

**REPUBLIC OF TÜRKİYE
İSTANBUL GELİŞİM UNIVERSITY
INSTITUTE OF GRADUATE STUDIES**

Department of Civil Engineering

**COMPARATIVE SEISMIC ANALYSIS OF
REINFORCED CONCRETE BUILDINGS WITH
VARIED GEOMETRY OF STRUCTURAL MEMBERS**

Master's Thesis

Abdulahi Mohamed GURE

Supervisor

Asst. Prof. Dr. Ahmad Reshad NOORI

İstanbul – 2025

THESIS INTRODUCTION FORM

Name and Surname : Abdulahi Mohamed GURE

Language of the Thesis : English

Name of the Thesis : Comparative Seismic Analysis Of Reinforced Concrete Buildings With Varied Geometry Of Structural Members

Institute : Istanbul Gelisim University Institute of Graduate Studies

Department : Civil Engineering

Thesis Type : Master

Date of the Thesis : 09.07.2025

Page Number : 159

Thesis Supervisors : Asst. Prof. Dr. Ahmad Reshad NOORI

Index Terms : Structural Configuration, Earthquake-Resistant Design, Dynamic Analysis, Reinforced Concrete Structures.

Turkish Anstract : Bu tezde, farklı taşıyıcı eleman geometrilerine sahip betonarme binaların deprem sırasında nasıl davrandığı incelenmiştir. Yapıların dayanıklılık ve rijitlik özellikleri karşılaştırılmış, deprem etkilerinin yapılar üzerindeki etkisi değerlendirilmiştir. Bu çalışma, deprem güvenliği için daha iyi tasarımlar yapılmasına katkı sağlamayı hedeflemektedir.

Distribution List : 1. To the Institute of Graduate Studies of Istanbul Gelisim University
2. To the National Thesis Center of YÖK (Higher Education Council)

Signature

Abdulahi Mohamed GURE

**REPUBLIC OF TÜRKİYE
İSTANBUL GELİŞİM ÜNİVERSİTESİ
İNSTITUTE OF GRADUATE STUDIES**

Department of Civil Engineering

**COMPARATIVE SEISMIC ANALYSIS OF
REINFORCED CONCRETE BUILDINGS WITH
VARIED GEOMETRY OF STRUCTURAL MEMBERS**

Master's Thesis

Abdulahi Mohamed GURE

Supervisor

Asst. Prof. Dr. Ahmad Reshad NOORI

İstanbul – 2025

DECLARATION

I hereby declare that in the preparation of this thesis, scientific ethical rules have been followed, the works of other persons have been referenced in accordance with the scientific norms if used, there is no falsification in the used data, any part of the thesis has not been submitted to this university or any other university as another thesis.

Abdulahi Mohamed GURE

.../.../2025



TO ISTANBUL GELISIM UNIVERSITY
THE DIRECTORATE OF INSTITUTE OF GRADUATE STUDIES

The thesis study of Abdulahi Mohamed Gure titled as “Comparative Seismic Analysis of Reinforced Concrete Buildings with Varied Geometry of Structural Members” has been accepted as MASTER THESIS in the department of Civil Engineering by out jury.

Director *Assoc. Prof. Dr. Metin MEHMETOĞLU*

Member *Asst. Prof. Dr. Ahmad Reshad NOORI*
(Supervisor)

Member *Asst. Prof. Dr. Burak TOYDEMİR*

APPROVAL

I approve that the signatures above signatures belong to the aforementioned faculty members.

... / ... / 2025

Prof. Dr. İzzet GÜMÜŞ
Director of the Institute

SUMMARY

This thesis compares the seismic performance of reinforced concrete buildings with different structural element configurations, focusing on how their geometric variations affect earthquake response. A total of eight distinct building models are developed using SAP2000, each sharing the same basic floor layout but differing in the design of one or more structural elements. To ensure a consistent basis for comparison, all models are analyzed under identical seismic loading conditions defined by the Turkish Earthquake Code of 2018. The findings show that structural geometry plays a significant role in how buildings perform during seismic events. For instance, certain shear wall placements contributed to higher stiffness and better Drift control, while optimized slab configurations improved force distribution across floors. Likewise, adjustments to beam and column dimensions has notable effects on ductility and overall structural integrity. Rather than focusing solely on code compliance, this research emphasizes the importance of strategic design choices in enhancing seismic resilience. The study provides practical insights for engineers and designers, highlighting how thoughtful changes to individual elements can collectively improve a building's capacity to withstand earthquakes. By grounding the analysis in a widely used structural software and aligning it with a current national standard, the results offer both relevance and applicability to real-world engineering practice. Ultimately, the thesis supports a more holistic approach to structural design one that values the relationship between geometry, performance, and safety in earthquake-prone regions. These insights are especially valuable in today's world, where urban density and seismic risk often intersect. As cities continue to grow, designing safer, smarter buildings becomes not just a challenge, but a responsibility. The study's methodology is adaptable to other structural systems or seismic zones and can support future optimization research to balance cost, safety, and performance. This work contributes meaningfully to the ongoing development of earthquake-resistant design strategies in modern civil engineering.

Keywords: Structural Configuration, Earthquake-Resistant Design, Dynamic Analysis, Reinforced Concrete Structures.

ÖZET

Bu tez, farklı taşıyıcı eleman düzenlemelerine sahip betonarme binaların sismik performansını karşılaştırmakta ve bu elemanların geometrik değişimlerinin deprem davranışı üzerindeki etkilerini incelemektedir. Çalışmanın temel amacı, bu yapısal elemanların boyutlaradde değişikliklerin, binaların depreme karşı gösterdiği genel davranış üzerindeki etkilerini incelemektir. Bu kapsamda, SAP2000 yazılımı kullanılarak toplam sekiz farklı bina modeli oluşturulmuştur. Modellerin tümü aynı mimari plana sahip olacak şekilde tasarlanmış; ancak her birinde yalnızca kiriş, kolon, döşeme veya perde duvar gibi yapısal elemanlardan biri veya birkaçı farklılaştırılmıştır. Tüm modellere, 2018 Türkiye Deprem Yönetmeliği'ne göre belirlenmiş aynı deprem yükleri uygulanarak analizler gerçekleştirilmiştir. Yapıların davranışı dinamik analizler ve ayrıntılı sonlu eleman modelleri aracılığıyla değerlendirilmiş; yer değiştirme profilleri, taban kesme kuvvetleri, doğal titreşim periyotları ve kat öteleme oranları gibi kritik parametreler analiz edilmiştir. Elde edilen sonuçlar, taşıyıcı sistem geometrisinin sismik performans üzerinde belirleyici bir rol oynadığını göstermektedir. Örneğin, belirli perde duvar yerleşimlerinin yatay rijitliği artırdığı ve kat ötelenmelerini önemli ölçüde azalttığı gözlemlenmiştir. Benzer şekilde, döşeme düzenlemelerinin yük aktarımı üzerinde olumlu etkiler yarattığı, kolon ve kiriş boyutlarındaki değişikliklerin ise süneklik ve yapısal bütünlük açısından fark yarattığı görülmüştür. Bu çalışma, yalnızca yönetmeliklere uygunluk sağlamanın ötesine geçerek, yapı tasarımında bilinçli ve stratejik kararların depreme dayanıklılık üzerindeki etkisini vurgulamaktadır. Gerçek mühendislik uygulamalarına doğrudan katkı sağlayacak nitelikte olan bu tez, deprem riski yüksek bölgelerde daha güvenli ve dayanıklı betonarme yapıların tasarlanmasına yönelik kapsamlı ve uygulanabilir öneriler sunmaktadır. Analizlerin hem yaygın kullanılan bir mühendislik yazılımı ile yapılmış olması hem de güncel bir ulusal yönetmeliğe dayanması, çalışmanın gerçek hayattaki geçerliliğini artırmaktadır. Günümüzde kentleşmenin hızla arttığı ve sismik risklerin giderek daha fazla gündeme geldiği düşünüldüğünde, bu tür araştırmaların önemi daha da artmaktadır. Güvenli ve akıllı yapıların tasarımı artık yalnızca teknik bir zorunluluk değil, aynı zamanda mesleki bir sorumluluktur. Bu çalışmada kullanılan yöntem, farklı taşıyıcı sistemlere veya deprem bölgelerine uyarlanabilir ve maliyet, güvenlik ve performans dengesini hedefleyen optimizasyon çalışmalarına zemin hazırlar. Bu tez, modern inşaat

mühendisliğinde depreme dayanıklı tasarım stratejilerinin gelişimine anlamlı bir katkı sunmaktadır.

Anahtar Kelimeler:Yapısal Konfigürasyon,Depreme Dayanıklı Tasarım,Dinamik Analiz, Betonarme Yapılar.



TABLE OF CONTENTS

SUMMARY	i
ÖZET.....	ii
TABLE OF CONTENTS.....	iv
ABBREVIATION	vii
LIST OF FIGURES	viii
LIST OF TABLES	xi
PREFACE	xvii
INTRODUCTION.....	1

CHAPTER ONE

PREVIOUS STUDIES

1.1 Comparative Seismic Codes for RC Structures	3
1.2 Design Code Comparisons for Structural Elements.....	4
1.3 Seismic Behavior and Analysis Methods.....	6
1.4 Experimental and Advanced Modeling Studies	6
1.5 Material Innovation and Fiber-Reinforced Systems	7
1.6 Special Structures and Tanks	8

CHAPTER TWO

MATERIAL AND METHOD

2.1. Effective Earthquake Load and Procedures for Linear Earthquake Analysis.....	9
2.1.1. Classification of the Building by Intended Use and Determination of the Importance Factor	9
2.1.2. Determination of Earthquake Ground Motion Level and Definition of the Elastic Design Spectrum.	10
2.1.3. Earthquake Design Class Determination.	15
2.1.4. Determination of the Building Height Class.....	16
2.2. Building Performance Objectives	16
2.2.1. Building Performance Target and Design Approach Determination.....	17
2.2.2. Determination of the Carrier System.	17
2.3. Irregular Buildings Under Earthquake Effects.....	18
2.3.1. Irregularities in Plan.....	18
2.4. Control of Interstory Drift.....	25
2.5. Control of Second-Order Effects (θ_i)	26
2.6. Linear Seismic Analysis Using the Equivalent Seismic Load Method.....	28
2.6.1. Determination of Total Equivalent Earthquake Load.	29
2.6.2. Determination of Equivalent Earthquake Loads Acting on the Floors	29
2.6.3. Determination of the Dominant Natural Vibration Period of the Building. ..	31
2.7. Structural Analysis in Accordance with the Principles of TBDY-2018	32

