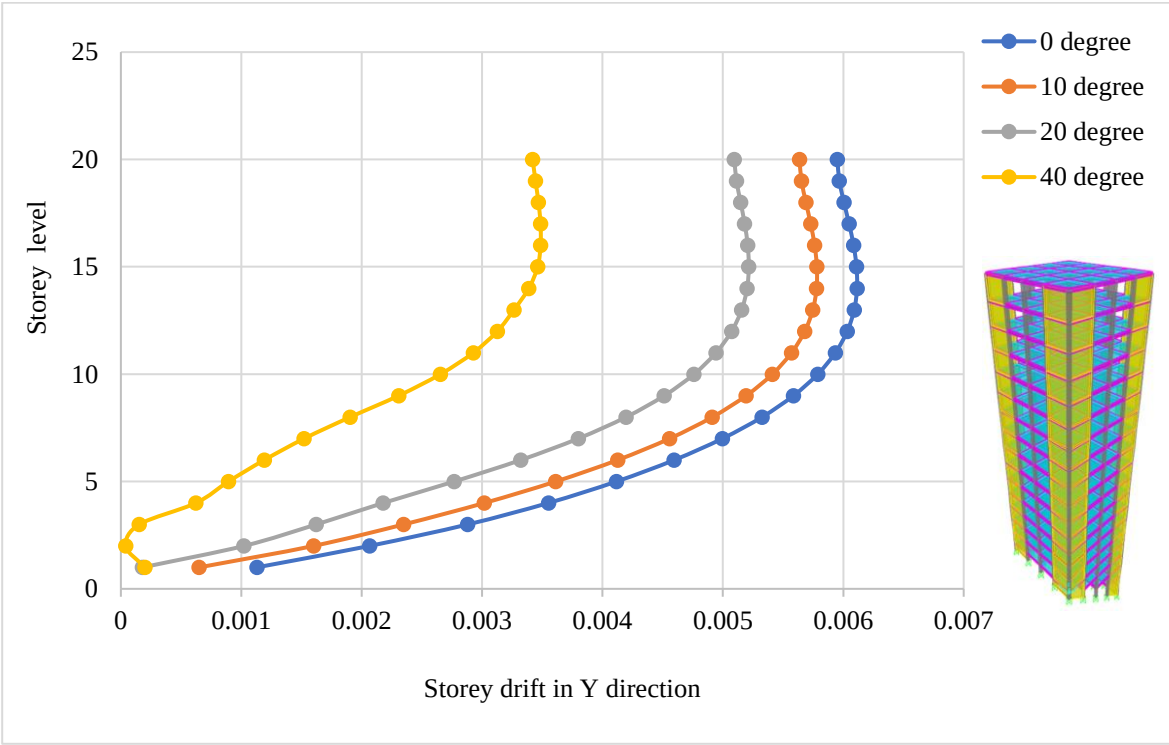


Figure 4.133: Storey Drift in Y Direction When the No. of Storeys were 20 (case III).

Case IV:

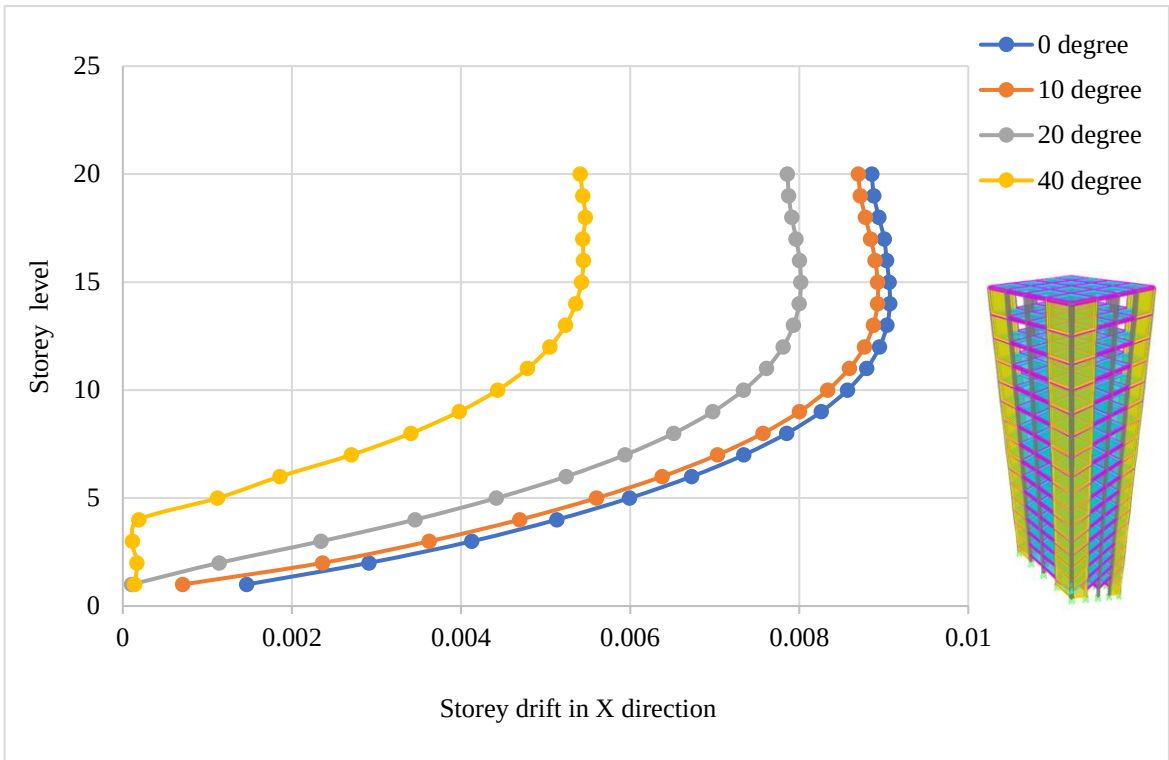


Figure 4.134: Storey Drift in X Direction When the No. of Storeys were 20 (case IV).

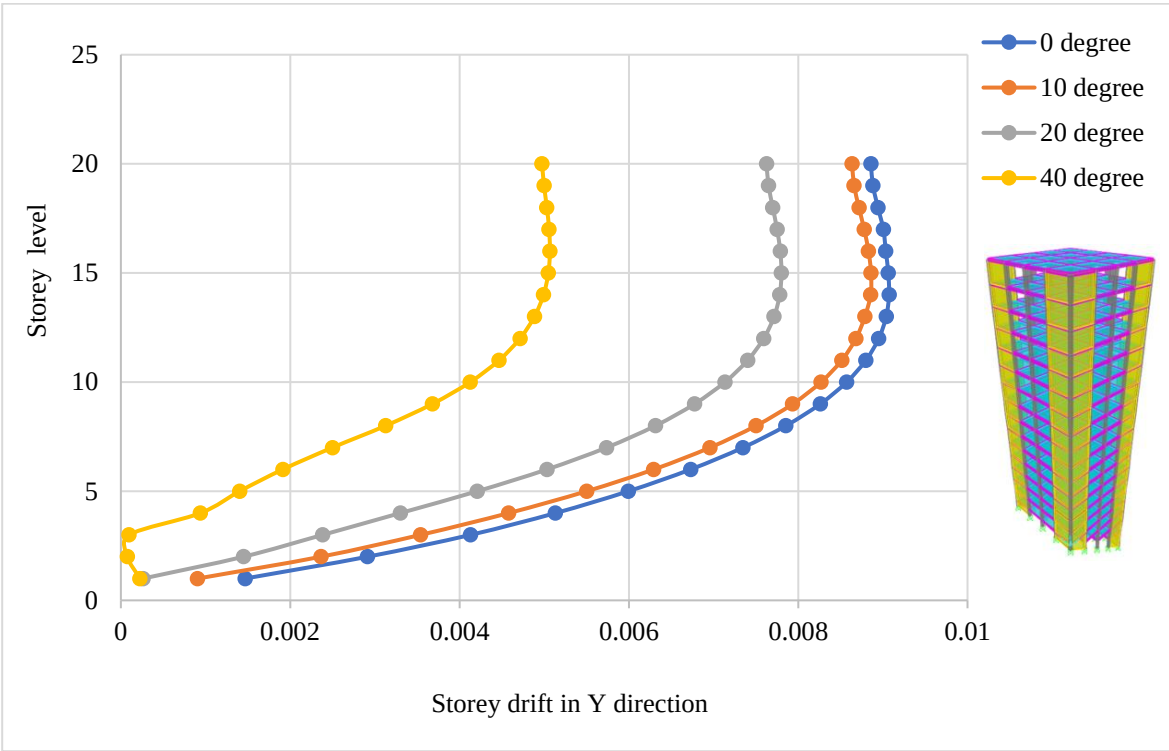


Figure 4.135: Storey Drift in Y Direction When the No. of Storeys were 20 (case IV).

Case V:

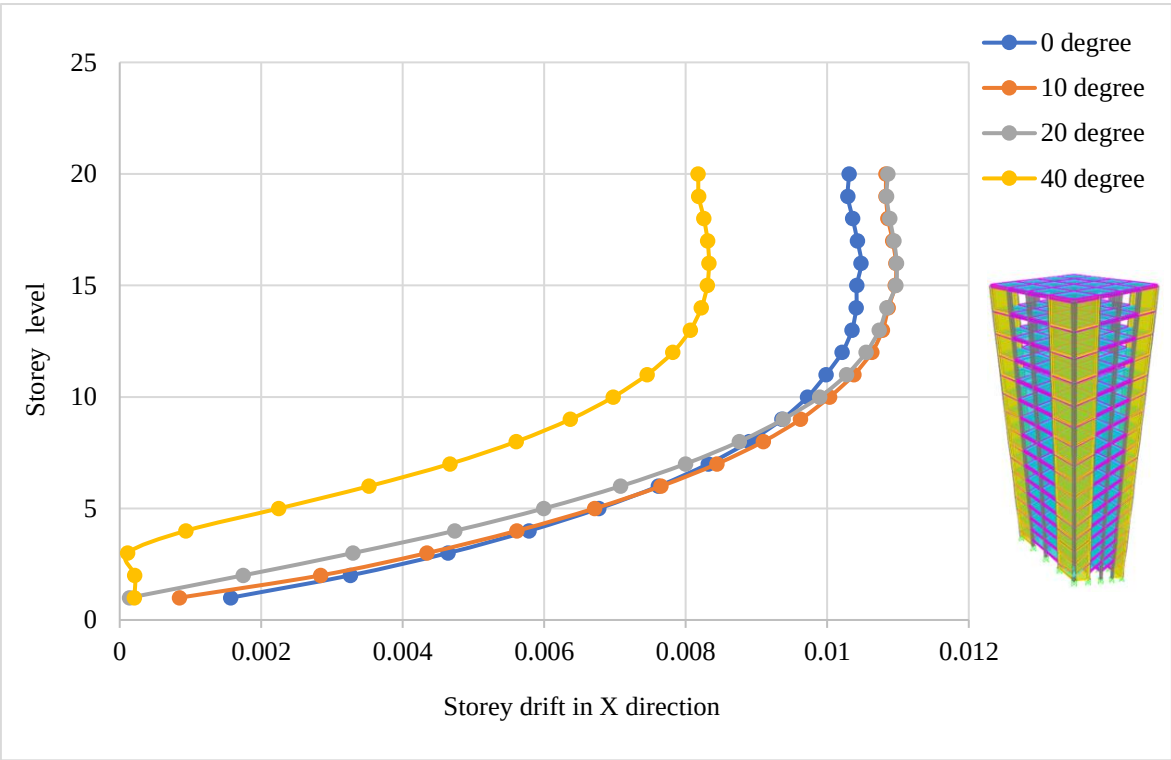


Figure 4.136: Storey Drift in X Direction When the No. of Storeys were 20 (case V).

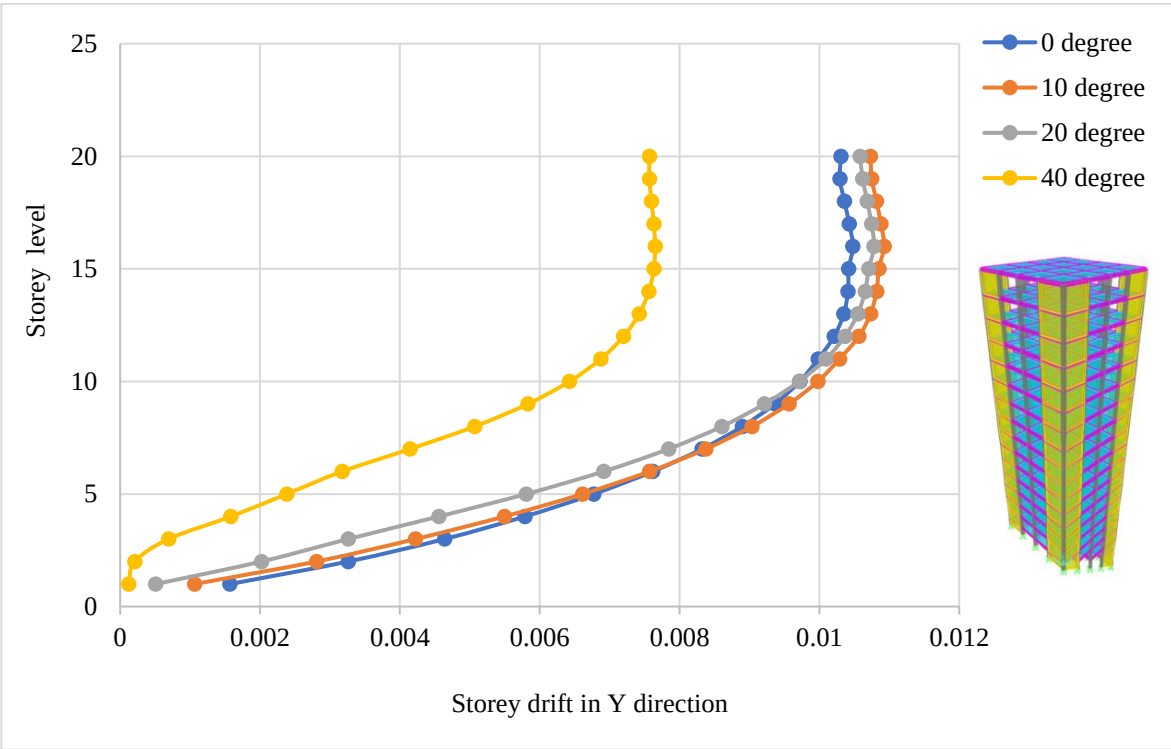


Figure 4.137: Storey Drift in Y Direction When the No. of Storeys were 20 (case V).

4.3.3 Response Spectrum Analyzed of The Buildings

The response spectrum method had been used to analyze the buildings with or without shear walls under the influence of change in the degree of foundation inclination (0° , 10° , 20° & 40°). All buildings had been analyzed when the span width and storey height was (6 m and 3 m) respectively. The response curve had been represented in terms of the displacements and spectral accelerations with time period, as shown in (Figure 4.138 to Figure 4.177) (for more information see section 2.3.2).

4.3.3.1 Response spectrum analyzed of the buildings without shear walls

The response spectrum method had been used to analyze the buildings without shear walls. The displacements values obtained from the response spectrum analysis decreased when the degree of foundation inclination of the building increased. As shown in Figure 4.143, the value of displacements decreased by (69%, 97% & 98%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 2nd storey level. While its value decreased by (10%, 23% & 56%) at the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 12th storey level.