2.7.1. Building Information.....	32
2.7.2 Material Information	33
2.7.3. Loads	33
2.7.4. Setup of the Structural Model and Modal Analysis	33

CHAPTER THREE

NUMERICAL METHODS AND APPLICATIONS

3.1 Analysis Using the Equivalent Seismic Load Method.....	50
3.1.1 Calculation of Weights.....	50
3.1.2. Calculation of Floor Weights	50
3.1.3. Calculation of the Period Using Modal Analysis.....	51
3.2 Solution Under Equivalent Seismic Loads	59

CHAPTER FOUR

COMPARATIVE ANALYSIS OF RESULTS

4.1 Torsional Irregularity Check	75
4.1.1 Torsional Irregularity Check for Model 1	75
4.1.2 Torsional Irregularity Check for Model 2.....	77
4.1.3 Torsional Irregularity Check for Model 3.....	78
4.1.4 Torsional Irregularity Check for Model 4.....	80
4.1.5 Torsional Irregularity Check for Model 5.....	82
4.1.6 Torsional Irregularity Check for Model 6.....	84
4.1.7 Torsional Irregularity Check for Model 7	86
4.1.8 Torsional Irregularity Check for Model 8.....	88
4.2. Soft Floor Check	90
4.2.1 Soft Floor Check For Model 1	90
4.2.2 Soft Floor Check For Model 2	92
4.2.3 Soft Floor Check For Model 3	93
4.2.4 Soft Floor Check For Model 4	95
4.2.5 Soft Floor Check For Model 5	97
4.2.6 Soft Floor Check For Model 6	98
4.2.7 Soft Floor Check For Model 7	100
4.2.8 Soft Floor Check For Model 8	102
4.3 Interstory Drift Control	104
4.3.1 Interstory Drift Control For Model 1	104
4.3.2 Interstory Drift Control For Model 2	105
4.3.3 Interstory Drift Control For Model 3	106
4.3.4 Interstory Drift Control For Model 4	108
4.3.5 Interstory Drift Control For Model 5	109
4.3.6 Interstory Drift Control For Model 6	111
4.3.7 Interstory Drift Control For Model 7	112

4.3.8 Interstory Drift Control For Model 8	113
4.4 2nd Order Effect.....	115
4.4.1 2nd Order Effect For Model 1.....	115
4.4.2 2nd Order Effect For Model 2.....	116
4.4.3 2nd Order Effect For Model 3.....	118
4.4.4 2nd order effect for model 4	119
4.4.5 2nd Order Effect For Model 5.....	120
4.4.6 2nd Order Effect For Model 6.....	122
4.4.7 2nd Order Effect For Model 7.....	123
4.4.8 2nd Order Effect For Model 8.....	125

CHAPTER FIVE

SUMMARY OF RESULTS

5.1 Summarized result of torsional irregularity	127
5.2 Summarized result of soft floors	128
5.3 Summarized result of interstory Driftt control.....	128
5.4 Summarized result of 2nd order effect.....	129

CONCLUSION AND RECOMMANDATIONS.....	130
--	------------

REFERENCES.....	132
------------------------	------------

ABBREVIATION

AFAD	:	Disaster and Emergency Management Authority (of Turkey)
D	:	Strength reduction factor (Resistance factor)
DD-2	:	Probability of exceedance 10% in 50 years (period 475 years)
DD-3	:	Probability of exceedance 50% in 50 years (period 43 years)
F_s	:	Local ground effect coefficient for a period of 1.0 seconds
F₁	:	Local ground impact coefficient for the short period region
H	:	Story height
n	:	Total number of stories with vertical load-bearing system
PGA	:	Maximum ground acceleration [g]
PGV	:	Maximum ground speed [cm/sec]
R	:	Structural behavior factor
S	:	Maximum ground acceleration [g]
S₁	:	Map spectral acceleration coefficient for 1.0 second period
S_{DS}	:	Short period design spectral acceleration coefficient
S_{D1}	:	Design spectral coefficient for 1.0 second period
S_{ae}(T)	:	Horizontal elastic design spectral acceleration [g]
S_{aeD}(T)	:	Vertical elastic design spectral acceleration [g]
S_{aR}(T)	:	reduced design spectral acceleration
S_s	:	Short period map spectral acceleration coefficient
T	:	Natural vibration period [s]
T_A	:	Horizontal elastic design spectrum corner period[s]
T_{AD}	:	Vertical elastic design spectrum corner period(s)
T_B	:	Horizontal elastic design spectrum corner period [s]
T_{BD}	:	Vertical elastic design spectrum corner period [s]
TBDY-2018	:	Turkish Building Earthquake Code 2018
V	:	Average shear wave velocity at upper 30 meters [m/s]
ZB	:	Soil Class Definition

LIST OF FIGURES

Figure 1. Building Usage Categories	9
Figure 2. DD2 Afad map output	10
Figure 3. DD2 local soil class	11
Figure 4. DD2 local ground effect coefficient	11
Figure 5. DD2 Design spectral acceleration coefficient	12
Figure 6. DD2 Elestic design spectrum.....	12
Figure 7. DD3-Afad map outputs.....	13
Figure 8. DD3-local soil class	13
Figure 9. DD3-Design spectral acceleration coefficient	14
Figure 10. DD3 localground effect coefficient	14
Figure 11. DD3- elastic design spectrum	15
Figure 12. Earthquake design class(DTS).....	15
Figure 13. Building Height Classes and Building Height Ranges	16
Figure 14. Building Performance Targets	17
Figure 15. Building Carrier System	17
Figure 16. Relative story displacements	19
Figure 17. Shifted mass centers.....	19
Figure 18. Criteria for Using the Equivalent Seismic Force Approach on Buildings.....	20
Figure 19. A2 Type Irregularity Condition-I	20
Figure 20. A2 Type Irregularity Condition-I I	21
Figure 21. A2-type irregularity conditions – III.....	21
Figure 22. A3 Type Irregularity Condition	21
Figure 23. Relative Story Displacements	22
Figure 24. Condition where columns are seated on cantilevers or corbels	23
Figure 25. Situation where a column is seated on a beam supported at both ends	24
Figure 26. Situation where the shear wall is seated on columns.....	24
Figure 27. Equivalent Seismic Load	28
Figure 28. Moving Load Mass Participation Coefficient.....	31
Figure 29. Defining the System of Units	34
Figure 30. Creating a New Model in SAP2000	34

Figure 31. Template Selection	35
Figure 32. Defining Grid Dimensions.....	35
Figure 33. Editing Grid Spacings.....	36
Figure 34. Material Assignment.....	37
Figure 35. Setting Region and Material Type	37
Figure 36. Entering Material Properties	38
Figure 37. Selection of Concrete Property Type.....	38
Figure 38. Beam Section Definition and Dimensions.....	39
Figure 39. Effective Cross-Sectional Rigidity Multipliers of Reinforced Concrete Carrier System Elements	40
Figure 40. Beam Stiffness Modification	40
Figure 41. column Section Definition and Dimensions	41
Figure 42. column Stiffness Modification.....	41
Figure 43. Slab Section Setup	42
Figure 44. Shear Wall Section Setup	43
Figure 45. Beam Drawing	44
Figure 46. Slab Drawing	44
Figure 47. Slab Meshing I.....	45
Figure 48. Slab Meshing II.....	45
Figure 49. Slab Meshing III	46
Figure 50. Beam Division	46
Figure 51. Assigning Fixed Supports.....	48
Figure 52. Rigid Diaphragm Setup	48
Figure 53. Rigid Diaphragm Setup I	49
Figure 54. Rigid Diaphragm Setup II.....	49
Figure 55. Moving Load Mass Participation Coefficient.....	50
Figure 56. Preparing Model for Seismic Load Reanalysis.....	67
Figure 57. Setting Up Quake Load Type for EXP Direction	67
Figure 58. EXP Load Pattern Definition.....	68
Figure 59. EXN Load Pattern Definition	68
Figure 60. EYP Load Pattern Definition.....	68

Figure 61. EYN Load Pattern Definition	69
Figure 62. Displacements Under Seismic Load	69
Figure 63. Displacements Under Seismic Loads II.....	70



LIST OF TABLES

Table 1. Structural Dimensions per Model.....	33
Table 2. Floor Weight	51
Table 3. Calculated Periods for Model 1.....	51
Table 4. Calculated Periods for Model 2.....	52
Table 5. Calculated Periods for Model 3.....	52
Table 6. Calculated Periods for Model 4.....	53
Table 7. Calculated Periods for Model 5.....	53
Table 8. Calculated Periods for Model 6.....	54
Table 9. Calculated Periods for Model 7.....	54
Table 10. Calculated Periods for Model 8.....	55
Table 11. Period Check Summary.....	56
Table 12. DD2 Seismic Parameters per model.....	57
Table 13. DD3 Seismic Parameters per model.....	58
Table 14. Earthquake Load Reduction Coefficients.....	59
Table 15. reduced horizontal elastic design spectra	59
Table 16. equivalent seismic loads per Model	60
Table 17. total equivalent seismic loads for top floors.....	61
Table 18. EX-direction total equivalent seismic loads for Model 1	61
Table 19. EY-direction total equivalent seismic loads for Model 1	62
Table 20. EX total equivalent seismic loads for Model 2	62
Table 21. EY total equivalent seismic loads for Model 2	62
Table 22. EX total equivalent seismic loads for Model 3	63
Table 23. EY total equivalent seismic loads for Model 3	63
Table 24. Ex total equivalent seismic loads for Model 4	63
Table 25. EY total equivalent seismic loads for Model 4	64
Table 26. EX total equivalent seismic loads for Model 5	64
Table 27. EY total equivalent seismic loads for Model 5	64
Table 28. EX total equivalent seismic loads for Model 6	65
Table 29. EY total equivalent seismic loads for Model 6	65
Table 30. EX total equivalent seismic loads for Model 7	65