The Results of Response Spectrum Analyzed When the No. of Storeys were 8:

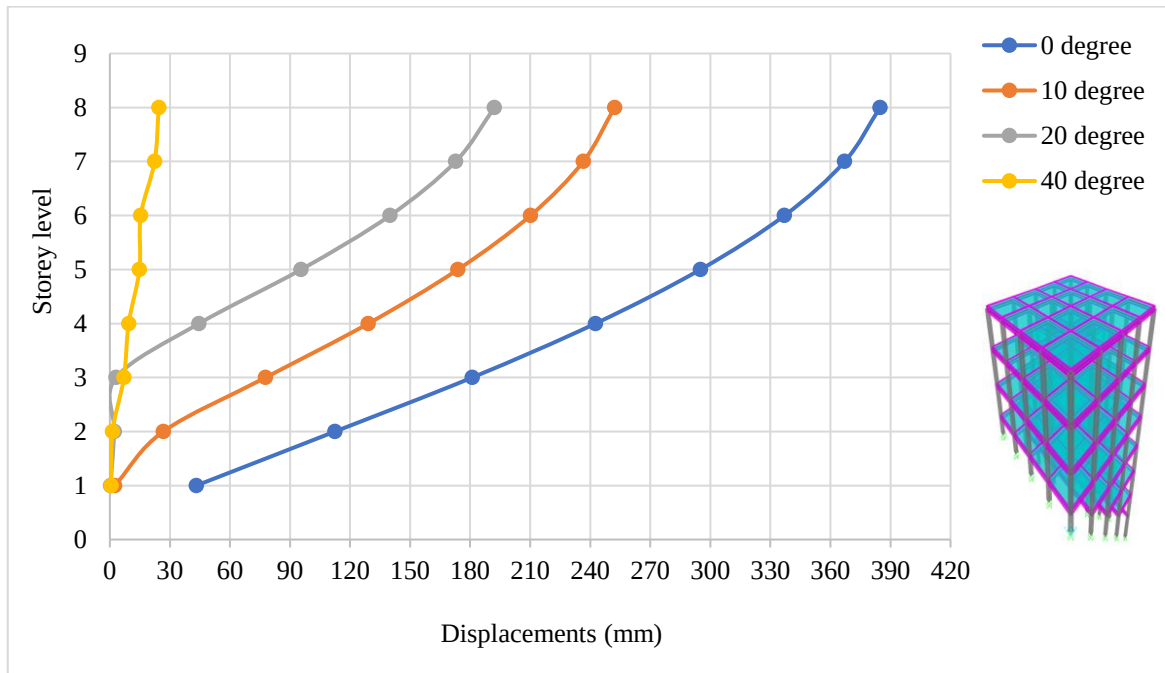


Figure 4.138: Displacements of the Buildings without Shear Walls When the No. of Storeys were 8.

The peak values of the response decreased when the degree of foundation inclination of the building increased. As shown in (Figure 4.139 and Figure 4.142) the peak values shown in (0.1, 0.4 and 1.2 sec.) when the degree of the foundation inclination was 0° , while its values shown in (0.1, 0.25 and 0.35 sec.) when the degree of the foundation inclination was 40° .

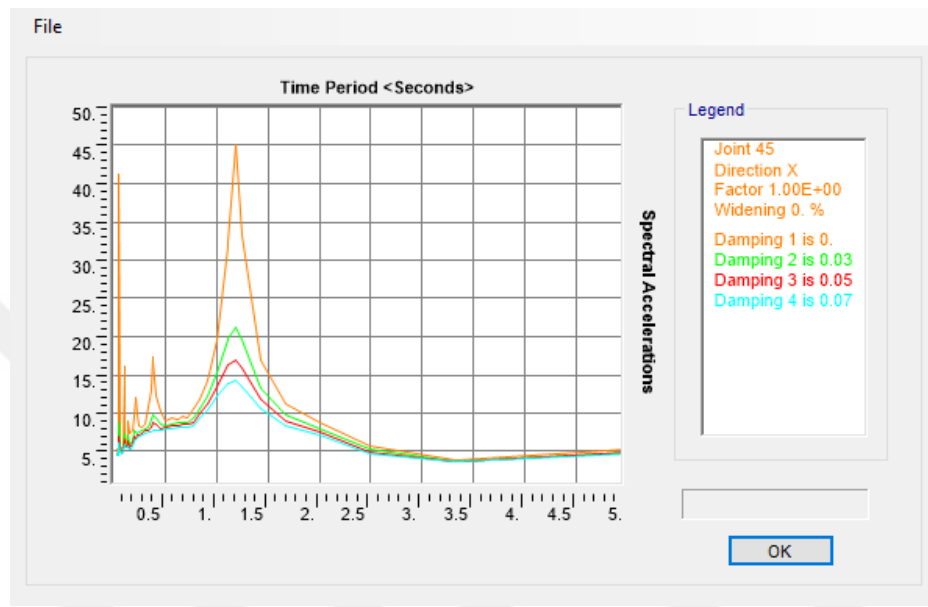


Figure 4.139: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 0° without Shear Wall.

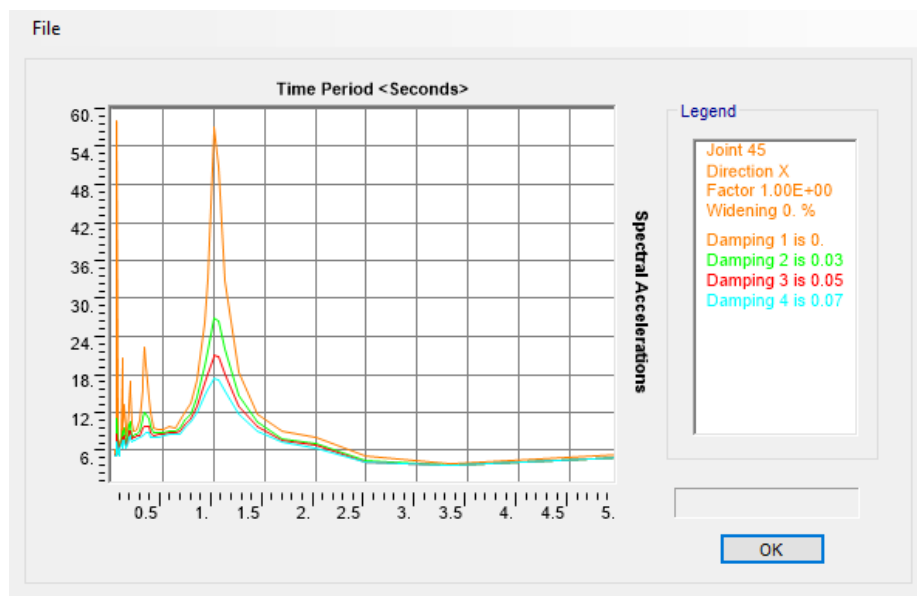


Figure 4.140: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 10° without Shear Wall.

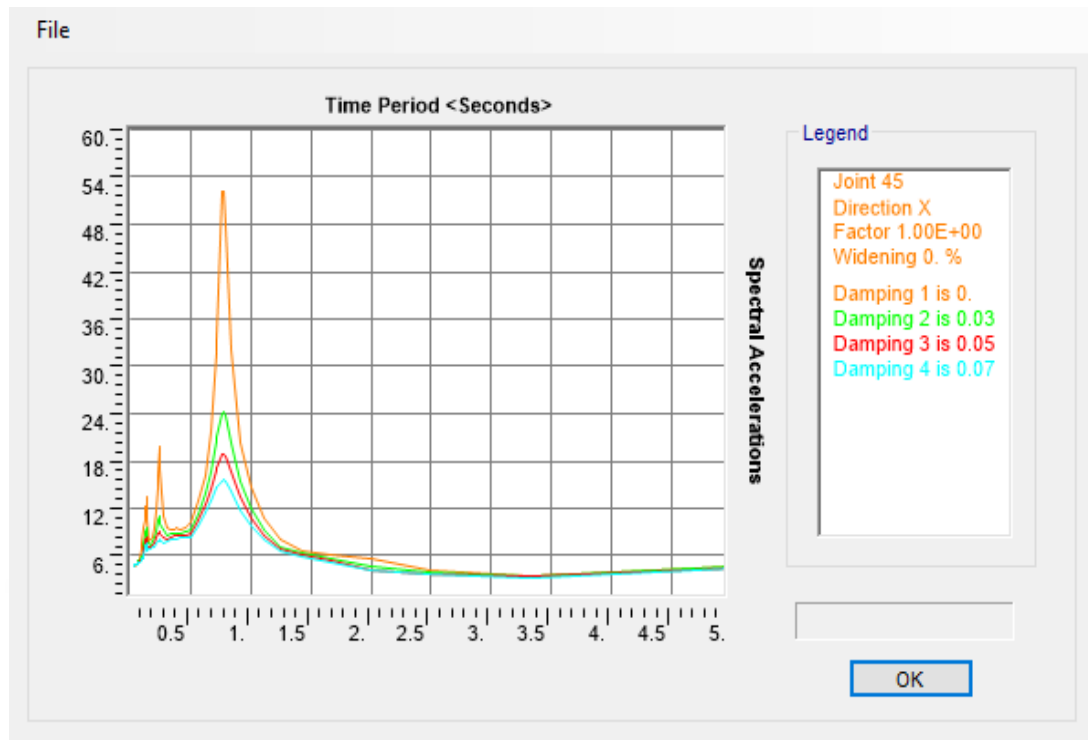


Figure 4.141: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 20° without Shear Wall.

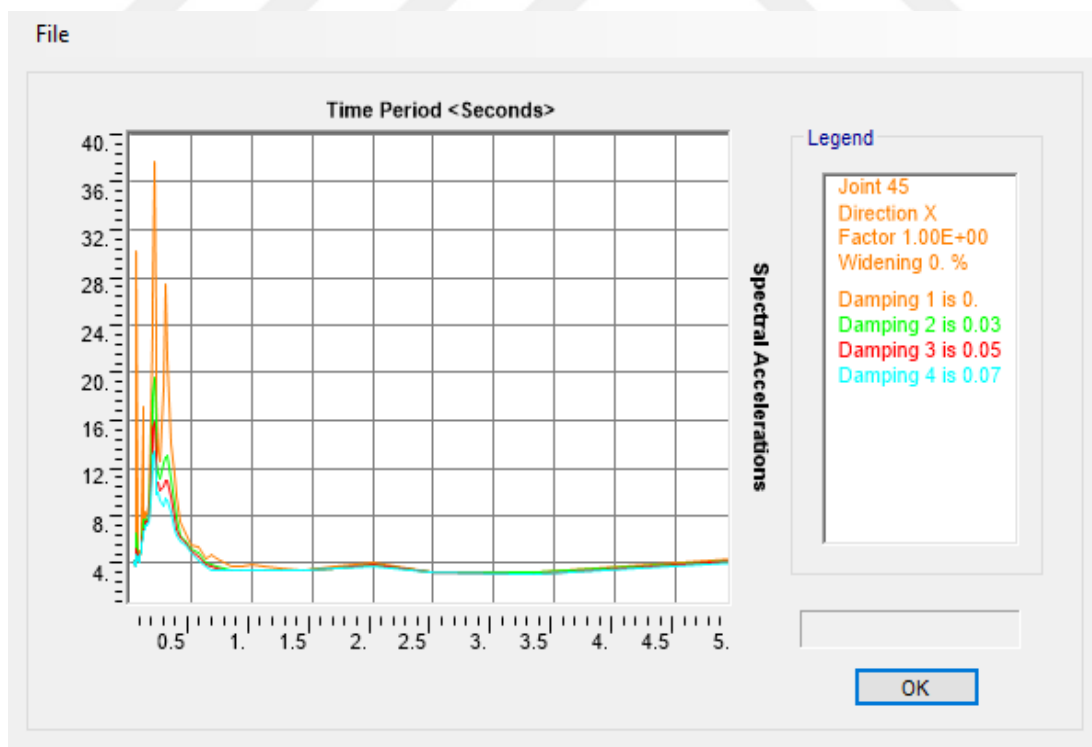


Figure 4.142: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 40° without Shear Wall.

The Results of Response Spectrum Analyzed When the No. of Storeys were 12:

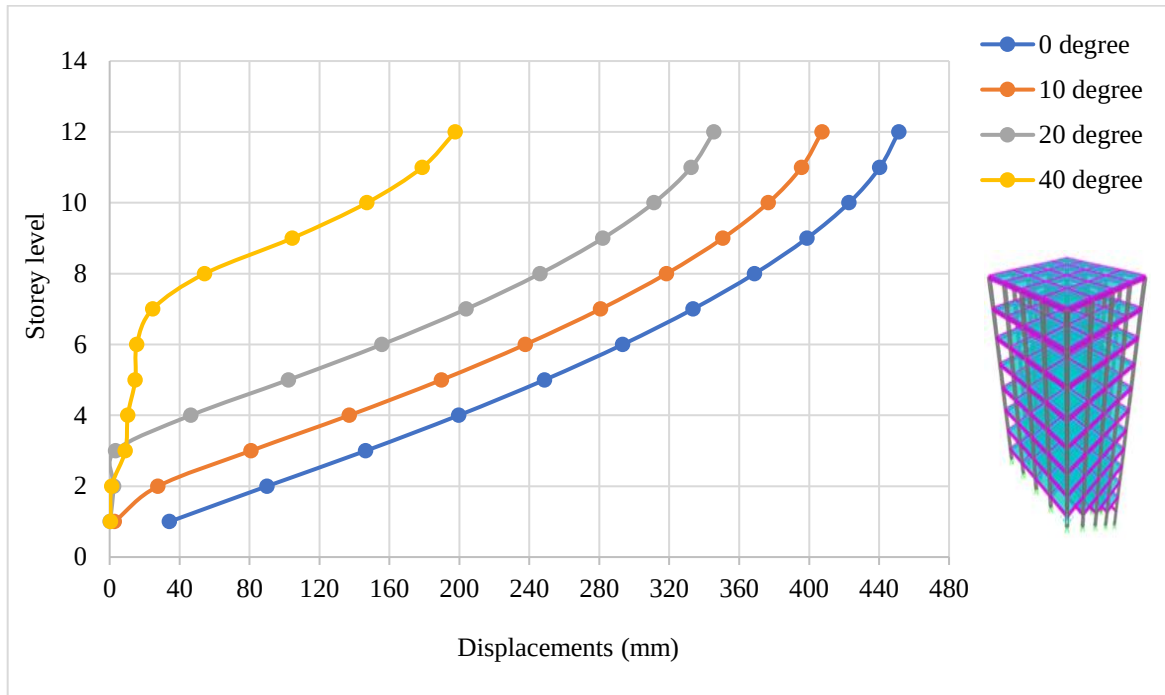


Figure 4.143: Displacements of the Buildings without Shear Walls When the No. of Storeys were 12.

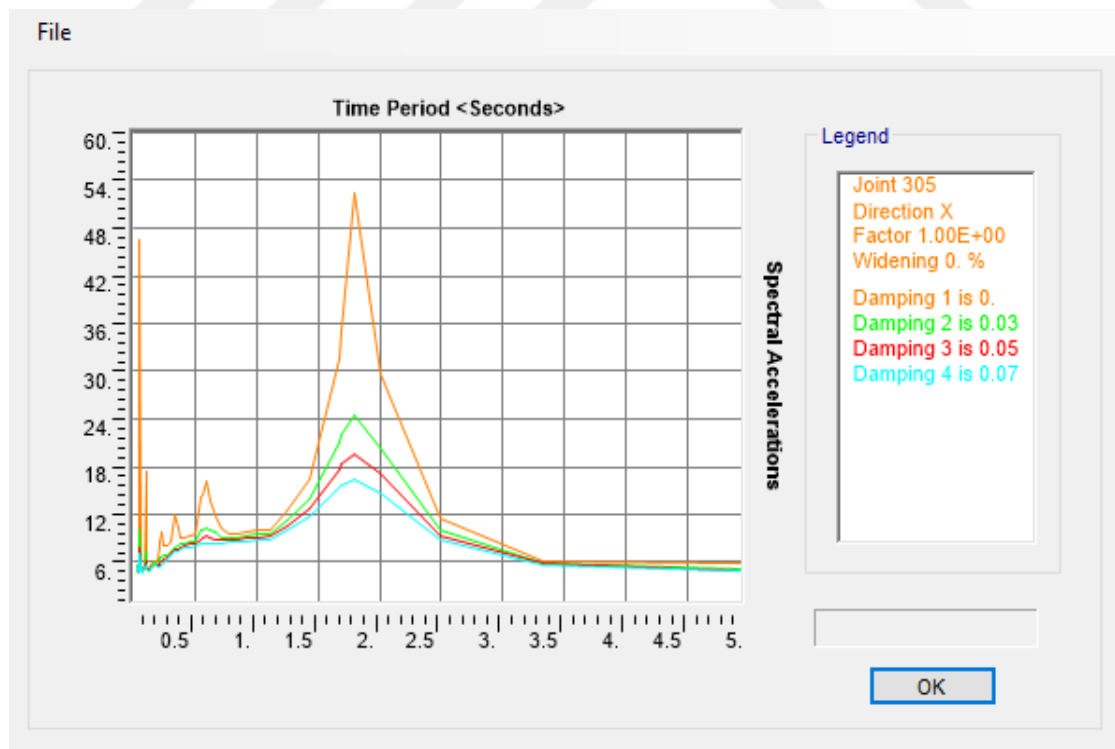


Figure 4.144: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 0° without Shear Wall.