Table 31. EY total equivalent seismic loads for Model 7	65
Table 32. EX total equivalent seismic loads for Model 8	66
Table 33. EY total equivalent seismic loads for Model 8	66
Table 34. Floor Displacements for Model 1.....	70
Table 35. Floor Displacements for Model 2.....	71
Table 36. Floor Displacements for Model 3.....	71
Table 37. Floor Displacements for Model 4.....	72
Table 38. Floor Displacements for Model 5.....	72
Table 39. Floor Displacements for Model 6.....	73
Table 40. Floor Displacements for Model 7.....	73
Table 41. Floor Displacements for Model 8.....	74
Table 42. Model 1 EXP for torsional irregularity	75
Table 43. Model 1 EXN for torsional irregularity	76
Table 44. Model 1 EYP for torsional irregularity	76
Table 45. Model 1 EYN for torsional irregularity	76
Table 46. Model 2 EXP for torsional irregularity	77
Table 47. Model 2 EXN for torsional irregularity	77
Table 48. Model 2 EYP for torsional irregularity	78
Table 49. Model 2 EYN for torsional irregularity	78
Table 50. Model 3 EXP for torsional irregularity	78
Table 51. Model 3 EXN for torsional irregularity	79
Table 52. Model 3 EYP for torsional irregularity	79
Table 53. Model 3 EYN for torsional irregularity	80
Table 54. Model 4 EXP for torsional irregularity	80
Table 55. Model 4 EXN for torsional irregularity	81
Table 56. Model 4 EYP for torsional irregularity	81
Table 57. Model 4 EYN for torsional irregularity	82
Table 58. Model 5 EXP for torsional irregularity	82
Table 59. Model 5 EXN for torsional irregularity	83
Table 60. Model 5 EYP for torsional irregularity	83
Table 61. Model 5 EYN for torsional irregularity	84

Table 62. Model 6 EXP for torsional irregularity	84
Table 63. Model 6 EXN for torsional irregularity	85
Table 64. Model 6 EYP for torsional irregularity	85
Table 65. Model 6 EYN for torsional irregularity	86
Table 66. Model 7 EXP for torsional irregularity	86
Table 67. Model 7 EXN for torsional irregularity	87
Table 68. Model 7 EYP for torsional irregularity	87
Table 69. Model 7 EYN for torsional irregularity	88
Table 70. Model 8 EXP for torsional irregularity	88
Table 71. Model 8 EXN for torsional irregularity	88
Table 72. Model 8 EYP for torsional irregularity	89
Table 73. Model 8 EYN for torsional irregularity	89
Table 74. Model 1 EXP for soft floor	90
Table 75. Model 1 EXN for soft floor	90
Table 76. Model 1 EYP for soft floor	91
Table 77. Model 1 EYN for soft floor	91
Table 78. Model 2 EXP for soft floor	92
Table 79. Model 2 EXN for soft floor	92
Table 80. Model 2 EYP for soft floor	92
Table 81. Model 2 EYN for soft floor	93
Table 82. Model 3 EXP for soft floor	93
Table 83. Model 3 EXN for soft floor	94
Table 84. Model 3 EYP for soft floor	94
Table 85. Model 3 EYN for soft floor	95
Table 86. Model 3 EYN for soft floor	95
Table 87. Model 4 EXN for soft floor	95
Table 88. Model 4 EYP for soft floor	96
Table 89. Model 4 EYN for soft floor	96
Table 90. Model 5 EXP for soft floor	97
Table 91. Model 5 EXN for soft floor	97
Table 92. Model 5 EYP for soft floor	98

Table 93. Model 5 EYN for soft floor	98
Table 94. Model 6 EYN for soft floor	98
Table 95. Model 6 EXP for soft floor	99
Table 96. Model 6 EXN for soft floor	99
Table 97. Model 6 EYN for soft floor	99
Table 98. Model 7 EXP for soft floor	100
Table 99. Model 7 EXN for soft floor	100
Table 100. Model 7 EYP for soft floor	101
Table 101. Model 7 EYN for soft floor	101
Table 102. Model 8 Exp for soft floor	102
Table 103. Model 8 Exn for soft floor	102
Table 104. Model 8 Eyp for soft floor	103
Table 105. Model 8 EYN for soft floor	103
Table 106. Model 1 EXP for interstory drif control	104
Table 107. Model 1 EXN for interstory drif control	104
Table 108. Model 1 EYP for interstory drif control	104
Table 109. Model 1 EYN for interstory drif control	105
Table 110. Model 2 EXP for interstory drif control	105
Table 111. Model 2 EXN for interstory Drift control	105
Table 112. Model 2 EYP for interstory Drift control	106
Table 113. Model 2 EYN for interstory drif control	106
Table 114. Model 3 EXP for interstory drif control	106
Table 115. Model 3 EXN for interstory drif control	107
Table 116. Model 3 EYP for interstory drif control	107
Table 117. Model 3 EYN for interstory drif control	107
Table 118. Model 4 EXP for interstory drif control	108
Table 119. Model 4 EXN for interstory drif control	108
Table 120. Model 4 EYP for interstory drif control	108
Table 121. Model 4 EYN for interstory drif control	109
Table 122. Model 5 EXP for interstory drif control	109
Table 123. Model 5 EXN for interstory drif control	109

Table 124. Model 5 EYP for interstory drif control	110
Table 125. Model 5 EYN for interstory drif control	110
Table 126. Model 6 EXP for interstory drif control	111
Table 127. Model 6 EXN for interstory drif control	111
Table 128. Model 6 EYP for interstory drif control	111
Table 129. Model 6 EYN for interstory drif control	112
Table 130. Model 7 EXP for interstory drif control	112
Table 131. Model 7 EXN for interstory drif control	112
Table 132. Model 7 EYP for interstory drif control	113
Table 133. Model 7 EYN for interstory drif control	113
Table 134. Model 8 EXP for interstory drif control	113
Table 135. Model 8 EXN for interstory drif control	114
Table 136. Model 8 EYP for interstory drif control	114
Table 137. Model 8 EYN for interstory drif control	114
Table 138. Model 1 EXP for 2nd order effect	115
Table 139. Model 1 EXN for 2nd order effect	115
Table 140. Model 1 EYP for 2nd order effect	116
Table 141. Model 1 EYN for 2nd order effect	116
Table 142. Model 2 EXP for 2nd order effect	116
Table 143. Model 2 EXN for 2nd order effect	117
Table 144. Model 2 EYP for 2nd order effect	117
Table 145. Model 2 EYN for 2nd order effect	117
Table 146. Model 3 EXP for 2nd order effect	118
Table 147. Model 3 EXN for 2nd order effect	118
Table 148. Model 3 EYP for 2nd order effect	118
Table 149. Model 3 EYN for 2nd order effect	119
Table 150. Model 4 EXP for 2nd order effect	119
Table 151. Model 4 EXN for 2nd order effect	119
Table 152. Model 4 EYP for 2nd order effect	120
Table 153. Model 4 EYN for 2nd order effect	120
Table 154. Model 5 EXP for 2nd order effect	120

Table 155. Model 5 EXN for 2nd order effect	121
Table 156. Model 5 EYP for 2nd order effect.....	121
Table 157. Model 5 EYN for 2nd order effect	121
Table 158. Model 6 EXP for 2nd order effect.....	122
Table 159. Model 6 EXN for 2nd order effect	122
Table 160. Model 6 EYP for 2nd order effect.....	123
Table 161. Model 6 EYN for 2nd order effect	123
Table 162. Model 7 EXP for 2nd order effect.....	123
Table 163. Model 7 EXN for 2nd order effect	124
Table 164. Model 7 EYP for 2nd order effect.....	124
Table 165. Model 7 EYN for 2nd order effect	124
Table 166. Model 8 EXP for 2nd order effect.....	125
Table 167. Model 8 EXN for 2nd order effect	125
Table 168. Model 8 EYP for 2nd order effect.....	125
Table 169. Model 8 EYN for 2nd order effect	126
Table 170. Summary of Torsional Irregularities	127
Table 171. Summary Of Soft Floors	128
Table 172. Summary Of Soft Floors	128
Table 173. Summary 2nd Order Effect	129

PREFACE

First and foremost, I would like to express my sincere gratitude to Allah, the Almighty, for granting me the strength, patience, and clarity to complete this thesis and reach this significant milestone in my academic journey. I am profoundly thankful to my supervisor, Asst. Prof.Dr Ahmad Reshad NOORI, for his invaluable guidance, unwavering support, and constructive feedback throughout the research process. His encouragement and mentorship have been instrumental in shaping the direction and quality of this work.

I also wish to express my appreciation to the Civil Engineering Department at Istanbul Gelişim University and all its staff for providing a supportive academic environment that enabled me to complete my master's studies and pursue this research. My deepest gratitude goes to my beloved family for their unconditional love, endless prayers, and continuous encouragement. Your patience and support have been the foundation of my perseverance throughout this journey. Finally, I would like to extend my thanks to everyone who contributed in any way to the completion of this research and the achievement of my master's degree.

INTRODUCTION

Earthquake-prone regions around the world face significant risks that challenge the safety and sustainability of their infrastructure. In these areas, understanding the structural behavior of reinforced concrete (RC) buildings under seismic loads is one of the most vital aspects of earthquake engineering research. RC buildings remain a popular choice due to their inherent strength, versatility, and widespread use, but their actual performance during earthquakes can vary greatly depending on how their structural elements such as shear walls, beams, columns, and slabs are designed and arranged. Small variations in the geometry of these components can lead to substantial differences in how a building responds to seismic forces, influencing factors like stiffness, ductility, and energy dissipation capacity. Therefore, gaining a deep understanding of these effects is critical for developing robust, earthquake-resistant structures.

This thesis aims to explore these relationships by conducting a thorough comparative seismic analysis of RC buildings with varying structural geometries. Utilizing the advanced capabilities of SAP2000, a state-of-the-art structural analysis software, a total of 8 detailed analyses are carefully carried out. These models differ primarily in the geometric configurations of their key structural elements but maintain consistent floor layouts and material properties to ensure fair and accurate comparisons. The analyses strictly adhere to the guidelines and requirements of the 2018 Turkish Seismic Code, which incorporates contemporary performance-based design principles designed to improve the resilience of buildings in seismic zones.

The research focuses on assessing crucial seismic response parameters such as base shear, inter-story drift, mode shapes, natural vibration periods, and overall displacement patterns. To maintain consistency, uniform seismic loading conditions and boundary constraints are applied across all models. Dynamic analyses are carried out to capture a realistic range of structural behaviors under earthquake excitation. By doing so, this study not only examines the immediate effects of geometry on seismic response but also investigates how these variations impact the ductility and energy dissipation abilities of RC buildings, which are essential for preventing catastrophic failures.