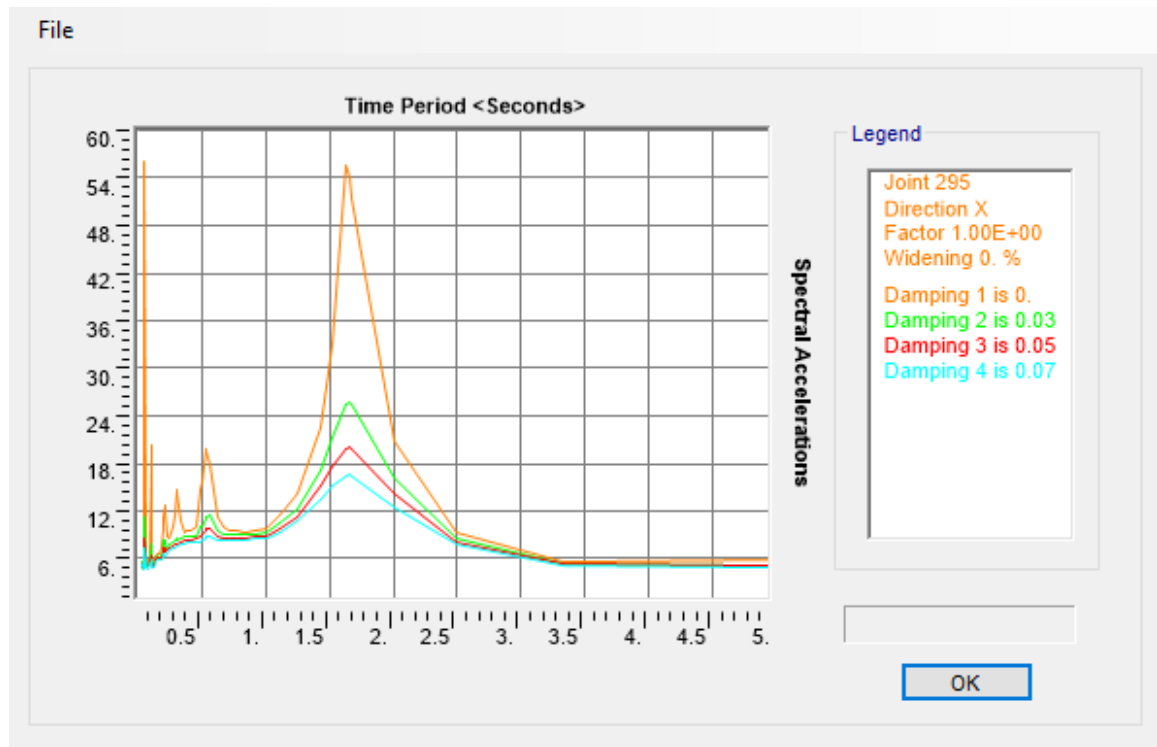


Figure 4.145: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 10° without Shear Wall.

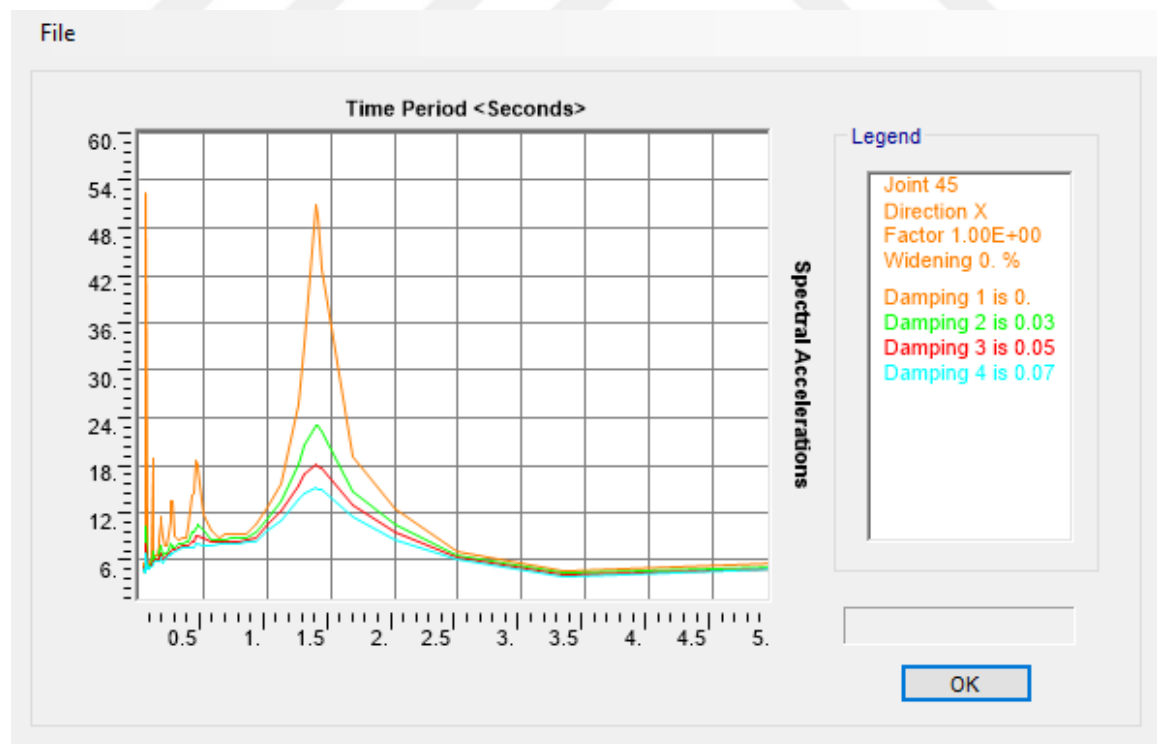


Figure 4.146: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 20° without Shear Wall.

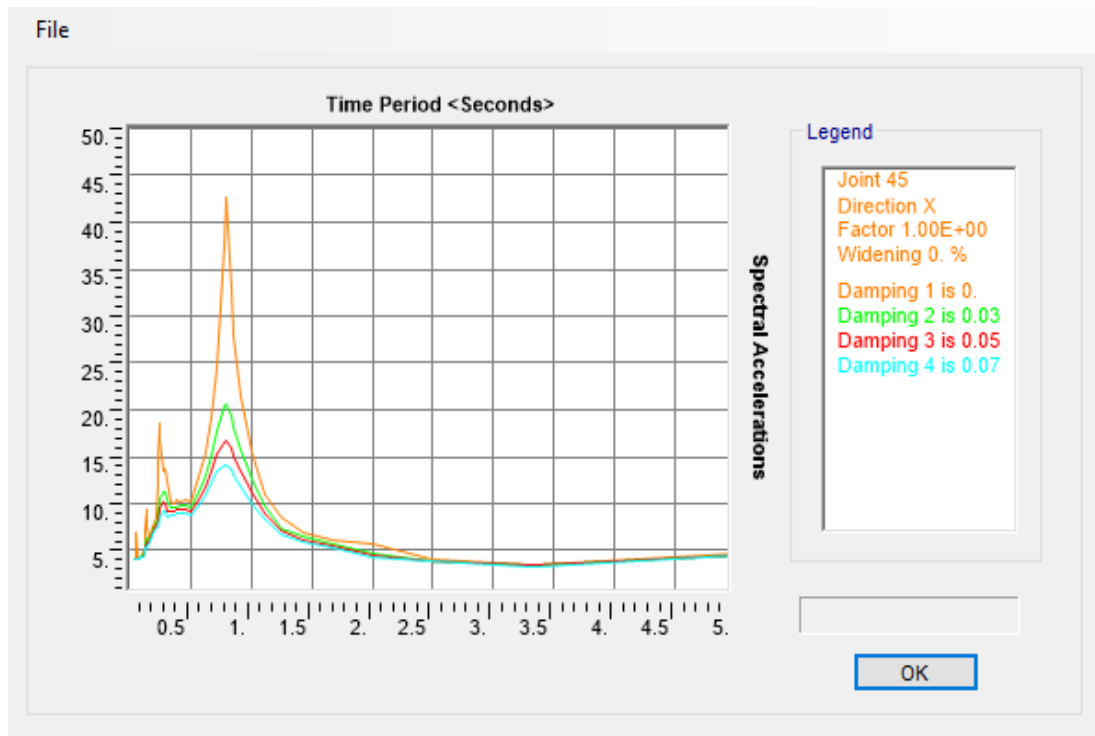


Figure 4.147: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 40° without Shear Wall.

The Results of Response Spectrum Analyzed When the No. of Storeys were 16:

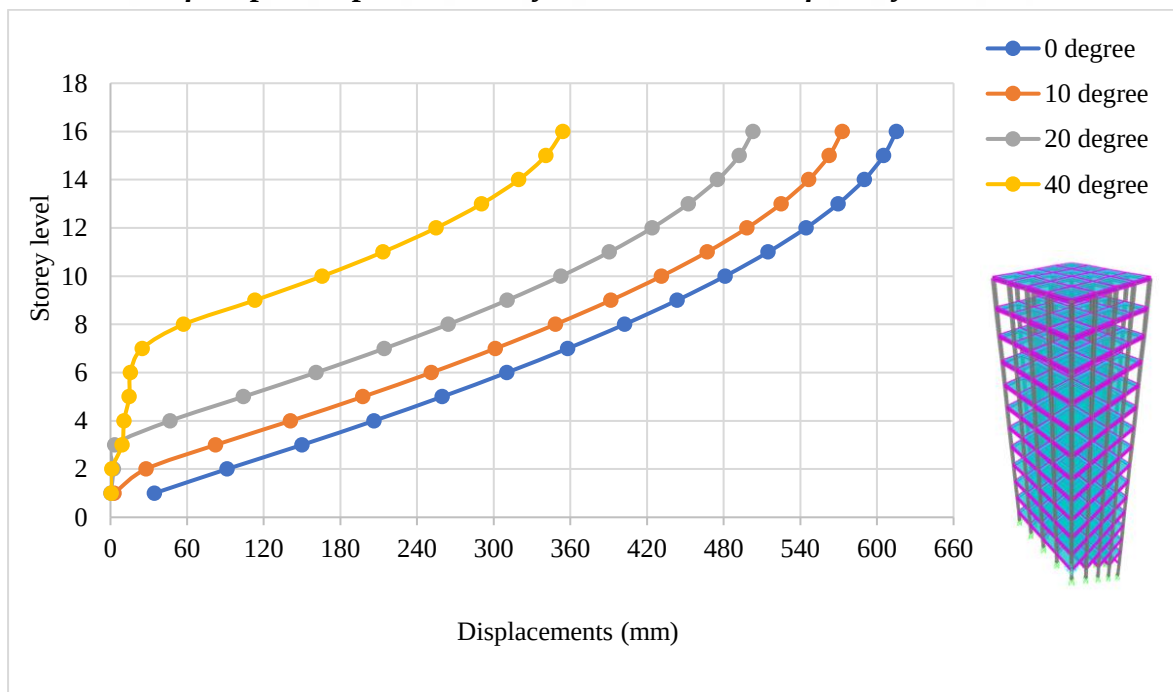


Figure 4.148: Displacements of the Buildings without Shear Walls When the No. of Storeys were 16.

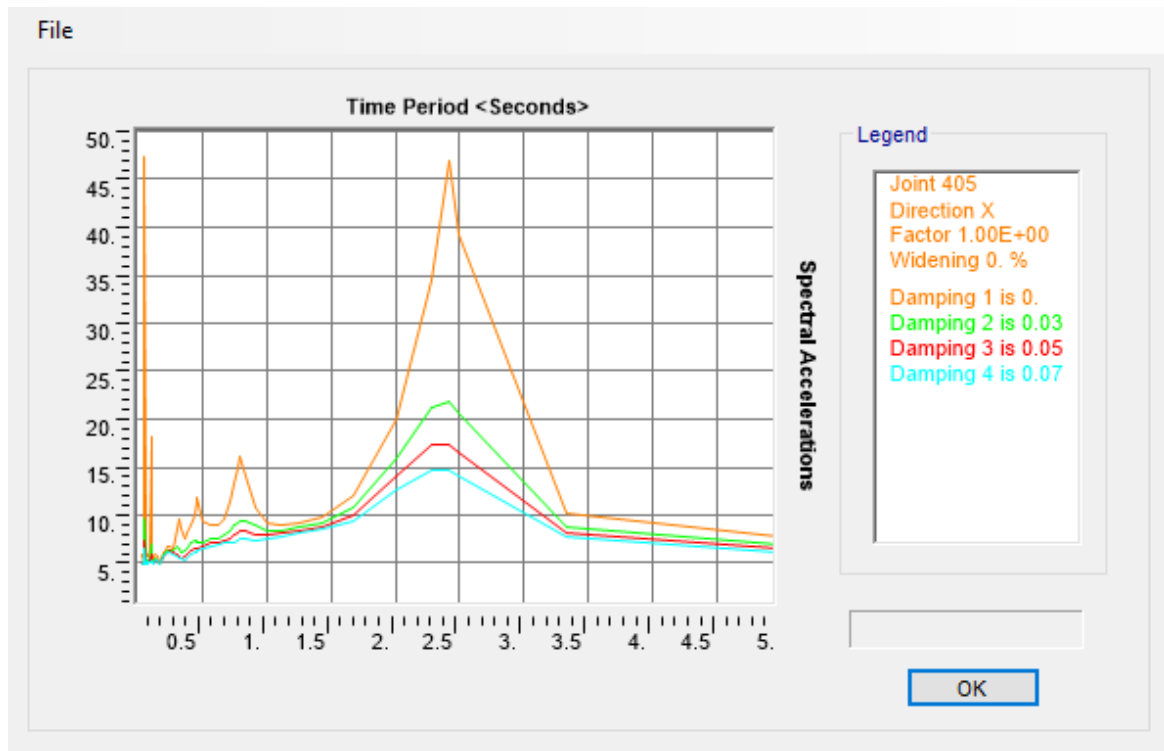


Figure 4.149: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 0° without Shear Wall.

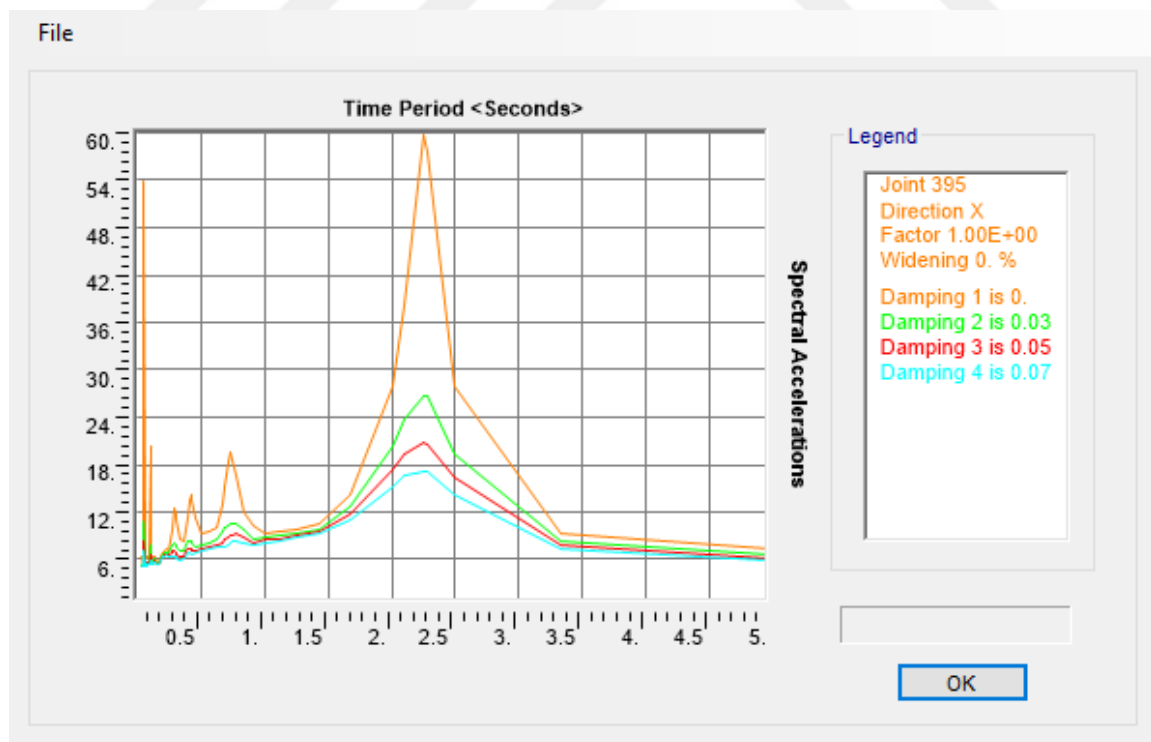


Figure 4.150: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 10° without Shear Wall.