Beyond the numerical and technical analyses, this research highlights the practical implications of geometric design choices in real-world engineering applications. It demonstrates that the careful positioning and sizing of shear walls, the optimization of slab layouts, and the precise dimensioning of beams and columns can collectively enhance a building's ability to withstand seismic forces while minimizing damage. Moreover, the study stresses the critical importance of meeting and exceeding code requirements through thoughtful detailing and design innovations.

Ultimately, this thesis contributes to the broader field of earthquake engineering by providing valuable data and insights that can inform engineers, architects, researchers, and policymakers. It supports the advancement of seismic design strategies that balance safety, cost-effectiveness, and constructability. As urban populations grow and construction accelerates in seismic regions, the need for resilient, well-designed structures has never been greater. This work helps pave the way for smarter building practices that not only comply with regulations but push beyond them to ensure the safety of communities and the longevity of infrastructure. Through this comprehensive approach, the thesis aims to inspire further research and development in optimizing reinforced concrete structural systems to meet the challenges posed by earthquakes worldwide.

CHAPTER ONE

PREVIOUS STUDIES

1.1 Comparative Seismic Codes for RC Structures

Suliman and Lu's (2024) study used four codes—EBCS-8, ECP-201, RPA-99, and GB-50011—to analyze the seismic performance of MRF-RC frames. Using linear time-history and static pushover analyses, the study focused on characteristics such as base shear and story Drift for different frame heights. Results demonstrated that, in comparison to African codes, the Chinese code (GB-50011) is more cautious and overestimates seismic performance. According to the study, with modifications for the local soil and seismic circumstances, the Chinese code can be used in Africa. Using SAP2000 and SOFiSTiK, Santos et al. (2013) analyzed seismic design standards for conventional structures in the US, Europe, and other countries. Key findings indicate significant variances in response spectrum shapes that impact results, but agreement on design parameters. The paper recommends more investigation on recurrence times and spectral structure to raise earthquake requirements.

Rajeev et al. (2019) studied the seismic performance of OMRF structures that were developed by British, European, and Indian norms. They discovered, using static pushover research, that the Indian code performed better than the others, requiring more steel for compliance and demonstrating superior base shear and displacement capability. In 2024, Kunwar et al. used seismic codes from China, India, Nepal, and Pakistan to investigate the seismic performance of RC low-rise buildings. Base shear, displacement, and tale Drift were among the responses they compared using linear static analysis and finite element Modeling. With base shear up to 3.1 times that of the Indian code, the Chinese code generated the highest seismic demands, highlighting significant disparities in seismic safety requirements between the two nations.

Landingin et al. (2013) analyze American code (IBC 2009), Philippine code (NSCP 2006), and Eurocode to assess a structure. The goal is to look into the variety that these codes cause. According to the findings, Eurocode 8 was more conservative, requiring

greater reinforcing and taking into account both directions of seismic effects, which resulted in safer structural designs. When comparing the seismic behavior of structures built to Eurocode 8 and Indian Standards (IS 1893), Bhavsar et al. (2014) discovered that Eurocode 8 increased base shear, story Drift, and reinforcement needs, which led to safer, more reinforced designs for RC columns.

The seismic response of isolated foundation buildings under various soil conditions was investigated by Hassan et al. (2018). They discovered that soft soils result in greater displacements and Drifts, and that base shear rises with soil flexibility. The seismic performance of reinforced concrete buildings developed using the Turkish Earthquake Code of 1998 was compared by Ergün et al. (2015). When comparing buildings designed between 1991 and 1998 to those designed between 1980 and 1990, they discovered that the former had better seismic capacity.

Resatoglu and Hamed (2019) applied RSM and ELM to compare EC 8 and NCSC 2015 for RC buildings. Although they observed ELM's larger and unfeasible levels, they discovered comparable base shear results.

1.2 Design Code Comparisons for Structural Elements

In 2013, Tabsh conducted a comparison of the reinforced concrete design codes of ACI 318 and BS 8110. Shear was found to be considerable, axial compression to be moderate, and flexure to be minimal. Because ACI 318 predicted lesser strength and more load impacts, it resulted in larger cross-sections and greater construction costs. The design codes for reinforced concrete (European, Indian, American, British, and Canadian) were compared by Izhar and Dagar (2018). The Canadian code needed the most reinforcing, while IS 456:2000 needed the least, they discovered.

ACI 318M-11 and BS 8110-97 were compared by Bashir (2014) for the design of short columns in Nigeria. They conducted research and design using SAP 2000 and Prokon 32 and discovered that, on average, ACI 318M-11 required less reinforcement than BS 8110-97, making it roughly 3% more cost-effective. ACI 318-08, TEC-07, and EC8 structural wall design methodologies were compared by Kurç et al. in (2011). In order to increase safety and cost-effectiveness, they pointed out flaws in TEC-07,

especially in the shear design, and recommended fixes, such as changing the criteria for reinforcement and magnification factors.

Gullu and Mohammed (2023) used the TS500 and ACI318-19 programs to compare the shear strength predictions of RC columns. They concluded that TS500 produced more trustworthy outcomes, especially when it came to concrete contributions. Using examinations, Amulu and Ezeagu (2017) examined BS 8110, Eurocode 2, and ACI 318 for RC beams under combined loads; ACI 318 provided the maximum shear, whereas Eurocode 2 provided the highest bending and torsion.

In 2019, Uzel evaluated the TS500-2000 shear strength equations for deep beams and developed a shear enhancement technique to increase precision. Gowrishankar (2008) used theory, literature, and ETABS Modeling to compare ACI 318 with BS 8110. It was determined that BS 8110 was more cost-effective and more appropriate for UAE building methods. In 2017, Nwoji¹ and Ugwu used a medium-rise concrete structure Model to compare BS 8110 and Eurocode 2. They discovered that EC2 is more adaptable, sensible, and cost-effective than BS 8110 and provides reduced span moments and column loads.

Zhang et al. (2021) applied ETABS and PKPM to compare the ACI and GB codes for the design of reinforced concrete. They discovered that the Chinese code required 9% less reinforcement, making it more cost-effective. Algott and Al Kafri (2023) compared BS 8110-97 and ACI 318M-11 for short column design using software analysis and found BS 8110 requires about 21.5% less reinforcement, thus being more economical.

ACI, EN, and IS codes for building design were compared by Adhav et al. (2019). They discovered that although EN and ACI codes were more cost-effective in some situations, they often required more reinforcing than IS, particularly for columns. According to a 2015 study by Nwofor et al., Eurocode 2 is more cost-effective than BS 8110 for continuous reinforced concrete beam design. It achieves required safety margins while using less reinforcement, reducing material costs. This makes Eurocode 2 a more economical and efficient option without compromising structural safety.

When comparing the seismic and wind design of a 50-story building using ACI 318-19 and Eurocode, Oussadou (2021) found that Eurocode was more economical and required less reinforcement.

1.3 Seismic Behavior and Analysis Methods

Using 532 data, Akkar and Bommer (2007) created empirical formulas to forecast displacement spectra in the Middle East and Europe. They discovered that Eurocode 8 understates long-period displacements and recommended changes for plateau period and spectral shapes. Arroyo et al. (2021) evaluated ASCE 7, NSR-10, and NEC-2015 for low-rise RC frame design using pushover and dynamic analysis. Despite minor design modifications, all codes demonstrated comparable seismic performance at the collapse protection level.

Tafheem et al. (2016) used the ESF and RS methodologies to investigate the seismic performance of a multistory RC building. They discovered that RS analysis resulted in reduced internal forces and displacements, indicating that dynamic analysis offers a more accurate seismic behavior prediction. The major influence of diaphragm and lateral rigidity on seismic demands is highlighted in Abdel-Raheem's 2010 work on Egyptian seismic codes, which suggests the application of nonlinear analytical approaches.

Özmen (2008) examined earthquake-resistant architecture in residential buildings in Turkey, highlighting the necessity of better building techniques to reduce the number of fatalities caused by disasters.

1.4 Experimental and Advanced Modeling Studies

Shear strength of RC beams was investigated by Jayasinghe et al. in 2021 using an ANN and 1237 experiments. They discovered that ANN outperformed the codes and that ACI 318-19 and AS 3600-2018 provided accurate forecasts. Using a database of 1237 shear tests, Jayasinghe et al. (2021) examined the minimum shear reinforcement requirements in AS 3600, ACI 318, and AS 5100. They discovered that AS 3600-2018 had a 50% smaller safety margin and suggested a constant factor of 0.75 for increased safety.

Using a database of 62 tests, Araújo et al. (2016) compared several design Models (NBR 9062, Eurocode 2, PCI, and three analytical methods) for precast concrete corbels. They discovered that, although all Models provided safe failure load estimates, methods

such as PCI and Campione et al.'s Model demonstrated superior accuracy based on failure mode and the presence of horizontal stirrups. In order to anticipate the behavior of reinforced concrete beams, Ahmad et al. (2023) used an Artificial Neural Network (ANN) technique, which they found to be highly accurate and closely matched experimental data.

Caterino et al. (2024) studied RC beams without using shear reinforcement using finite element analysis. They discovered that shear strength is greatly underestimated by the current coding formulations, particularly when beams fail in shear. The study highlights the necessity of code improvement and experimental validation. Using digital image correlation (DIC), Hamrat et al. (2022) experimentally examined the deflection of steel fibres reinforced concrete (SFRC) beams and contrasted the results with design codes. They discovered that major codes understated deflection in non-fibre beams and that SFRC beams had deflections that were 15–30% higher.

After comparing the minimum thickness requirements in CSA A23.3, ACI 318, and a suggested equation, Lee et al. (2013) came to the conclusion that the latter provides more accurate findings and ought to be used. Kiani et al. (2024) evaluated seismic variables in mixed concrete/steel buildings using the FEMA P695 technique and discovered that 18 archetypes performed adequately.

Yang and Ashour's (2008) study on reinforced concrete deep beams revealed that empirical and strut-and-tie Models were less conservative, especially when span-depth ratios and reinforcing circumstances varied.

1.5 Material Innovation and Fiber-Reinforced Systems

Bernard et al.(2020),analyzed 53 RC/FRC beams under flexure using different fiber types. They found that while current programs estimate crack widths quite well, improved inputs result in higher accuracy. Pacheco et al. (2019) analyzed 174 reinforced concrete beams and found that ACI 318 and Eurocode 2 give similar flexural predictions, but using recycled aggregates increases the cracking moment bias.

Kabashi et al. (2020) used code comparison and experiments to examine the flexural behavior of beams reinforced with steel bars, CFRP, and GFRP. They found that

GFRP/CFRP was appropriate for non-strict SLS circumstances and that ACI standards best matched test results. The flexural strength of corroded prestressed concrete beams is overestimated by Chinese, Eurocode, and ACI codes, according to Li et al. (2024), who suggest a more realistic Model based on the ACI standard.

1.6 Special Structures and Tanks

Izhar et al. (2019) compared seismic design standards using STAAD Pro V8i, examining RC buildings' behavior under seismic stresses, highlighting the importance of understanding international codes for safer structural design. Reinforced concrete structures during the 1999 Kocaeli earthquake were examined by Sezen et al. (2003). They discovered that although some buildings failed because of subpar detailing and construction, others with shear walls fared better.

In 2003, Fragomeni and Loo presented ACMC 2001 and compared it with AS3600-2001. They came to the conclusion that ACMC might be utilized on its own in Asia. Utilizing membrane simulation and finite element analysis, Workeluel et al. (2023) investigated the design of elevated Intze RCC water tanks utilizing EBCS, ACI, Eurocode, and IS codes. ACI 350.3 was the most thorough, IS codes were the most cost-effective, and Eurocode caught dynamic effects like vertical acceleration more accurately.

CHAPTER TWO

MATERIAL AND METHOD

2.1. Effective Earthquake Load and Procedures for Linear Earthquake Analysis

2.1.1. Classification of the Building by Intended Use and Determination of the Importance Factor

According to TBDY-2018, the building's usage category and importance factor are determined based on its intended function. This classification is made by referring to Figure 1, ensuring that the assigned values align with the purpose for which the structure is designed related values are presented in figures(1-11)

Building Use Class	Purpose of Use of the Building	Building Importance Coefficient (I)
BKS 1=	Buildings that need to be used after the earthquake, buildings where people are long-term and intensive, buildings where valuable goods are stored and buildings containing dangerous materials a) Buildings that need to be used immediately after the earthquake (Hospitals, dispensaries, health centers, fire brigade buildings and facilities, PTT and other communication facilities, transportation stations and terminals, energy production and distribution facilities, province, district governorship and municipality administration buildings, first aid and disaster planning stations) b) Schools, other educational buildings and facilities, dormitories and dormitories, military barracks, prisons, etc. c) Museums & Museums d) Buildings where toxic, explosive, flammable, etc. substances with properties are located or stored	1.5
BKS = 2	Buildings where people are located for a short time and intensively are shopping malls, sports facilities, cinemas, theaters, concert halls, places of worship, etc.	1.2
BKS = 3	Other buildings that do not fall within the definitions given for BKS=1 and BKS=2 (Residences, workplaces, hotels, building-type industrial structures, etc.)	1.0

Figure 1. Building Usage Categories

According to TBDY-2018, the building in question will be used for commercial purposes. Its Building Use Class (BKS) is 3, and its Building Importance Coefficient (I) is 1.0.

2.1.2. Determination of Earthquake Ground Motion Level and Definition of the Elastic Design Spectrum.

Earthquake hazard maps prepared for various ground motion levels can be accessed at <https://tdth.afad.gov.tr>.

By entering data such as coordinates, ground motion level, and site class into this system, the spectral acceleration coefficients calculated based on the site classification are obtained. Using these coefficients, the required horizontal and vertical elastic design spectra for the structure are generated.



The screenshot displays the 'Türkiye Earthquake Hazard Maps Interactive Web Application' interface. It features the AFAD logo and a map of Turkey with a red dot indicating the location. The 'User Inputs' section includes fields for Report Title (İC), Earthquake Ground Motion Level (DD-2), Local Soil Class (ZB), Latitude (40.6502°), and Longitude (35.8286°). The 'Outputs' section shows calculated values: $S_s = 1.045$, $S_1 = 0.319$, $PGA = 0.436$, and $PGV = 28.613$. Below these values are definitions for each parameter: S_s is the short period map spectral acceleration coefficient, S_1 is the map spectral acceleration coefficient for 1.0 second period, PGA is the maximum ground acceleration in g, and PGV is the maximum ground speed in cm/sec.

User Inputs			
Report Title:	İC		
Earthquake Ground Motion Level	DD-2	Earthquake ground motion level with a probability of being exceeded in 50 years of 10% (recurrence period of 475 years)	
Local Soil Class:	ZB	Slightly weathered, moderately strong rocks	
Latitude:	40.6502°		
Longitude	35.8286°		

Outputs			
$S_s = 1.045$	$S_1 = 0.319$	$PGA = 0.436$	$PGV = 28.613$
S_s : Short period map spectral acceleration coefficient [dimensionless]			
S_1 : Map spectral acceleration coefficient for 1.0 second period [dimensionless]			
PGA : Maximum ground acceleration [g]			
PGV : Maximum ground speed [cm/sec]			

Figure 2. DD2 Afad map output

Local Soil Classes				
Local Soil Class:	Soil Type	Average in the upper 30 meters		
		$(V_s)_{30}$ [m/s]	$(N_{60})_{30}$ [stroke/30 cm]	$(C_u)_{30}$ [kPa]
ZA	Solid, hard rocks	> 1500	-	-
ZB	Slightly weathered, moderately strong rocks	760 - 1500	-	-
ZC	Very dense layers of sand, gravel and hard clay or weak, weathered, highly fractured rocks	360 - 760	> 50	> 250
ZD	Medium dense - dense sand, gravel or very solid clay layers	180 - 360	15 - 50	70 - 250
ZE	Profiles containing loose sand, gravel or soft to solid clay layers ($C_u < 25$ kPa) with a total thickness of more than 3 m satisfying the conditions $PI > 20$ and $w > 40\%$	< 180	< 15	< 70
ZF	Soils requiring site-specific research and assessment: 1) Soils with a risk of collapse and potential collapse under the influence of an earthquake (liquefiable soils, highly sensitive clays, collapsible weakly cemented soils, etc.), 2) Clays with a total thickness of more than 3 meters of peat and/or high organic content, 3) High plasticity ($PI > 50$) clays with a total thickness of more than 8 meters, 4) Very thick (> 35 m) soft or medium-solid clays.			

Figure 3. DD2 local soil class

Local Ground Effect Coefficients						
Local Soil Class:	Local Ground Action Coefficient F_s for the short period region					
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s = 1.25$	$S_s \geq 1.50$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.9	0.9	0.9	0.9	0.9	0.9
ZC	1.3	1.3	1.2	1.2	1.2	1.2
ZD	1.6	1.4	1.2	1.1	1.0	1.0
ZE	2.4	1.7	1.3	1.1	0.9	0.8
ZF	Site-specific soil behavior analysis will be performed					

Local Soil Class: $F_s = 0.900$ for ZB and $S_s = 1.045$

Local Soil Class:	Local Ground Effect Coefficient F_1 for 1.0 second period					
	$ST \leq 0.10$	$ST = 0.20$	$ST = 0.30$	$ST = 0.40$	$ST = 0.50$	$ST \geq 0.60$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.8	0.8	0.8	0.8	0.8	0.8
ZC	1.5	1.5	1.5	1.5	1.5	1.4
ZD	2.4	2.2	2.0	1.9	1.8	1.7
ZE	4.2	3.3	2.8	2.4	2.2	2.0
ZF	Site-specific soil behavior analysis will be performed					

Figure 4. DD2 local ground effect coefficient

Local Soil Class: $F_1 = 0.800$ for ZB and $S_1 = 0.319$

Design Spectral Acceleration Coefficients

$$S_{DS} = S_S F_S = 1.045 \times 0.900 = 0.940$$

$$S_{D1} = S_1 F_1 = 0.319 \times 0.800 = 0.255$$

S_{DS} : Short period design spectral acceleration coefficient [dimensionless]

S_{D1} : Design spectral acceleration coefficient for 1.0 second period [dimensionless]

Figure 5. DD2 Design spectral acceleration coefficient

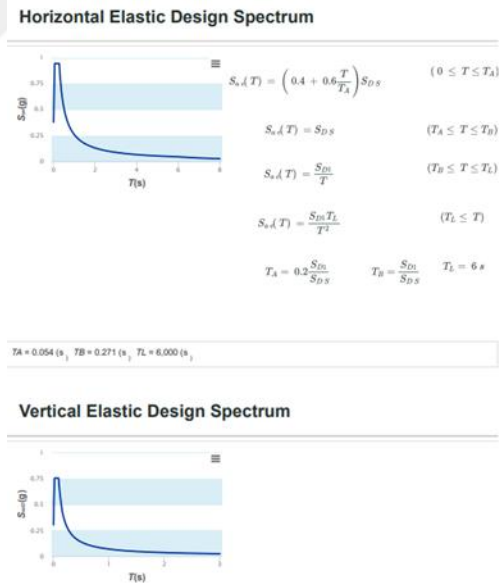


Figure 6. DD2 Elastic design spectrum

Türkiye Earthquake Hazard Maps Interactive Web Application

User Inputs

Report Title:	DD3
Earthquake Ground Motion Level:	DD-3 Earthquake ground motion level with a probability of being exceeded in 50 years of 50% (recurrence period of 72 years)
Local Soil Class:	ZB Slightly weathered, moderately strong rocks
Latitude:	40.6502°
Longitude:	35.8286°

Outputs

$S_s = 0.410$	$S_1 = 0.119$	$PGA = 0.177$	$PGV = 11.155$
S_s : Short period map spectral acceleration coefficient [dimensionless]			
S_1 : Map spectral acceleration coefficient for 1.0 second period [dimensionless]			
PGA : Maximum ground acceleration [g]			
PGV : Maximum ground speed [cm/sec]			

Figure 7. DD3-Afad map outputs

Local Soil Classes

Local Soil Class:	Soil Type	Average in the upper 30 meters		
		$(V_s)_{30}$ [m/s]	$(N_{60})_{30}$ [stroke/30 cm]	$(C_u)_{30}$ [kPa]
ZA	Solid, hard rocks	> 1500	-	-
ZB	Slightly weathered, moderately strong rocks	760 - 1500	-	-
ZC	Very dense layers of sand, gravel and hard clay or weak, weathered, highly fractured rocks	360 - 760	> 50	> 250
ZD	Medium dense - dense sand, gravel or very solid clay layers	180 - 360	15 - 50	70 - 250
ZE	Profiles containing loose sand, gravel or soft to solid clay layers or soft clay layers ($C_u < 25$ kPa) with a total thickness of more than 3 m satisfying the conditions $P_I > 20$ and $w > 40\%$	< 180	< 15	< 70
ZF	Soils requiring site-specific research and assessment: 1) Soils with a risk of collapse and potential collapse under the influence of an earthquake (liquefiable soils, highly sensitive clays, collapsible weakly cemented soils, etc.), 2) Clays with a total thickness of more than 3 meters of peat and/or high organic content, 3) High plasticity ($P_I > 50$) clays with a total thickness of more than 8 meters, 4) Very thick (> 35 m) soft or medium-solid clays.			