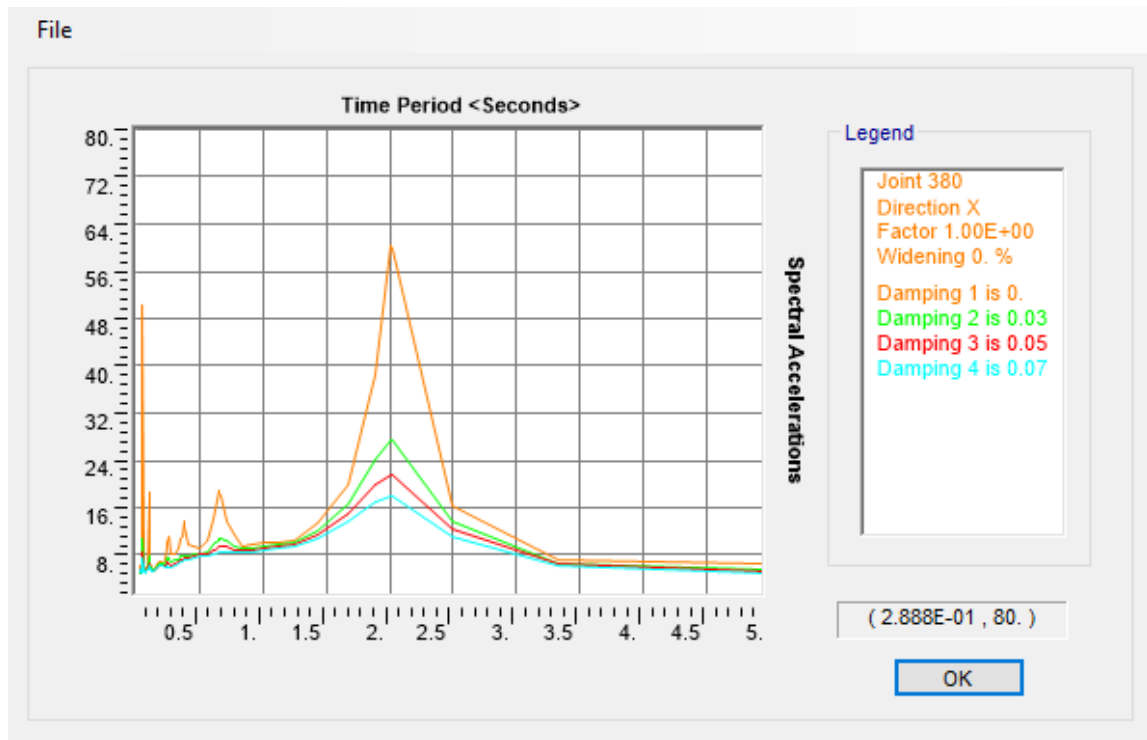


Figure 4.151: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 20° without Shear Wall.

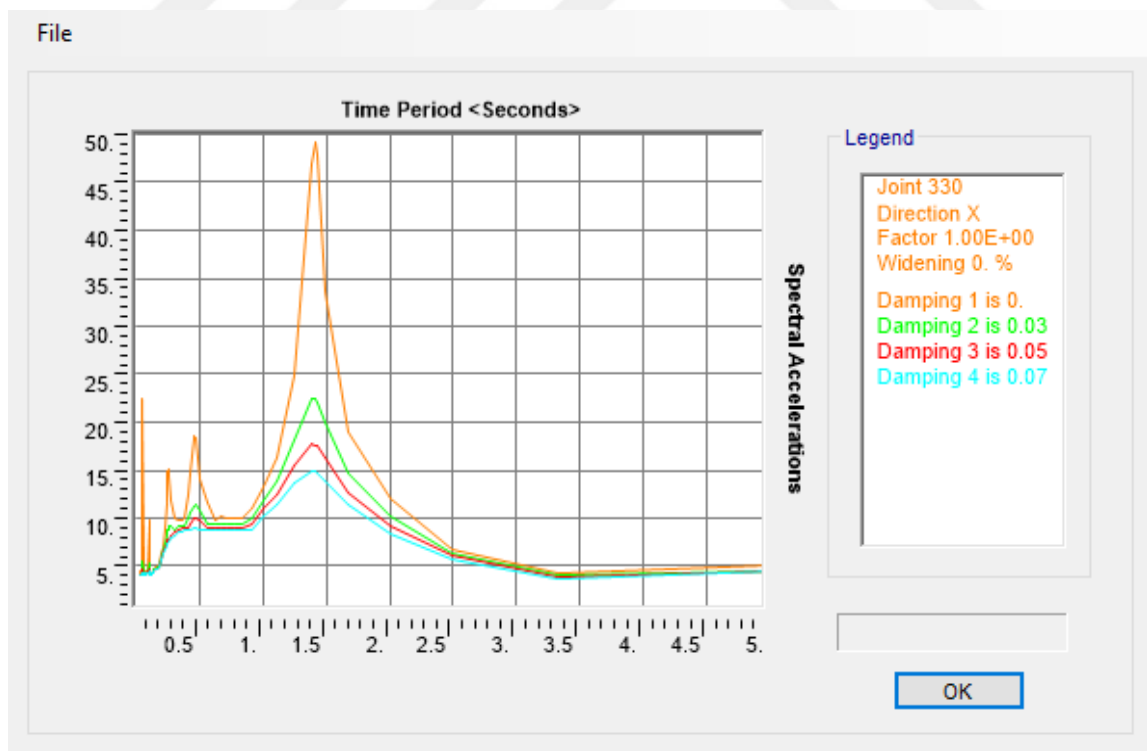


Figure 4.152: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 40° without Shear Wall.

The Results of Response Spectrum Analyzed When the No. of Storeys were 20:

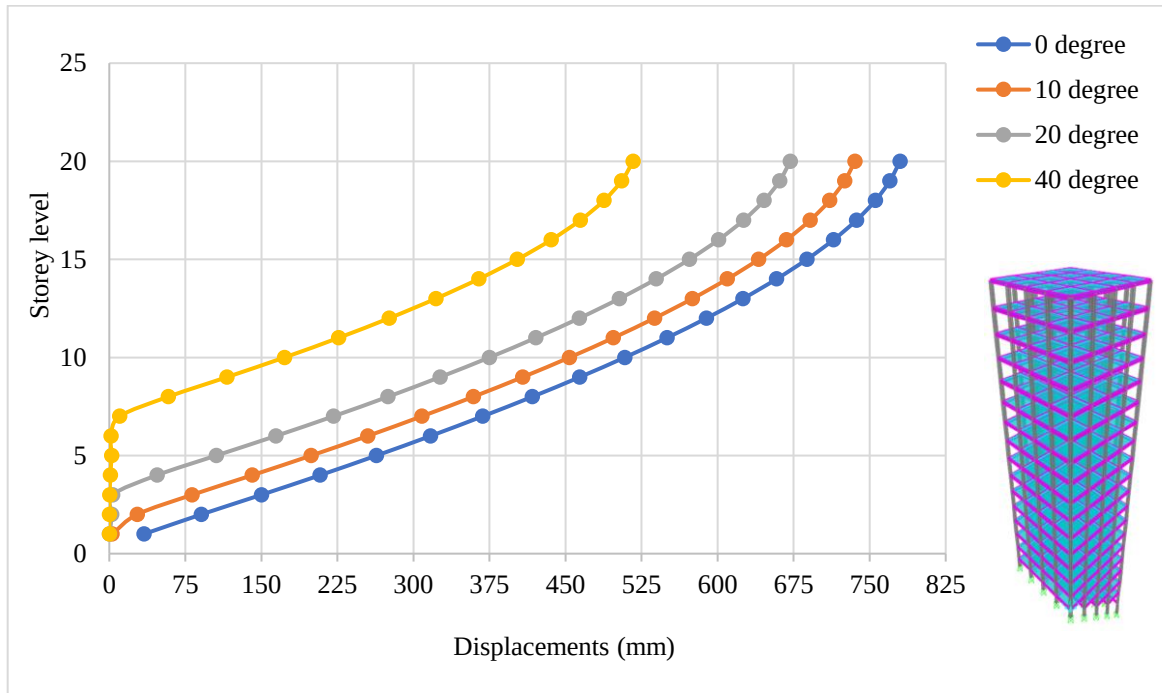


Figure 4.153: Displacements of the Buildings without Shear Walls When the No. of Storeys were 20.

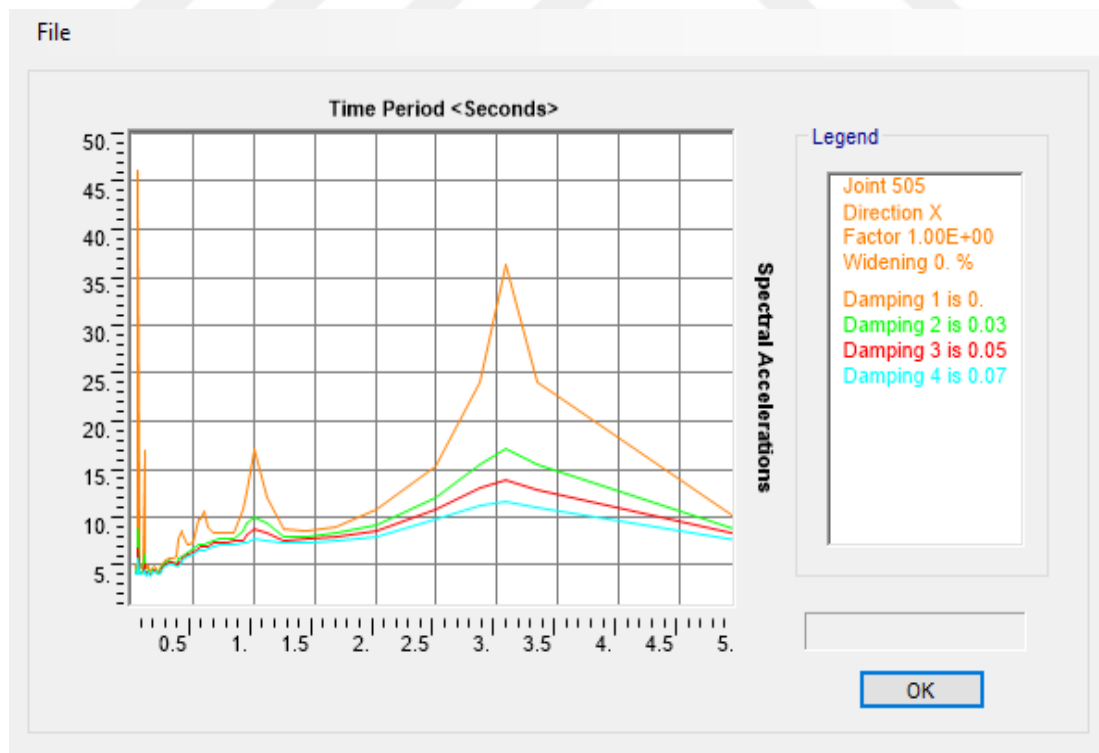


Figure 4.154: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 0° without Shear Wall.

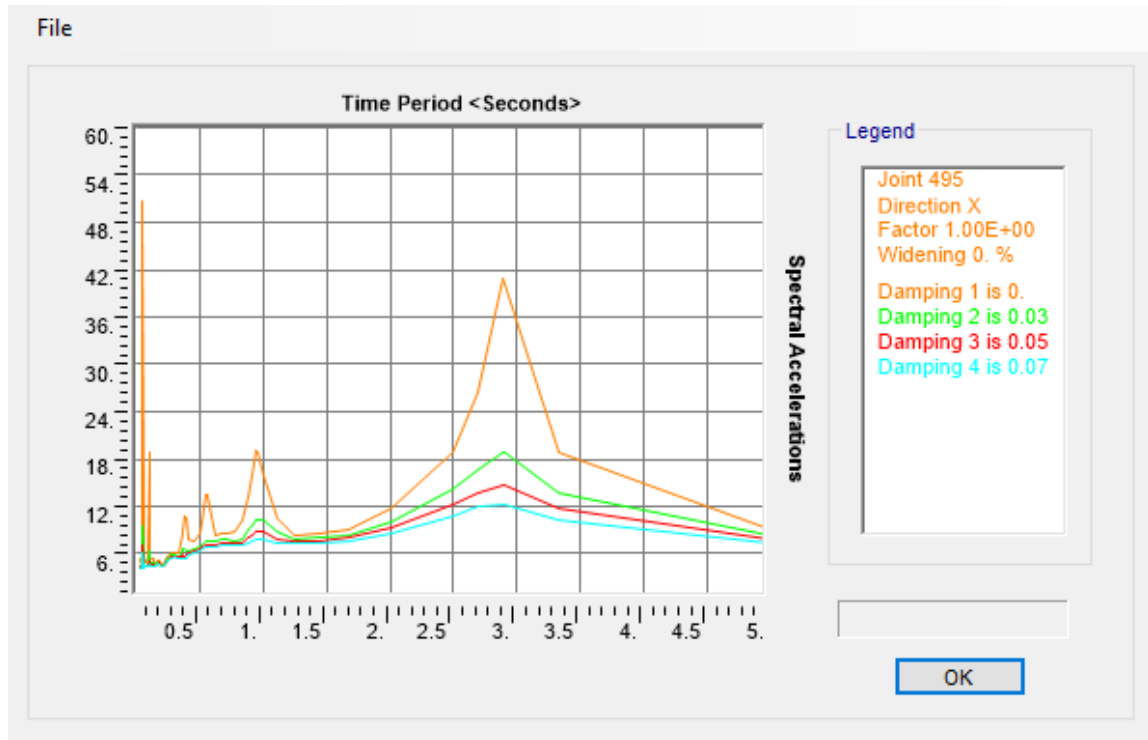


Figure 4.155: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 10° without Shear Wall.