Figure 8. DD3-local soil class

Local Soil Class: $F_1 = 0.800$ for ZB and $S_1 = 0.119$

Design Spectral Acceleration Coefficients

$$S_{DS} = S_S F_S = 0.410 \times 0.900 = 0.369$$

$$S_{D1} = S_1 F_1 = 0.119 \times 0.800 = 0.095$$

S_{DS} : Short period design spectral acceleration coefficient [dimensionless]

S_{D1} : Design spectral acceleration coefficient for 1.0 second period [dimensionless]

Figure 9. DD3-Design spectral acceleration coefficient

Local Soil Class:	Local Ground Effect Coefficient F_1 for 1.0 second period					
	$S1 \leq_{0.10}$	$S1 =_{0.20}$	$S1 =_{0.30}$	$S1 =_{0.40}$	$S1 =_{0.50}$	$S1 \geq_{0.60}$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.8	0.8	0.8	0.8	0.8	0.8
ZC	1.5	1.5	1.5	1.5	1.5	1.4
ZD	2.4	2.2	2.0	1.9	1.8	1.7
ZE	4.2	3.3	2.8	2.4	2.2	2.0
ZF	Site-specific soil behavior analysis will be performed.					

Figure 10. DD3 localground effect coefficient

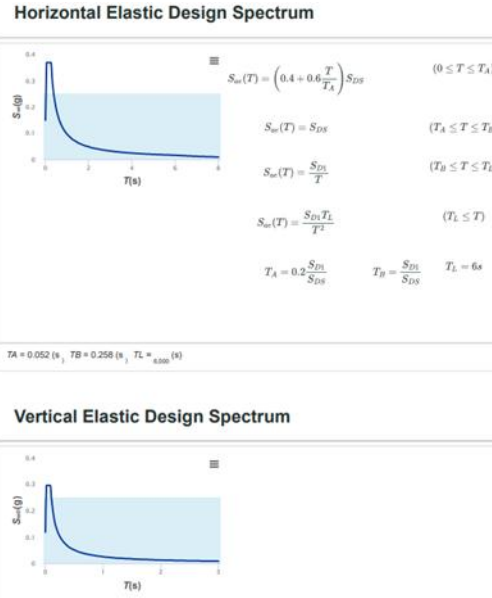


Figure 11. DD3- elastic design spectrum

2.1.3. Earthquake Design Class Determination.

The Earthquake Design Class (DTS) is determined in accordance with TBDY-2018, based on the Building Usage Category (BKS) and the short-period design spectral acceleration coefficient (SDS) as shown in Figure 12.

DD-2 Earthquake Ground Motion Level Short Period Design Spectral Acceleration Coefficient (S_{Ds})	Building Use Class	
	BKS 1=	BKS = 2, 3
$S_{Ds} < 0.33$	DTS = 4A	DTS = 4
$0.33 < S_{Ds} \leq 0.50$	DTS = 3A	DTS = 3
$0.50 < S_{Ds} \leq 0.75$	DTS = 2A	DTS = 2
$S_{Ds} \leq 0.75$	DTS = 1A	DTS = 1

Figure 12. Earthquake design class(DTS)

2.1.4. Determination of the Building Height Class.

Taking into account the total building height and the Earthquake Design Class (DTS), the Building Height Class (BYS) is determined in accordance with TBDY-2018 as given in Figure 13.

Building Height Class	Building Height Ranges defined by Building Height Classes and Earthquake Design Classes [m]		
	DTS = 1, 1a, 2, 2a	DTS 3, 3a=	DTS 4, 4a=
BYS 1=	$n70H >$	$> N 91H$	$n105H >$
BYS 2=	$n56 70 < H \leq$	$n70 91 < H \leq$	$n91 < 105H \leq$
BYS 3=	$n42 56 < H \leq$	$n56 70 < H \leq$	$n56 91 < H \leq$
BYS 4=	$n42 < 28 H \leq$	$n42 56 < H \leq$	
BYS 5=	$n17.5 < 28 \leq H$	$n42 < 28 H \leq$	
BYS 6=	$n10.5 \text{ to } 17.5 < H \leq$	$n17.5 < 28 \leq H$	
BYS 7=	$n7 10.5 < H \leq$	$n10.5 \text{ to } 17.5 < H \leq$	
BYS 8=	$n7H \leq$	$n10.5H \leq$	

Figure 13. Building Height Classes and Building Height Ranges

2.2. Building Performance Objectives

According to the earthquake ground motion levels, the performance objectives defined based on the Earthquake Design Classes (DTS) for buildings covered under this Regulation are presented in Table 8 and Table 9. For buildings in DTS = 1, 2, 3, 3a, 4, and 4a categories, Normal Performance Objectives are defined, while for buildings in DTS-1a and 2a categories, Enhanced Performance Objectives are specified.

Additionally, at the request of the building owner, it is possible to design using higher performance objectives corresponding to the earthquake ground motion levels. The building's design calls for seven floors and an overall height (HN) of eighteen meters. The Building Height Class (BYS) under the DTS-2 condition is $BYS = 5$, as shown in Figure 14. The figure indicates which case is applicable.

2.2.1. Building Performance Target and Design Approach Determination

Earthquake Location H. Level	DTS = 1, 2, 3, 3a, 4, 4a		DTS = 1a, 2A	
	Normal Performance Target	Evaluation/Design Approach	Advanced Performance Target	Evaluation/Design Approach
DD-4	QC	DGT	—	—
DD-3	—	—	.SH	SCTT
DD-2	KH	DGT(3)	KH	DGT(3.4)
DD-1	SEE	SCTT	KH	SCTT

Figure 14. Building Performance Targets

2.2.2. Determination of the Carrier System.

According to TBDY-2018, for Buildings where all earthquake effects are met with reinforced concrete shear walls with high ductility level bond beams, the structural system behavior factor is determined as $R = 7$, and the overstrength factor is $D = 2.5$. The building satisfies the permitted limits for Building Height Class $BYS = 3$ (see figure 15).

Building Carrier System	Carrier System Behavior Coefficient R	Excess Strength Coefficient D	Permitted Building Height Classes BYS
A. CAST REINFORCED CONCRETE BUILDING CARRIER SYSTEMS IN PLACE			
A1. High Ductility Carrier Systems			
A11. Buildings where all of the effects of earthquakes are met by reinforced concrete frames with <i>high ductility levels</i> that transmit momentum	8	3	$BYS \geq 3$
A12. Buildings where all earthquake effects are met with reinforced concrete curtains with <i>high ductility level bond beams (hollows)</i>	7	2.5	$BYS \geq 2$
A13. Buildings where all earthquake effects are met with reinforced concrete curtains with <i>high ductility levels</i>	6	2.5	$BYS \geq 2$
A14. Buildings where the effects of earthquakes are met together by reinforced concrete frames with <i>high ductility levels</i> and reinforced concrete curtains with <i>high ductility levels</i> (see 4.3.4.5)	8	2.5	$BYS \geq 2$
A15. Buildings where the effects of earthquakes are met together by reinforced concrete frames with a <i>high level of ductility</i> and reinforced concrete curtains with a <i>high level of ductility</i> (see 4.3.4.5)	7	2.5	$BYS \geq 2$
A16. Single-storey buildings where all the effects of earthquakes are met by reinforced concrete columns with articulated connections at the roof level and <i>high ductility levels</i> not exceeding 12 m in height	3	2	—

Figure 15. Building Carrier System

Irregularities in Buildings Under Earthquake Effects

In the regulation, irregularities are evaluated under two main categories.

- (1) irregularities in the plan layout, and
- (2) irregularities in the vertical (height) direction.

These types of irregularities are briefly outlined below.

2.3. Irregular Buildings Under Earthquake Effects

In the regulations, irregularities are examined in two separate groups. irregularities in plan and irregularities in the vertical direction. These irregularities are explained in detail below.

2.3.1. Irregularities in Plan

Irregularities that can occur in the building plan are examined under three headings.

A1 – Torsional Irregularity

The coefficient called the Torsional Irregularity Coefficient (η_{bi}) is defined as the ratio of the maximum relative story displacement to the average relative story displacement in the same direction on any story, for either of the two perpendicular earthquake directions.

If η_{bi} exceeds 1.2 on any story, torsional irregularity is considered to be present.

$$\eta_{bi} = (\Delta i)_{max} / (\Delta i)_{avg} > 1.2 \quad (1)$$

$$(\Delta i)_{max} = (d_i)_{max} - (d_{i-1})_{max} \quad (2)$$

$$(\Delta i)_{min} = (d_i)_{min} - (d_{i-1})_{min} \quad (3)$$

$$(\Delta i)_{avg} = ((\Delta i)_{max} + (\Delta i)_{min}) / 2 \quad (4)$$

Here, d_i is the displacement calculated under earthquake loads at the i -th story of the building (see figure 16-17).