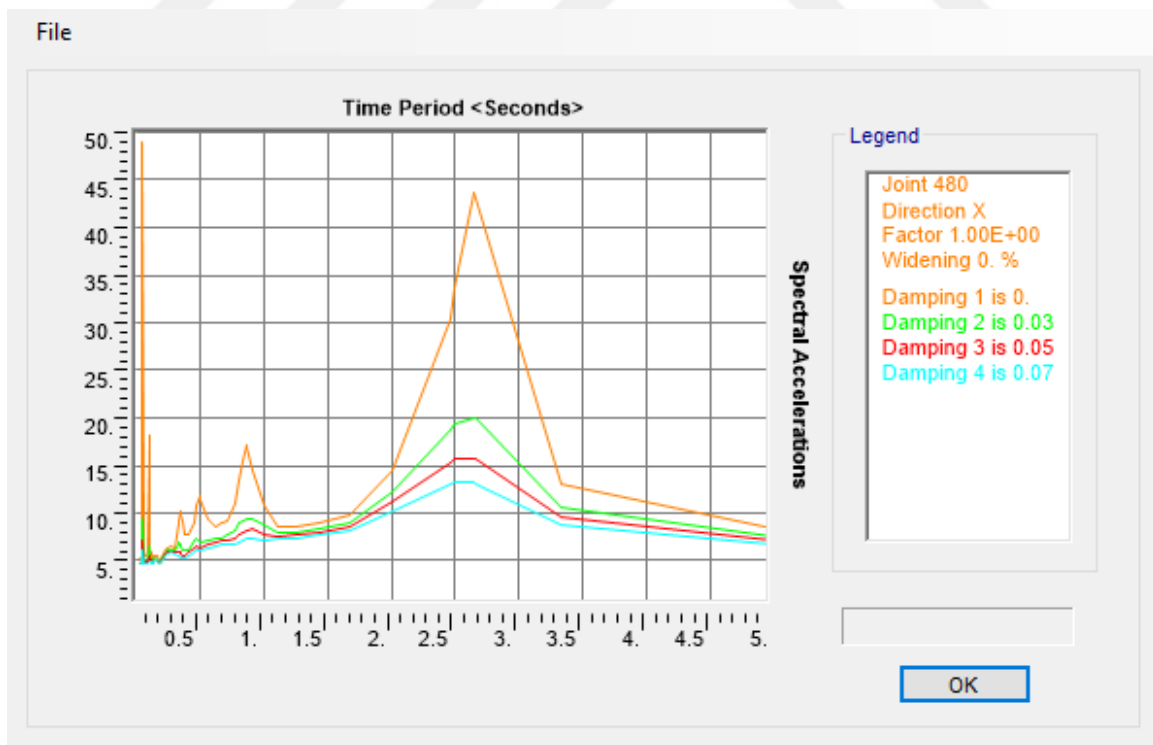


Figure 4.156: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 20° without Shear Wall.

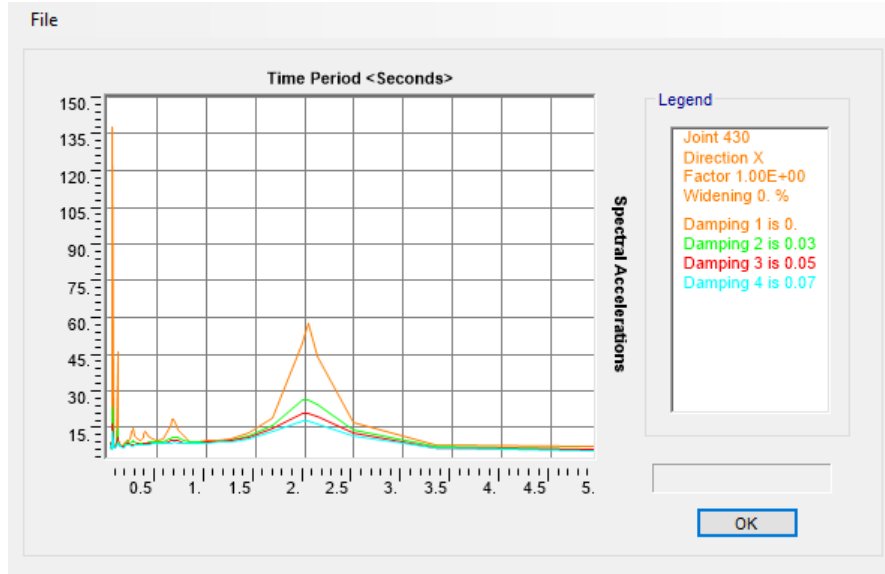


Figure 4.157: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 40° without Shear Wall.

4.3.3.2 Response spectrum analyzed of the buildings with shear walls

The response spectrum method had been used to analyze the buildings with shear walls. (Figure 4.148) and (Figure 4.168), had been compared to evaluate the effect of the presence of shear walls on the displacements values. The value of displacements decreased by (65-80%) when the storey level was (1 to 9). While its value decreased by (40-65%) when the storey level was (10 to 16).

The Results of Response Spectrum Analyzed When the No. of Storeys were 8:

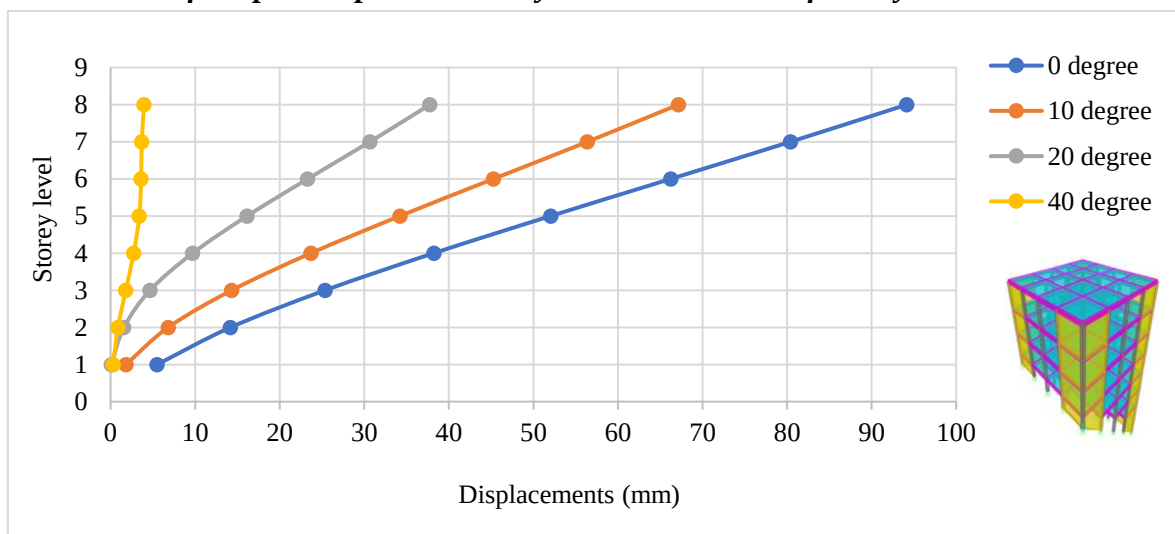


Figure 4.158: Displacements of the Buildings with Shear Walls When the No. of Storeys were 8.

The peak values of the response decreased in the case presence of shear wall. (Figure 4.139 and Figure 4.142) and (Figure 4.159 and Figure 4.162), had been compared to evaluate the effect of the presence of shear walls on the peak values. The peak values decreased by 65% when the degree of the foundation inclination was 0° , while its values decreased by 57% when the degree of the foundation inclination was 40° .

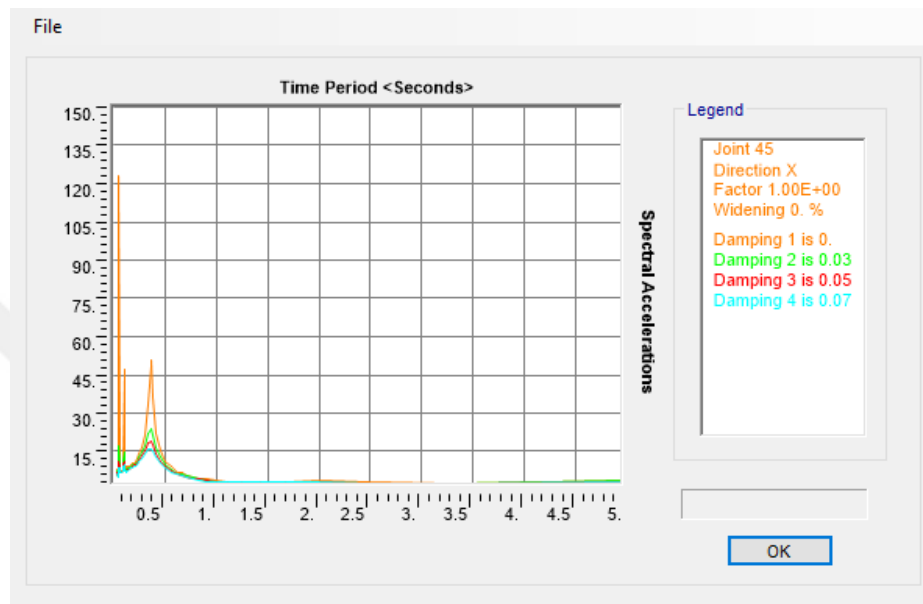


Figure 4.159: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 0° with Shear Wall.

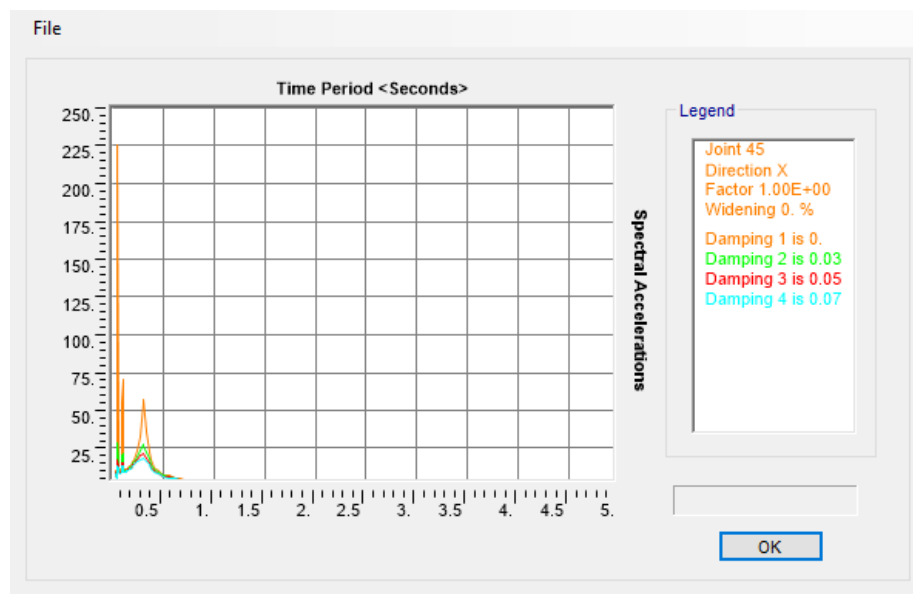


Figure 4.160: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 10° with Shear Wall.

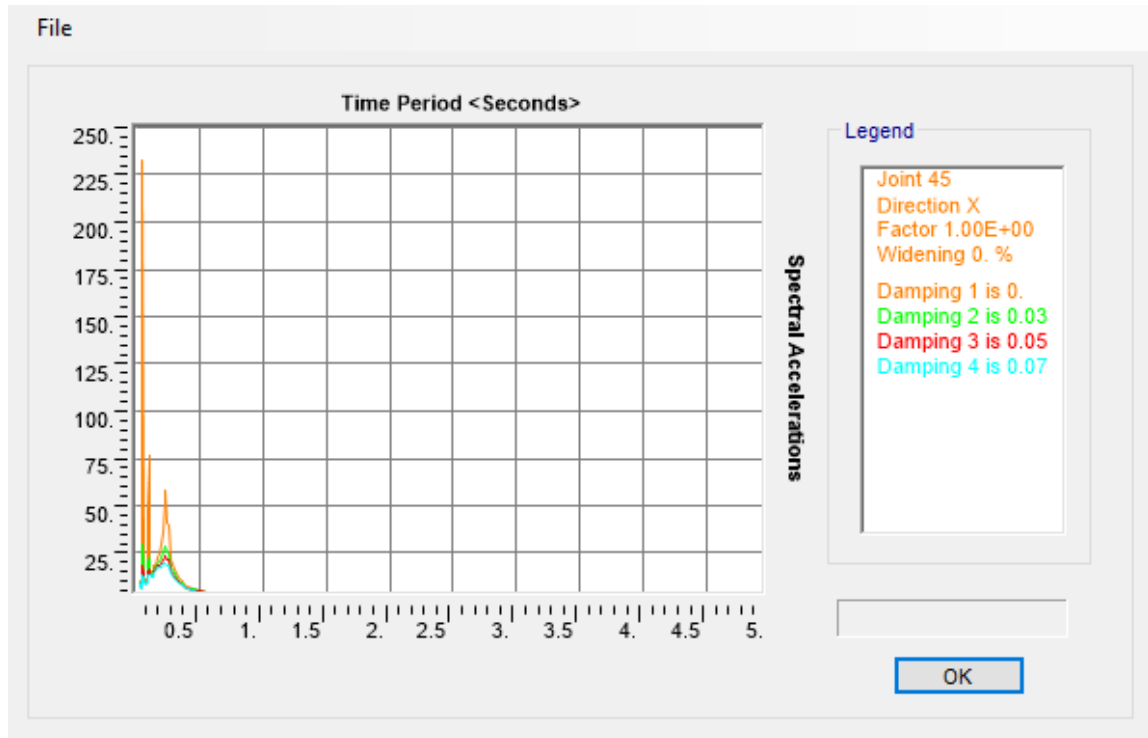


Figure 4.161: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 20° with Shear Wall.

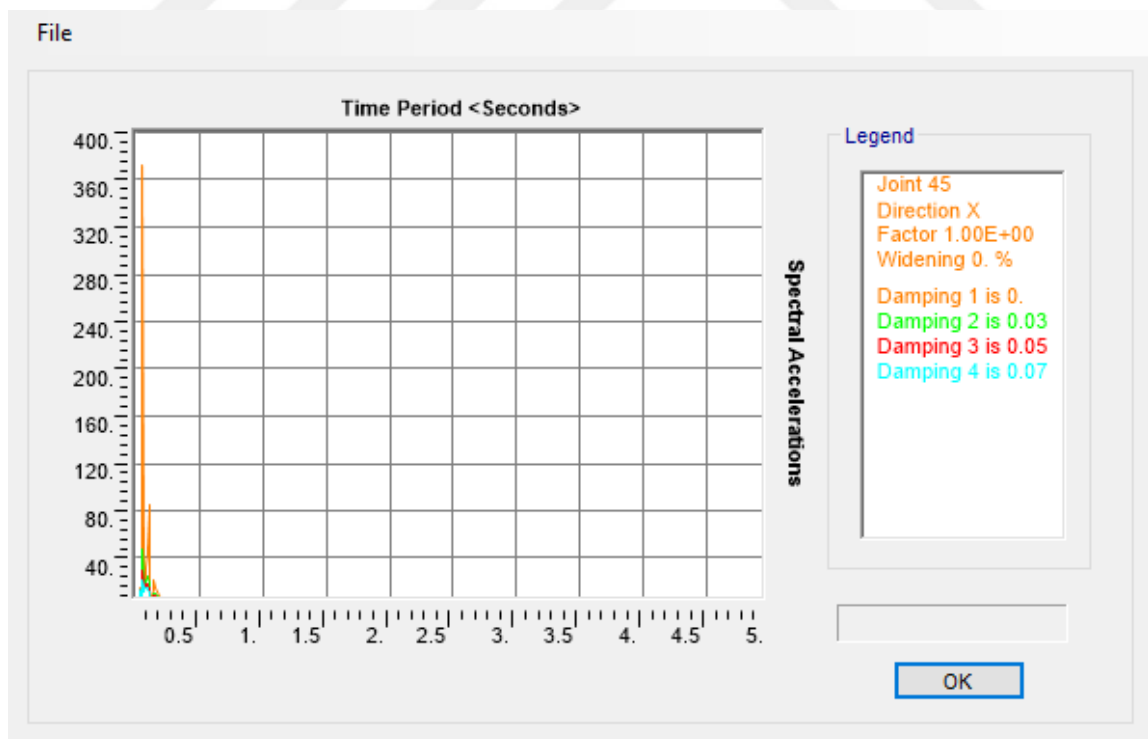


Figure 4.162: Spectral Accelerations with Time Period of 8-Storey Building Inclined with an Angle of 40° with Shear Wall.