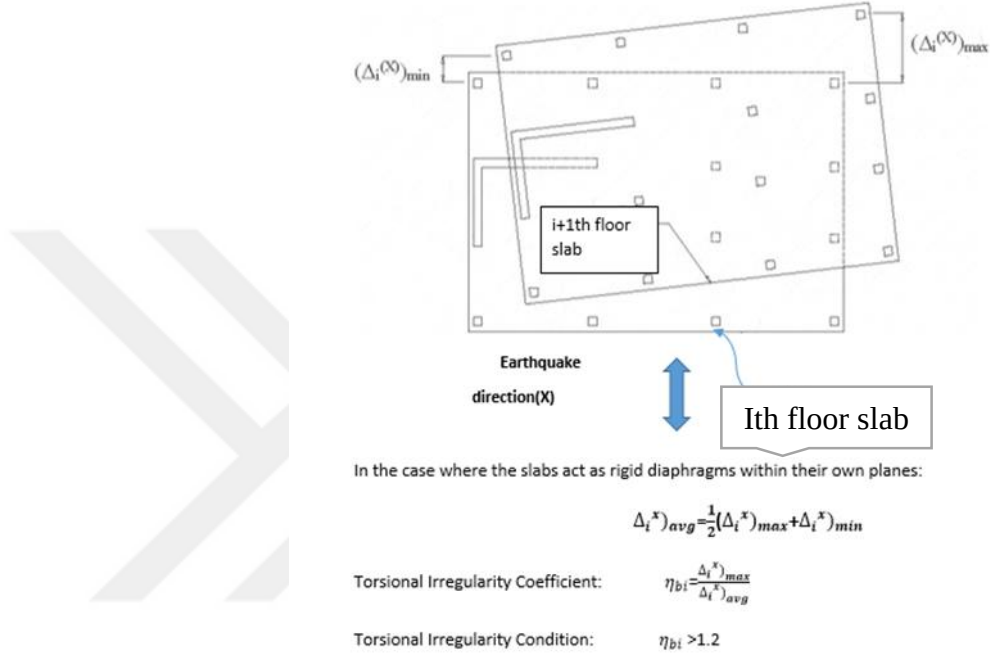


Figure 16. Relative story displacements

The story displacements (Δi) and the resulting relative story drifts $(\Delta i, r)$ must be calculated by applying the earthquake loads to the structure with a 5% eccentricity (See Figure 17).

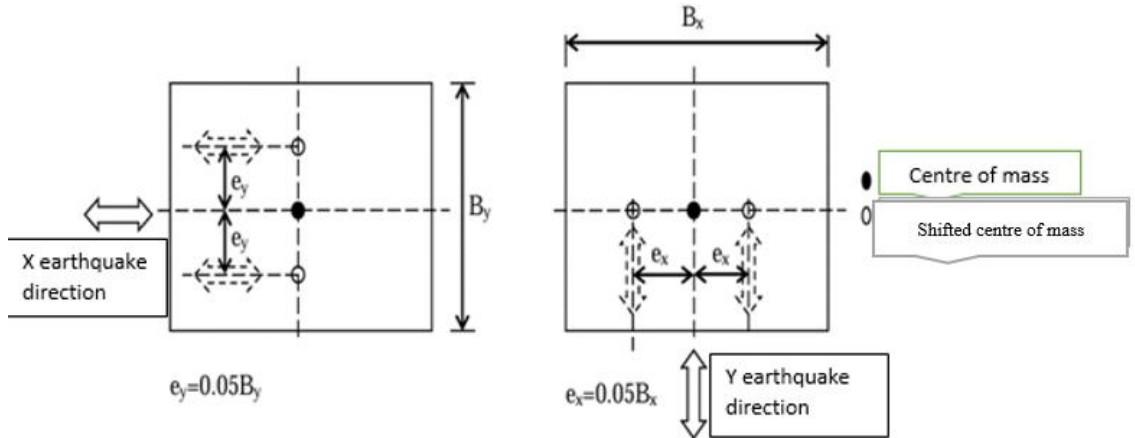


Figure 17. Shifted mass centers

If torsional irregularity exists at any i-th story of the building, and if $1.2 < \eta_{bi} \leq 2$, the eccentricity values in both directions must be amplified by the amplification factor D_{bi} and the analysis must be repeated.

$$D_{bi} = (\eta_{bi} / 1.2)^2 \quad (5)$$

It is expressed as follows.

If $\eta_{bi} > 2$, dynamic analysis is mandatory.

Building Type	Permissible Building Height Class	
	DTS = 1, 1a, 2, 2a	DTS = 3, 3a, 4, 4a
Buildings where the coefficient of torsional irregularity on each floor meets the condition of $\eta \leq 2.0$ and also does not have a type B2 irregularity	BYS ≥ 4	BYS ≥ 5
All other buildings	BYS ≥ 5	BYS ≥ 6

Figure 18. Criteria for Using the Equivalent Seismic Force Approach on Buildings

A2 – Floor Discontinuities

In any i-th floor slab.

I. If the total area of openings (A_b), including stairwells and elevator shafts, exceeds one-third ($1/3$) of the gross floor area (A) (see Figure 19).

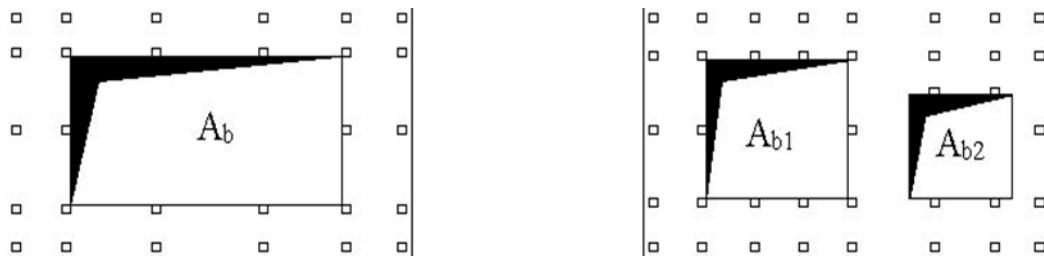


Figure 19. A2 Type Irregularity Condition-I

II. The presence of local slab openings (see Figure 20) that hinder the safe transfer of horizontal forces to the vertical load-resisting system elements.

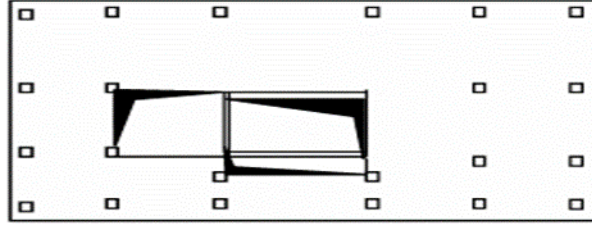


Figure 20. A2 Type Irregularity Condition-I I

III. Cases where there are sudden reductions in the in-plane stiffness and strength of the slab (see Figure 21).

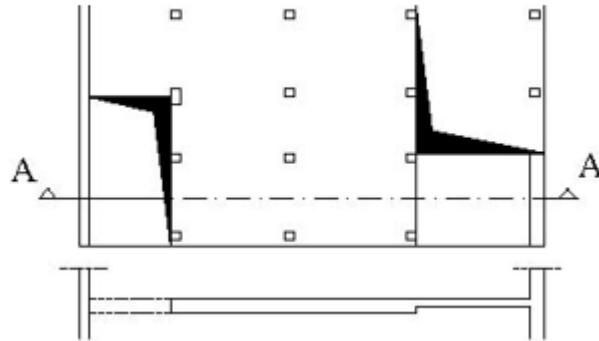


Figure 21. A2-type irregularity conditions – III

A3 – Presence of Plan Projections

This refers to cases where the indentations or projections in the building's floor plan have dimensions in both orthogonal directions (a_x , a_y) that exceed **20%** of the total plan dimensions (L_x , L_y) of that floor in the same directions (see Figure 22).

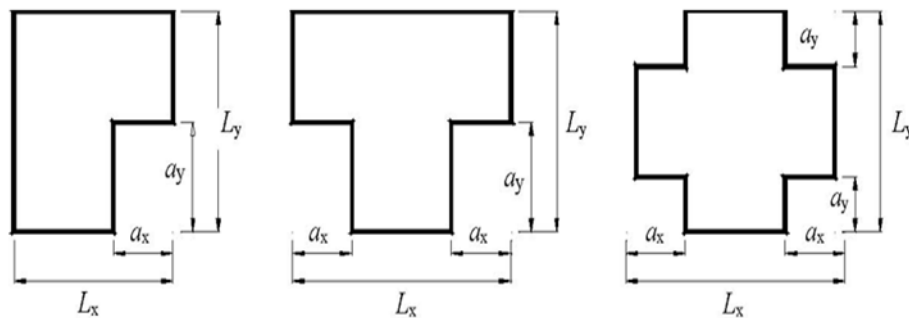


Figure 22. A3 Type Irregularity Condition

A2 and A3 Type Irregularities

In buildings where A2 or A3 type irregularities are present, the floor slabs must be Modeled using two-dimensional plate (membrane) or shell finite elements, in order to demonstrate that the slabs can safely transfer earthquake forces within their own plane to the vertical load-resisting system.

B2 – Adjacent Story Stiffness Irregularity (Soft Story)

This refers to the condition where, under $\pm 5\%$ accidental eccentricity horizontal force, the ratio of the average inter-story Drift at any i-th story to the average inter-story drift at the story above (defined as the stiffness irregularity coefficient, η_{ki}) exceeds 2.0 (see Figure 23).

$$\eta_{ki} = (\Delta_i / h_i)_{avg} / (\Delta_{i+1} / (h_{i+1})_{avg}) > 2 \quad (5)$$

$$\eta_{ki} = (\Delta_i / h_i)_{avg} / (\Delta_{i-1} / (h_{i-1})_{avg}) > 2 \quad (6)$$

A1 and B2 Type Irregularities

A1 (torsional irregularity) and B2 (adjacent story stiffness irregularity) are irregularities that, directly affect the selection of the seismic analysis method.

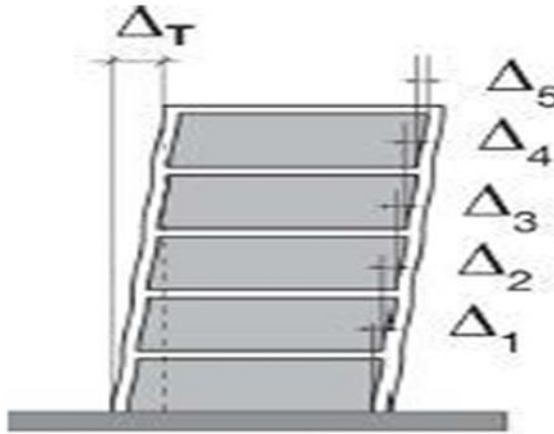


Figure 23. Relative Story Displacements

B3 – Discontinuity of Vertical Load-Bearing Elements

This refers to situations where vertical load-bearing elements such as columns or shear walls are removed on some floors, causing the beams or haunched columns to directly support the loads, or where shear walls on upper floors are seated directly on columns or beams below.