The Results of Response Spectrum Analyzed When the No. of Storeys were 12:

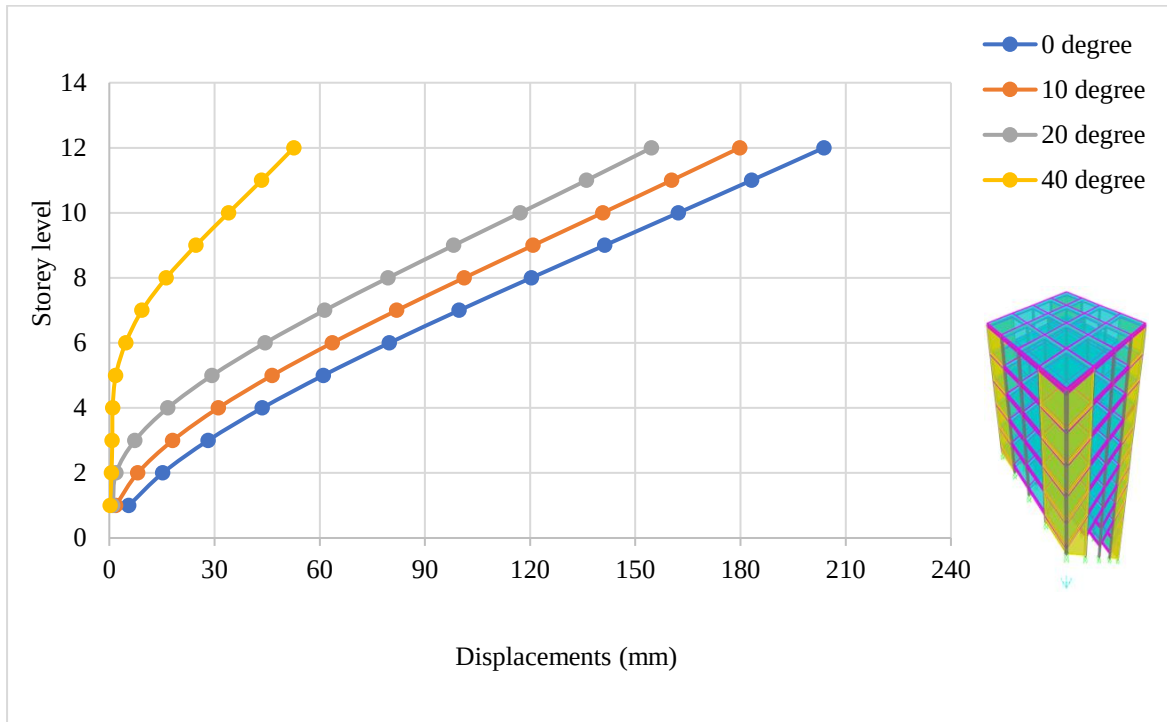


Figure 4.163: Displacements of the Buildings with Shear Walls When the No. of Storeys were 12.

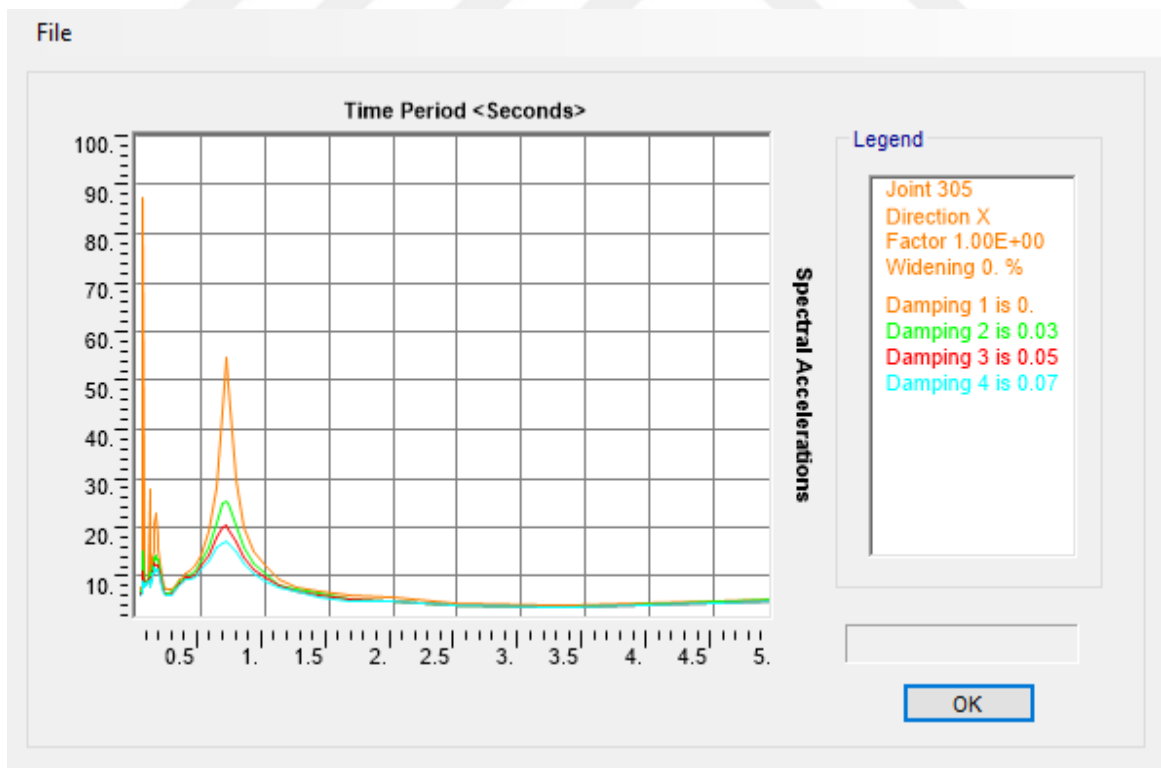


Figure 4.164: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 0° with Shear Wall.

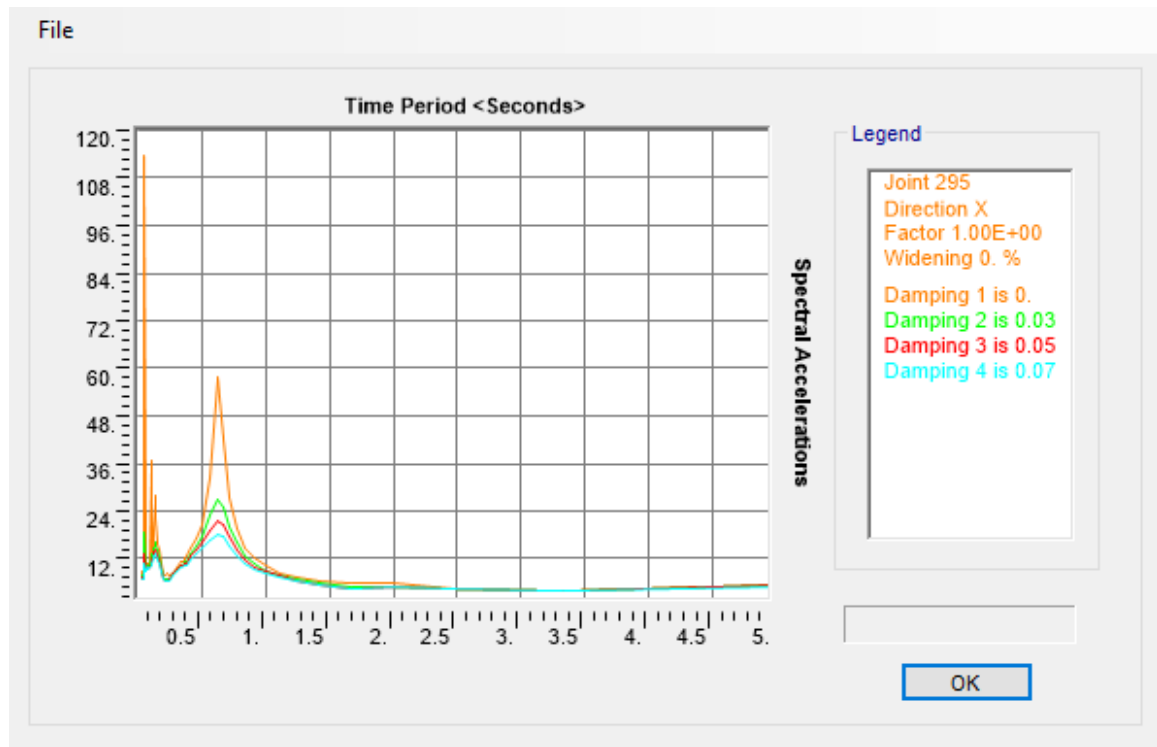


Figure 4.165: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 10° with Shear Wall.

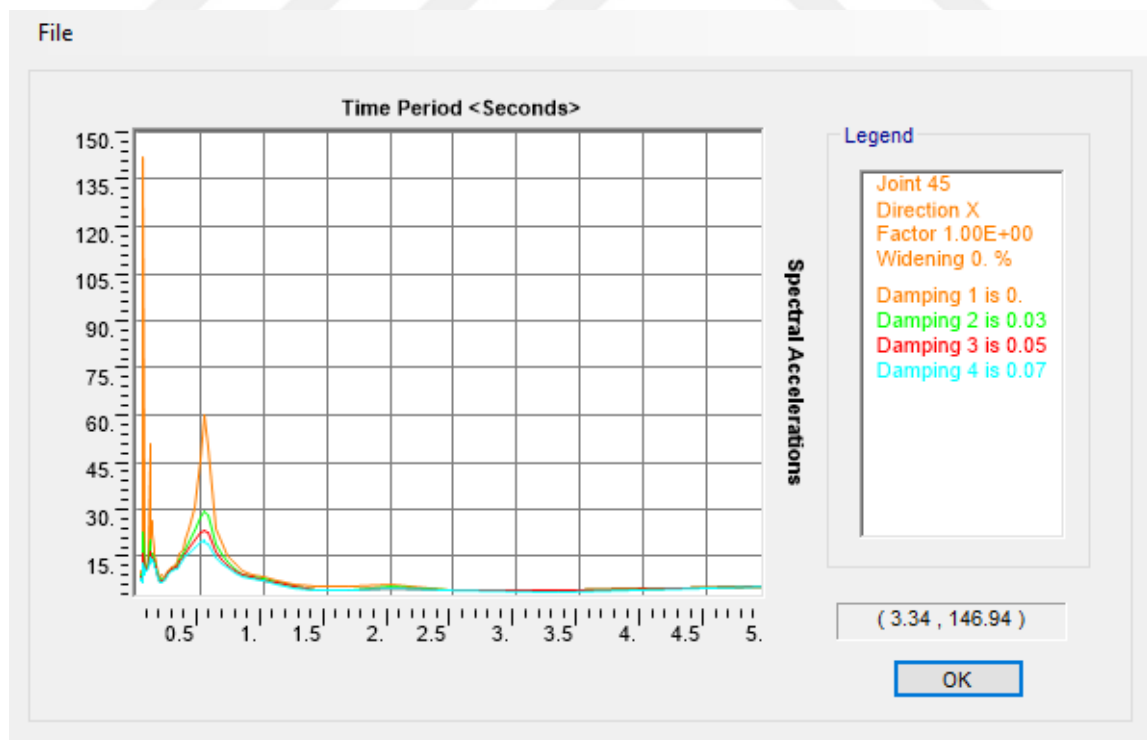


Figure 4.166: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 20° with Shear Wall.

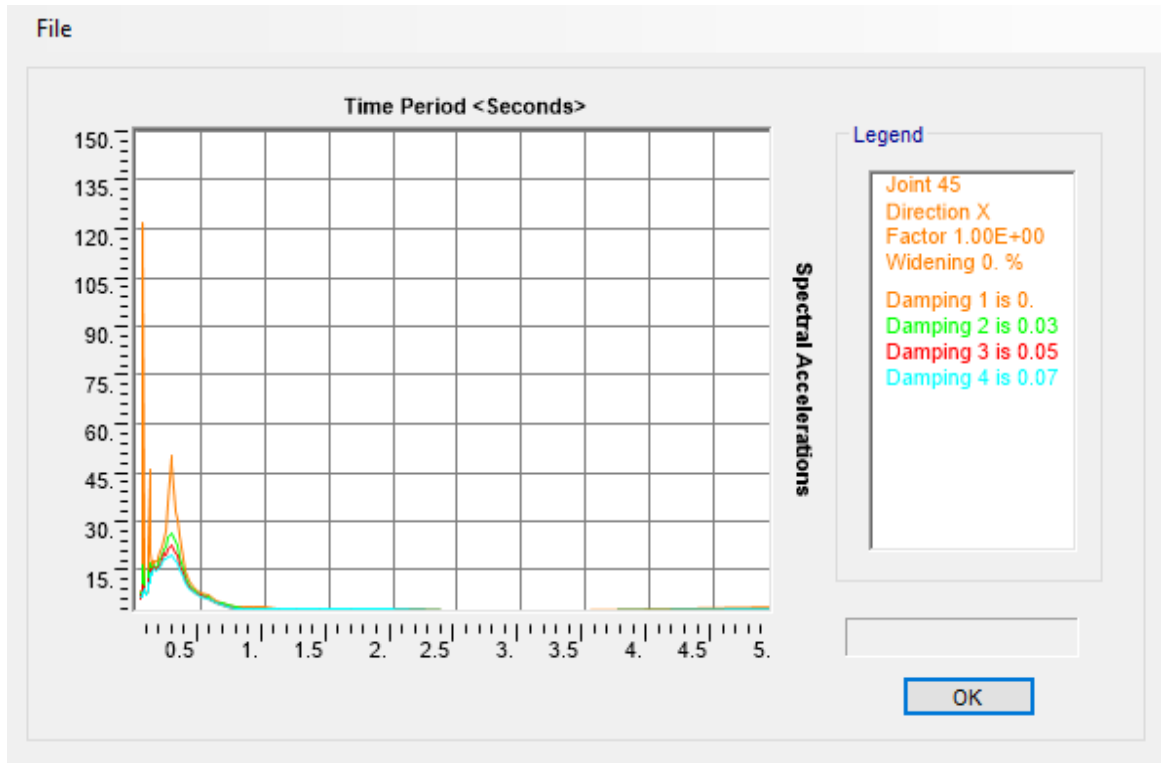


Figure 4.167: Spectral Accelerations with Time Period of 12-Storey Building Inclined with an Angle of 40° with Shear Wall.

The Results of Response Spectrum Analyzed When the No. of Storeys were 16:

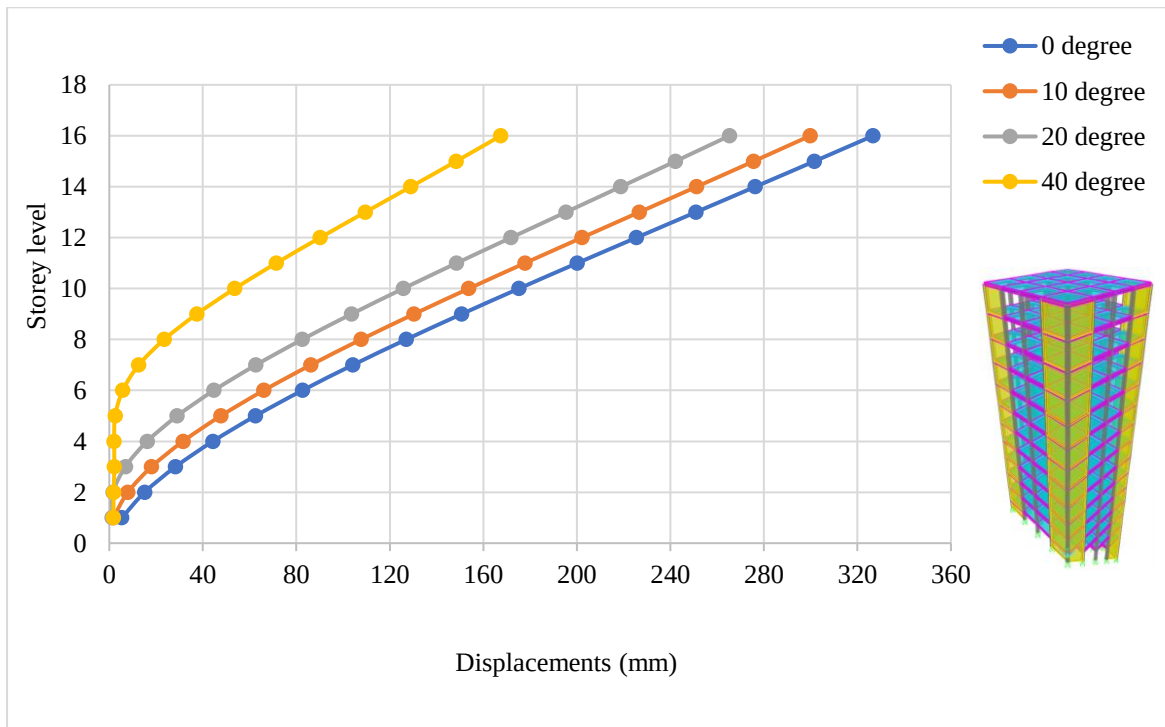


Figure 4.168: Displacements of the Buildings with Shear Walls When the No. of Storeys were 16.

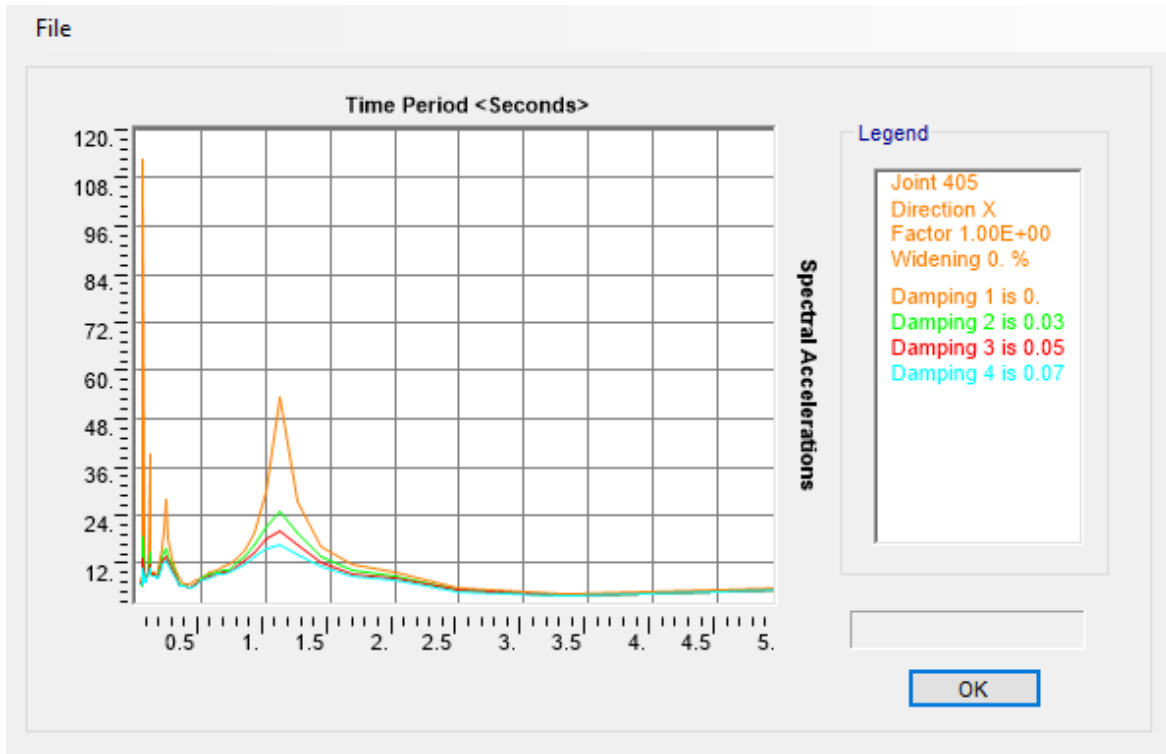


Figure 4.169: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 0° with Shear Wall.

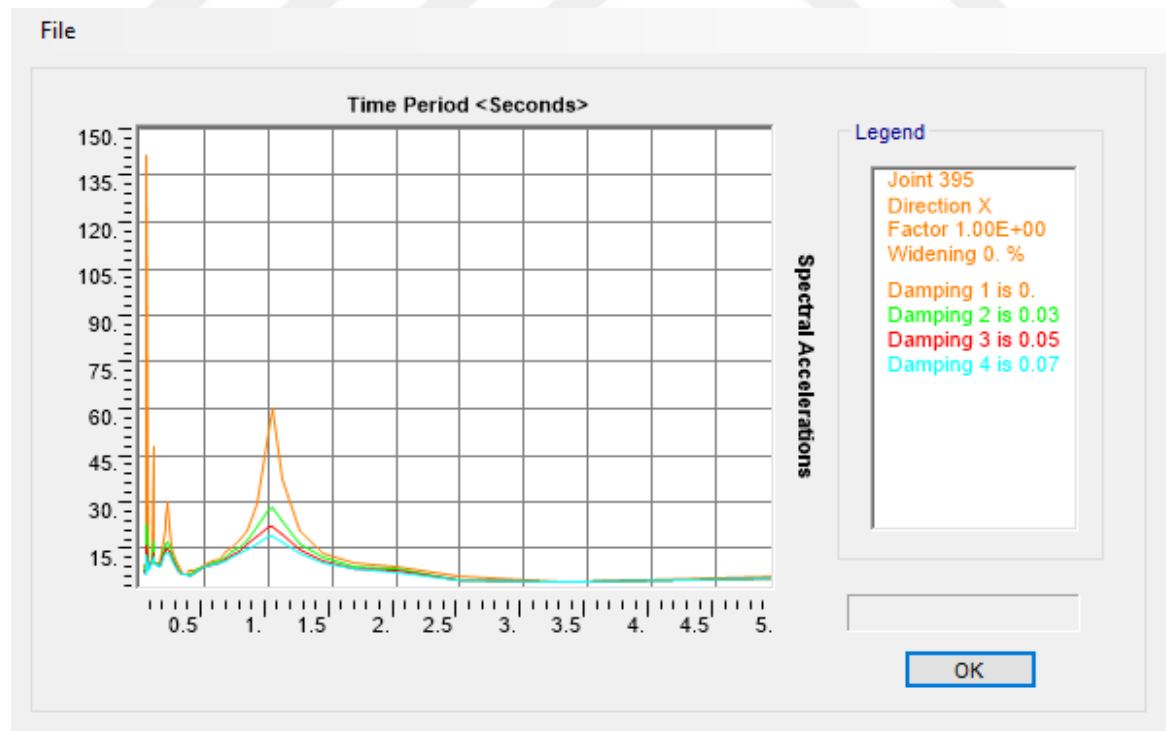


Figure 4.170: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 10° with Shear Wall.

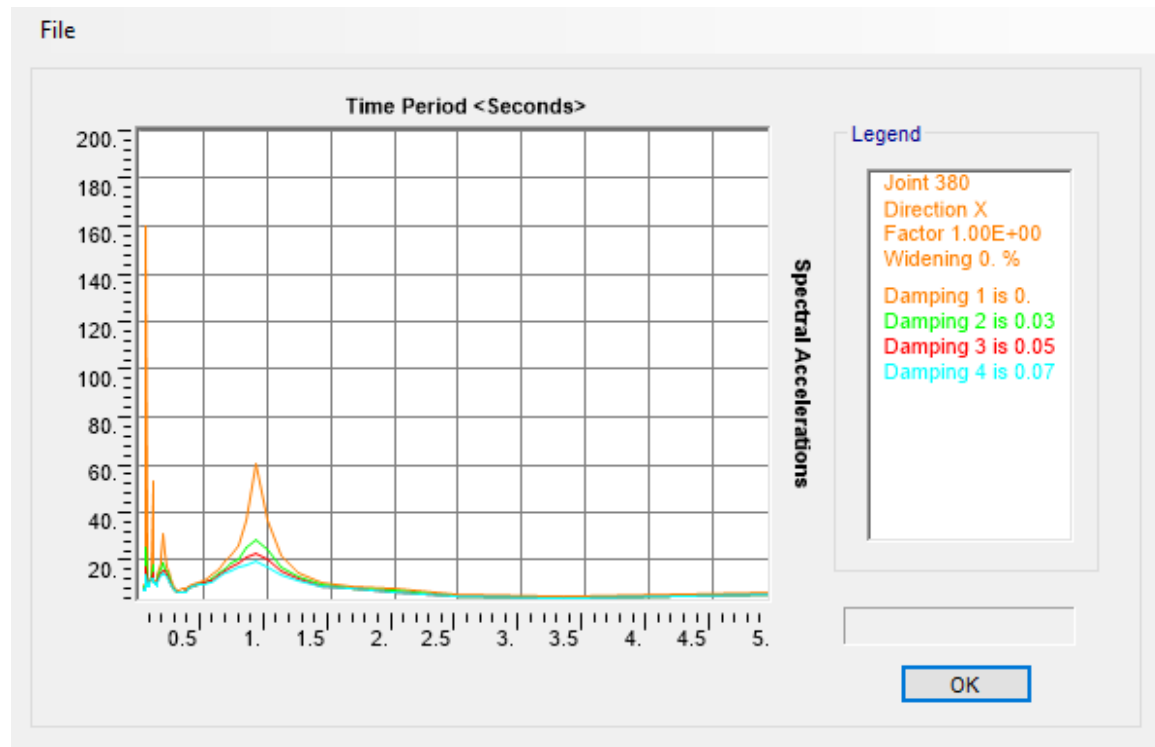


Figure 4.171: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 20° with Shear Wall.

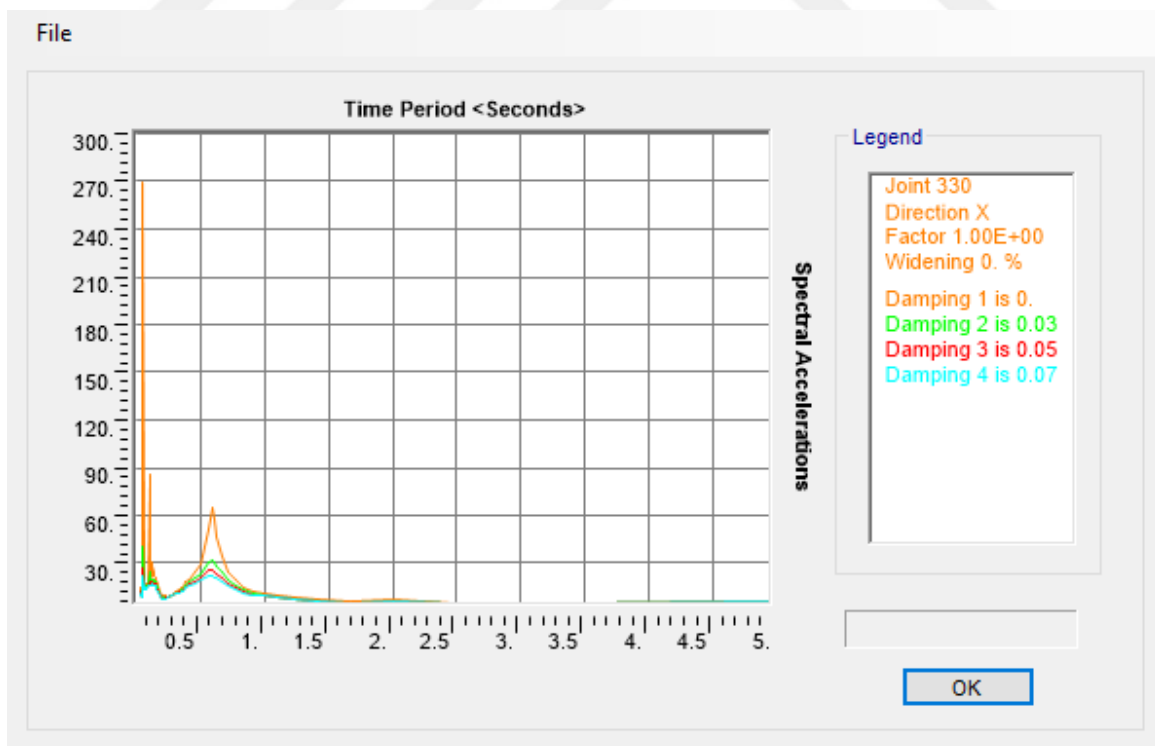


Figure 4.172: Spectral Accelerations with Time Period of 16-Storey Building Inclined with an Angle of 40° with Shear Wall.

The Results of Response Spectrum Analyzed When the No. of Storeys were 20:

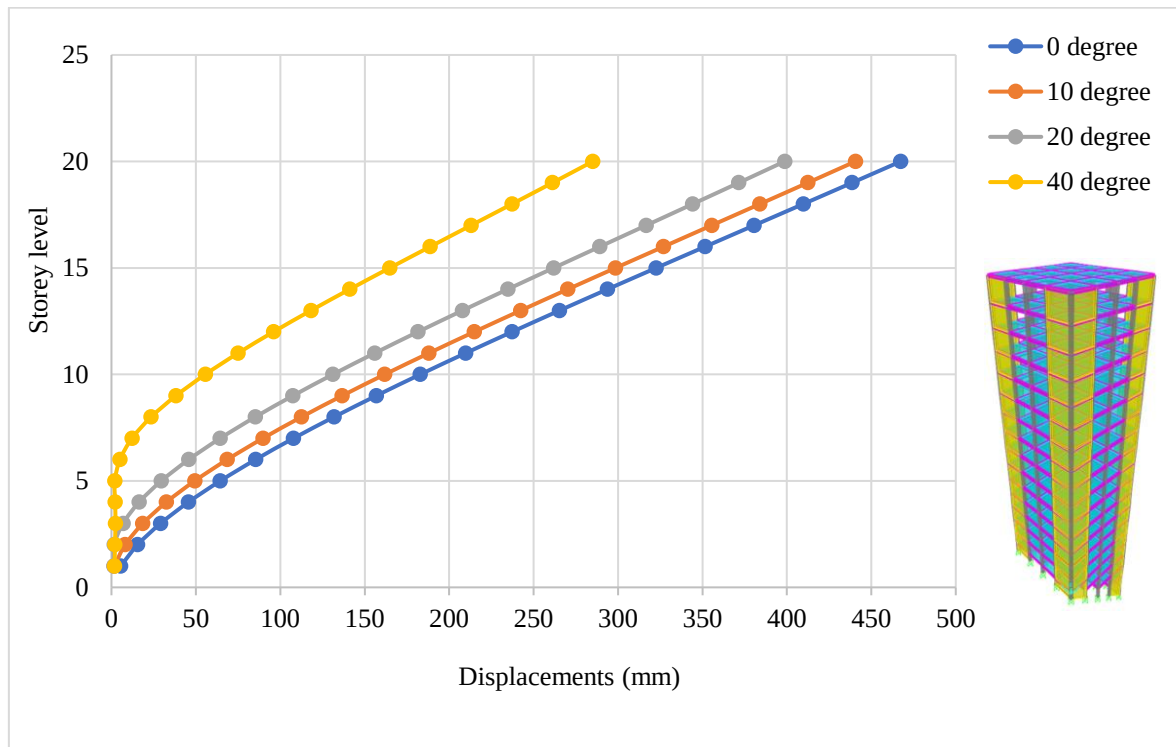


Figure 4.173: Displacements of the Buildings with Shear Walls When the No. of Storeys were 20.

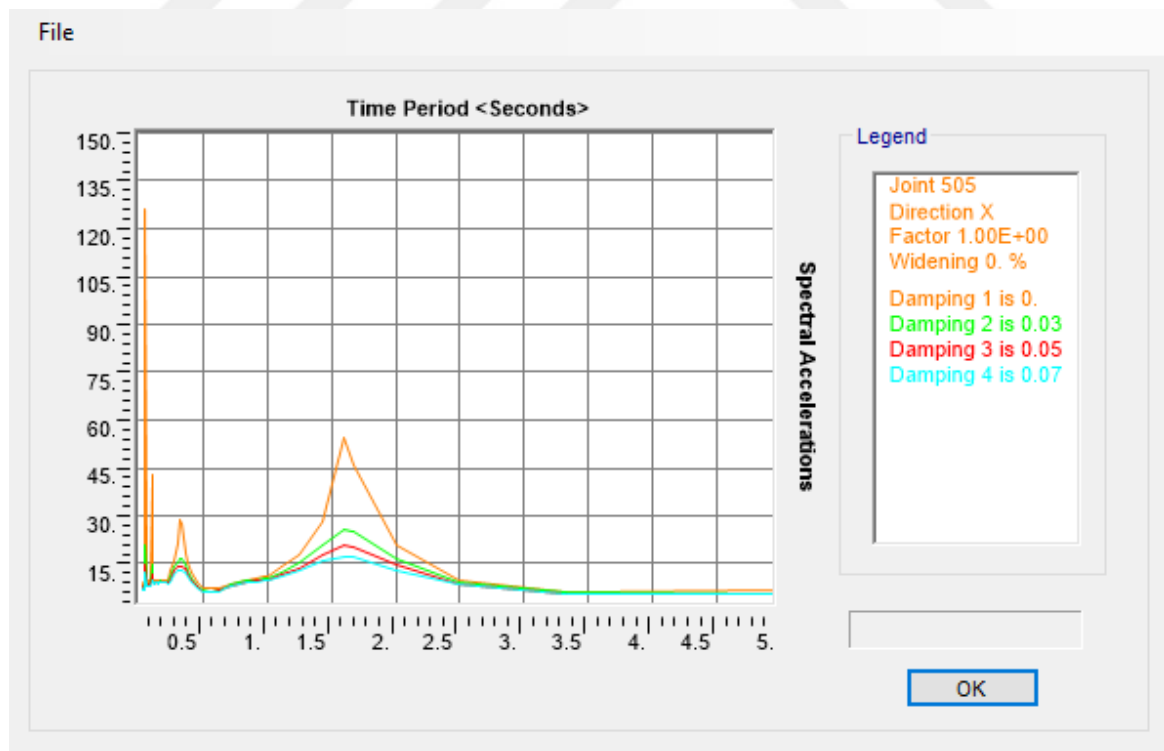


Figure 4.174: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 0° with Shear Wall.

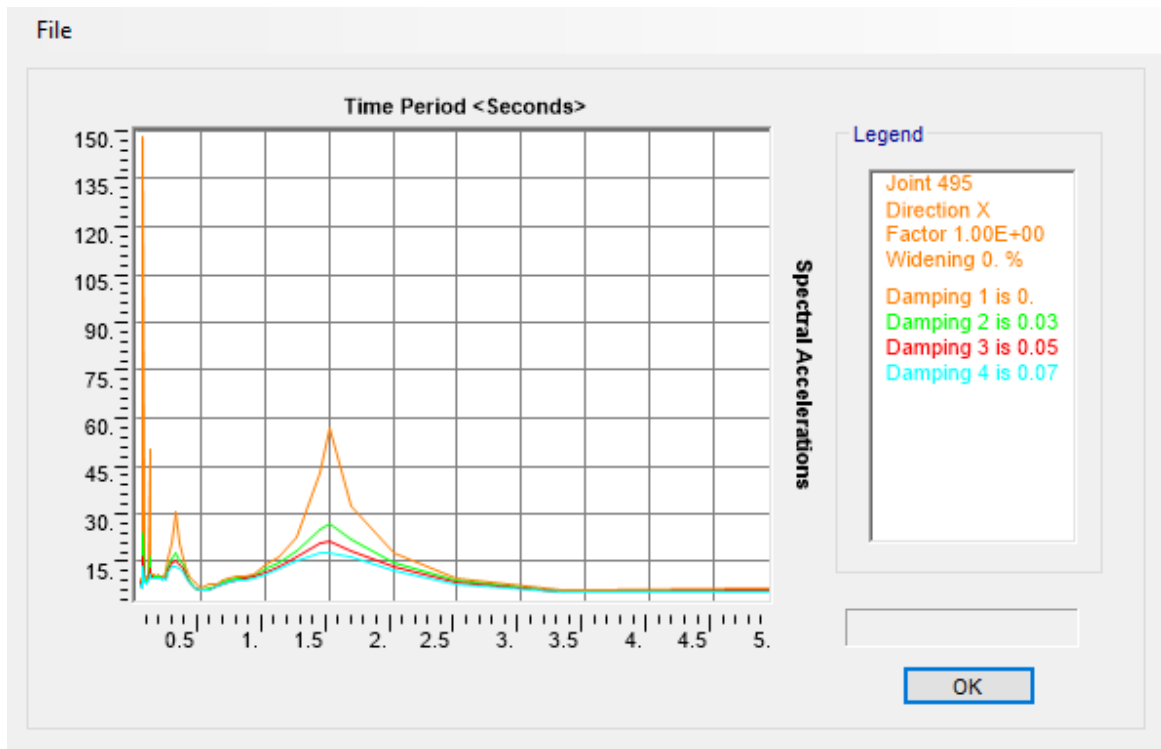


Figure 4.175: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 10° with Shear Wall.

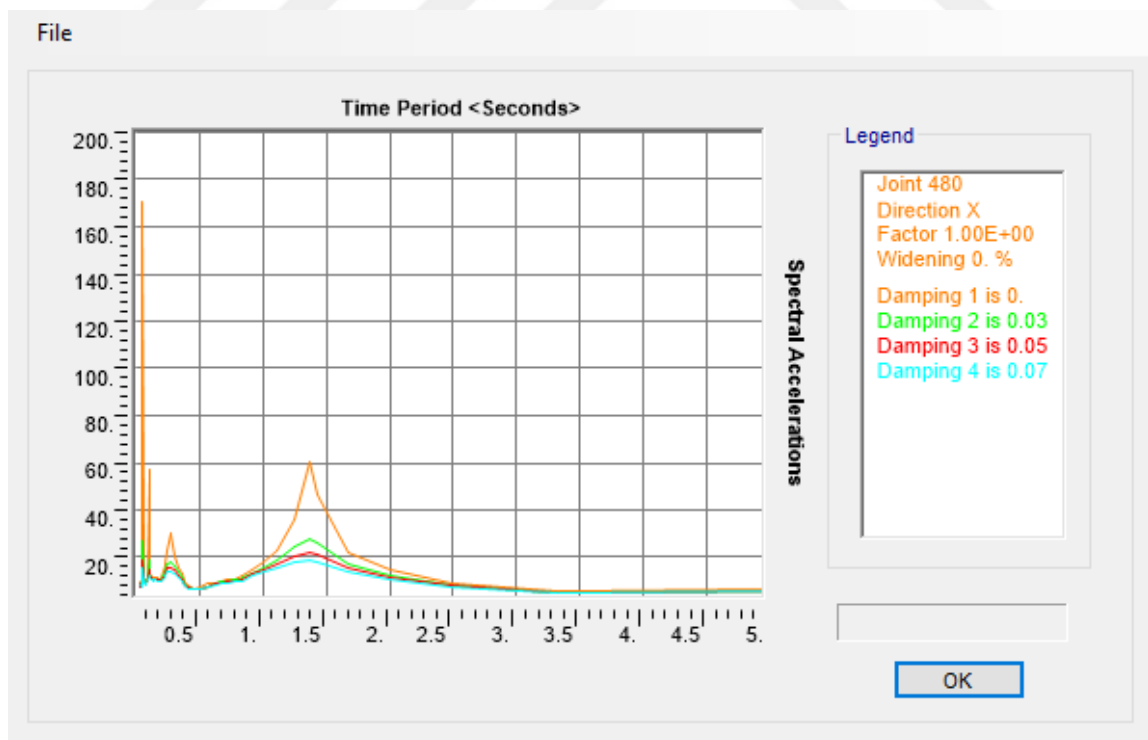


Figure 4.176: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 20° with Shear Wall.

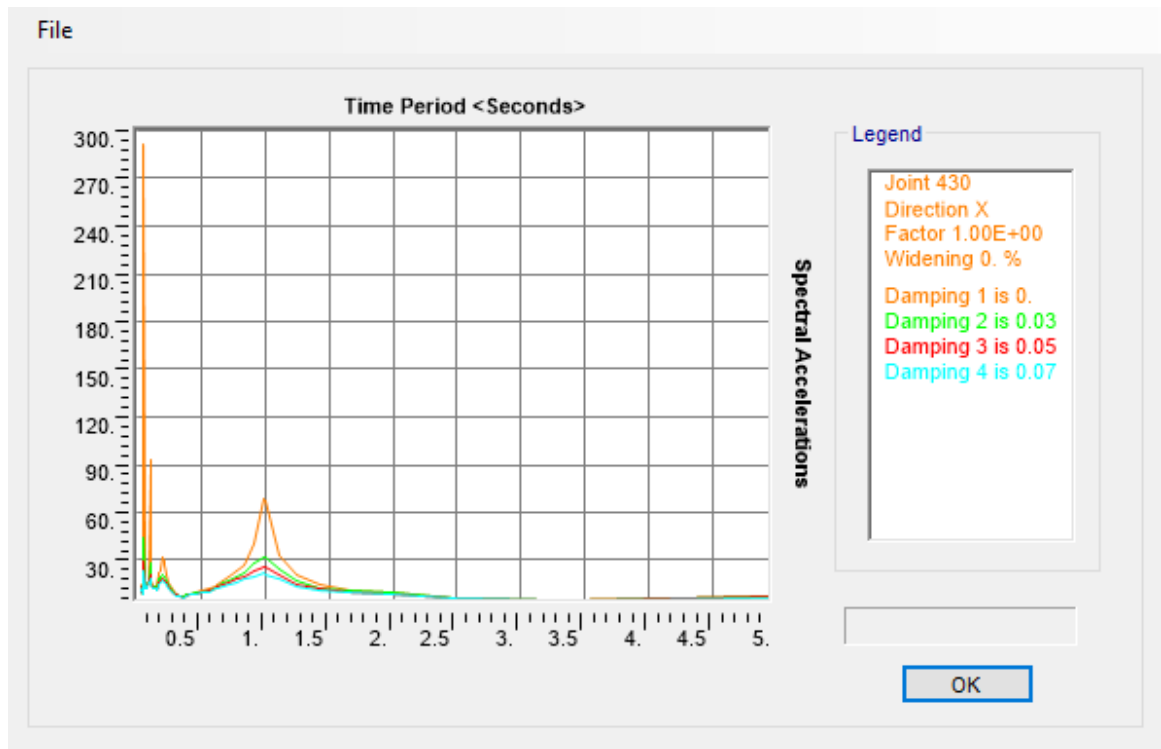


Figure 4.177: Spectral Accelerations with Time Period of 20-Storey Building Inclined with an Angle of 40° with Shear Wall.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

The numerical modelling applying is the commercial finite element (FE) software SAP2000 to the RC buildings having inclined foundation under the influence of the El Centro N-S 1940 earthquake acceleration was carried out in this study.

This study deals with the use of finite element analysis to study the response of an RC building that has inclined supporting leads in the foundations. A verification study was performed to analyze the RC building using SAP2000 software, which was collected from the previous literature. Several RC buildings were studied to evaluate the seismic performance of these buildings under the influence of change in four parameters using SAP2000 software. These parameters are the degree of inclination of the foundations (0° , 10° , 20° & 40°), the number of storeys (8, 12, 16 & 20 storey), the span length (4, 5 & 6 m), and the storey height (3, 3.5 & 4) m.

5.2 CONCLUSIONS

This study's conclusions are summarized as follows:

- a. This study aimed to verify the stability of multi-storey structures with sloping foundations under the influence of seismic load. The case studies were based on the time history analysis of buildings, where evaluated the performance of buildings under the influence of the El Centro N-S 1940 earthquake acceleration record of the imperial valley earthquake using SAP2000 software. In addition, the response spectrum method was used in the analysis of buildings that have inclined foundations. Buildings on the inclined foundations are found as more vulnerable than the buildings that have flat support points in the foundations, and the degree of vulnerability increases with the increment of slope angle.
- b. The verification modeling process was useful because it gave a perception of the results obtained by previous researchers, as well as developed the skill of using the SAP2000 software and gave confidence in the results obtained in the present work. All results obtained in the current work were close to the results of previous literature. The percentage of error in the results obtained from the applied models didn't exceed 5%.

- c. In the case absence of shear walls:
- i. The values of the base shear, time period and roof displacements decreased by (23%, 33% and 55%) respectively, when the degree of foundation inclination of the building increased from 0° to 20° , due to the difference in stiffness and geometry of the buildings having inclined foundation.
 - ii. The values of the base shear, time period and roof displacements increased by 68%, 53.28% and 137.6% respectively, when the No. of storeys increased from 8 to 12. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings. The increases in time period due to decrease the stiffness of RC building and it have more displacements at tip of buildings.
 - iii. The value of the base shear, Time period, frequency and displacements increased by (6.5%, 63% and 144%) respectively, when the storey height increased from 3 m to 4 m, when the degree of the foundation inclination 40° and storey number 20.
 - iv. The base shear, time period and roof displacements values increased by (29%, 10% and 24%) respectively, when the span length increased from 4 m to 5 m, when the degree of the foundation inclination 40° and storey number 20. However, it may lead to made to redistribution the internal forces and re-arranged the location of plastic hinges. This phenomenon can be accrued because the increasing of span length leads to decreasing the lateral stiffness of beams of studied RC building.
 - v. When the storey number was 12, the value of the storey drift decreased by (4.7%, 10.4% & 27.3%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 12th storey level. While its value increased by (24% & 55.8%) when the span length increased from 4 m to (5 & 6) m respectively, (at the 12th storey level and the degree of the foundation inclination was 40°). Also, its value increased by (24% & 55.8%) when the storey height increased from 3 m to (3.5 & 4) m respectively, (at the 12th storey level and the inclination foundation was 40°).
 - vi. Using response spectrum method, when the storey number was 12 the value of displacements decreased by (69%, 97% & 98%) when the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 2nd storey level. While its value decreased by (10%, 23% & 56%) at the degree of the foundation inclination increased from 0° to (10° , 20° & 40°) respectively, at the 12th storey level.

- d. In the case presence of shear walls (percentages had been calculated by comparing the results obtained in the case presence of shear walls with the case absence of shear walls, depending on one of the parameters studied, as shown below):
- i. The base shear values increased by 50% under the influence of the increase in the degree of inclination of the foundations. While its values increased by 20-40% under the influence of increase in the No. of storey. Also, the values of base shear increased by (32%, 20.5% & 94%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°), while its values increased by (94%, 50.7% & 46%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).
 - ii. The time period values decreased by 48% under the influence of the increase in the degree of inclination of the foundations. While its values decreased by 50-60% under the influence of the increase in the No. of storey. Also, the time period values decreased by (34%, 43.6% & 53.7%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°), while its value decreased by (53.7%, 50% & 50%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).
 - iii. The displacements in X direction values decreased by 60% under the influence of the increase in the degree of inclination of the foundations. While its values decreased by 70-80% under the influence of the increase in the No. of storey. The value of displacements in X direction decreased by (47.8%, 61% & 69%) when the span length was (4, 5 & 6) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°), while its value decreased by (69%, 60% & 60%) when the storey height was (3, 3.5 & 4) m respectively, (when the No. of storeys were 20 and the degree of foundation inclination 40°).
 - iv. The value of the storey drift decreased by 40-70% in the case presence of shear walls compared to its value in the absence of shear walls.
 - v. Using the response spectrum method, when the storey number was 16 the value of displacements decreased by (65-80%) when the storey level was (1 to 9). While its value decreased by (40-65%) when the storey level was (10 to 16).

5.3 RECOMMENDATIONS

This study's recommendations and future work are summarized as follows:

- a. In this study, the buildings that rest on inclined foundations in one direction were analyzed, while the buildings that rest on inclined foundations in two directions or set-back buildings can be studied.
- b. It is recommended to use single and combined base Isolation systems (such as Friction, Rubber and with the Addition of Rotational Friction Dampers) in multi-storey reinforced concrete buildings subject to seismic loads. It is also recommended to add the basement of floors to the buildings to obtain higher stability.
- c. In this study, square buildings were analyzed, so it is recommended to study the rest of the shapes, such as rectangular and circular buildings. Also study the effect of the number of spans on results.
- d. The methods of time history and response spectrum were used in the analysis of buildings, but there are other methods that can be used such as pushover analysis.
- e. In this study, the effect of soil wasn't considered, so it is recommended to study its effect.
- f. In this study, the buildings were studied under the influence of the El Centro N-S 1940 earthquake acceleration, so the effect of other types of earthquakes can be considered.

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