The new Earthquake Code recommends the following conditions to prevent the negative effects caused by B3-type irregularities.

Columns must never be placed on top of cantilever beams or on the ends or tops of haunched columns created in the lower stories (Figure 24).

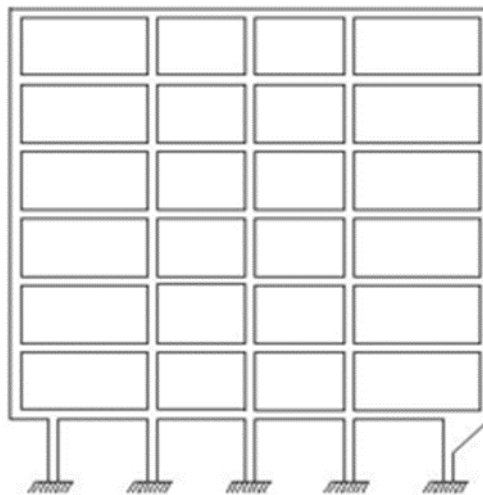


Figure 24. Condition where columns are seated on cantilevers or corbels

- A) In the case where a column is seated on a beam supported at both ends, it is sufficient to perform vertical earthquake analysis according to (Figure 25-26).

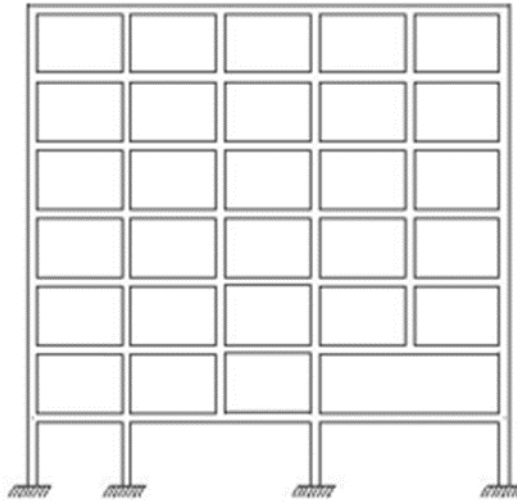


Figure 25. Situation where a column is seated on a beam supported at both ends

B) It is never permitted for the end of an upper-story shear wall to be seated directly on to columns below.

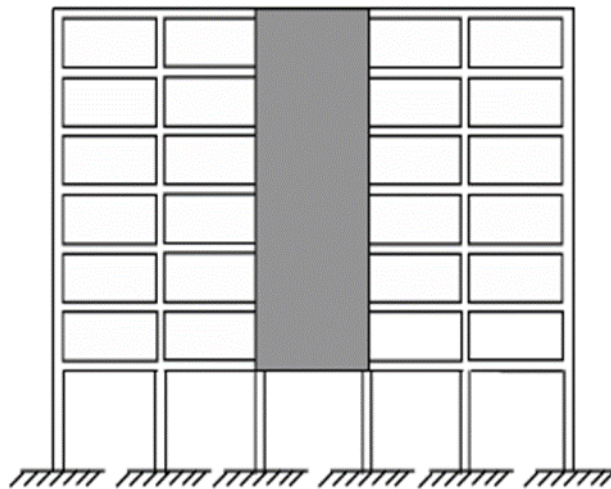


Figure 26. Situation where the shear wall is seated on columns

2.4. Control of Interstory Drift

For any column or shear wall in the (X) earthquake direction, the reduced interstory drift, denoted as $\Delta_i(x)$, representing the displacement difference between two consecutive stories, is obtained using the following equation.

$$\Delta_i^{(x)} = u_i^{(x)} - u_{i-1}^{(x)} \quad (7)$$

For the typical (X) earthquake direction, the effective interstory drift for the columns or shear walls at the i-th story of the building, denoted $\delta_i(x)$, is obtained using the following equation.

$$\delta_i(x) = \Delta_i(x) / h_i \quad (8)$$

where.

- $\Delta_i^{(x)}$ is the reduced interstory displacement (the displacement difference between floor i and floor i-1, as mentioned earlier),
- h_i is the clear story height between floors i and i-1.

$$\delta_i^{(x)} = \frac{R}{I} \quad (9)$$

For each earthquake direction, the maximum effective interstory drift, denoted as $\delta_{i,max}(x)$, among the effective interstory drifts $\delta_i(x)$ calculated by Equation (9) for the columns or shear walls at any i-th story of the building, shall satisfy one of the following conditions (a) or (b) given below.

Here, R is the structural system behavior factor, and I is the building importance factor.

(a) In cases where brittle materials such as hollow or solid infill walls, as well as façade elements, are placed directly adjacent to the frame elements without any joints or connections between them.

$$\lambda \frac{\delta_{i,max}^x}{h_i} \leq 0.008k \quad (10)$$

b) In cases where flexible joints are provided between brittle infill walls and frame elements, and where façade elements are structurally independent from the exterior frame.

$$\lambda \frac{\delta_{l,max}^x}{h_i} \leq 0.016\kappa \quad (11)$$

κ is taken as 1.0 for reinforced concrete buildings and 0.5 for steel buildings. The λ coefficient corresponds to the design spectrum value of the DD-3 earthquake ground motion for the dominant vibration period in the considered earthquake direction of the building.

The coefficient κ shall be taken as $\kappa = 1$ for reinforced concrete buildings and $\kappa = 0.5$ for steel buildings.

The coefficient λ is defined as the ratio of the elastic design spectral acceleration for the DD-3 earthquake ground motion to the elastic design spectral acceleration for the DD-2 earthquake ground motion, considering the dominant vibration period of the building in the relevant earthquake direction.

2.5. Control of Second-Order Effects (θ_i)

In systems subjected to lateral loads, second-order effects become significant when the normal forces in the columns are also large. The Second-Order Indicator, θ_i , is defined as.

defined as.

$$\theta_{l,i}^{(x)} = \frac{(\Delta_i^{(x)})_{avg} \sum_{k=i}^N w_k}{V_i^{(x)} h_i} \quad (12)$$

$$\theta_{l,max}^{(x)} \leq 0.12 \frac{D}{c_h R} \quad (13)$$

V_i denotes the shear force at the i-th story. h_i represents the story height at the i-th story, and $(\Delta_i^{(x)})_{avg}$ indicates the average interstory drift at the i-th story in the (X) earthquake direction.

The behavior factor of the structural system, R , and the overstrength factor, D , are provided in Table . In this case, local second-order effects can be considered in the element design according to the current reinforced concrete and steel design codes. The coefficient C_h represents a factor defined based on the nonlinear hysteretic behavior of the structural system. For reinforced concrete buildings, $C_h = 0.5$ while for steel and composite column buildings, $C_h = 1$

If the above condition is not satisfied, all internal forces for the considered (X) earthquake direction will be increased by multiplying them with the second-order amplification factor defined below

$$\beta_{II}^{(X)} = 0.88 + \frac{C_h}{D} \theta_{II,max}^{(X)} \geq 1 \quad (14)$$

Unless a less critical result is determined under the following provisions, the separation joints between adjacent blocks or buildings at each story shall not be less than the value obtained by multiplying the square root of the sum of the squared displacements of the neighboring blocks or buildings by the coefficient α defined below.

In cases where calculations for an existing (older) building cannot be performed, the displacements of the old building shall be assumed to be no less than the displacement values computed for the corresponding stories of the new building.

When the floor slabs of adjacent buildings or blocks are aligned at the same elevation across all stories, $\alpha = 0.25(R/I)$ shall be applied.

When the floor slabs of adjacent buildings or blocks are at different elevations, even if only at certain stories, $\alpha = 0.5(R/I)$ shall be applied to the entire structure.

In cases where two separate building blocks or two distinct sections of a building with different seismic behaviors are connected by a linking element such as a bridge, the displacement capacity of the movable support on one of the connected blocks, in both earthquake directions and senses, shall be at least 1.5 times the sum of the absolute values of the displacements calculated under reduced earthquake loads at the level of the connecting element, multiplied by the factor $1.5(R/I)$.

2.6. Linear Seismic Analysis Using the Equivalent Seismic Load Method

The Equivalent Seismic Load Method shall be applied separately for earthquakes acting in two orthogonal directions, namely the (X) and (Y) directions, on the building. The following formulations are provided for the (X) earthquake direction.

For both basement and non-basement buildings, the definitions of the building base and building height must adhere to the following considerations.

In basement buildings that satisfy both of the following conditions, the building base is defined at the floor level corresponding to the top elevation of the basement shear walls.

The presence of rigid basement shear walls that enclose the building either from all sides or at least on three sides;

The ratio of the fundamental vibration period calculated for the entire structure (including basement floors) in the dominant vibration mode along each principal axis, to the fundamental period calculated in the same direction without including the mass of the basement floors (but assuming the same structural system), is less than 1.1 ($T_{p,total} \leq 1.1T_{p,upper}$). For basement buildings that do not satisfy either of these conditions, as well as for non-basement buildings, the building base is defined at the top elevation of the foundation. For seismic analysis, the total building height H_N is defined as the vertical distance measured from the defined building base according to the above criteria. Within this definition, minor lightweight extensions situated above the roof slab such as elevator machine rooms or similar small-scale projections may be neglected (see figure 27).

Building Type	Permissible Building Height Class	
	DTS = 1, 1a, 2, 2a	DTS = 3, 3a, 4, 4a
Buildings where the coefficient of torsional irregularity on each floor meets the condition of $\eta \leq 2.0$ and also does not have a type B2 irregularity	$BYS \geq 4$	$BYS \geq 5$
All other buildings	$BYS \geq 5$	$BYS \geq 6$

Figure 27. Equivalent Seismic Load

2.6.1. Determination of Total Equivalent Earthquake Load.

In the considered (X) earthquake direction, the total equivalent earthquake load (base shear force) acting on the entire building, V_{tE}^X shall be determined using the following equation.

$$V_{tE}^X = m_t S_{aR}(T_p^x) \geq 0.04 m_t I S_{DS} g \quad (15)$$

In this context, $S_{aR}(T_p^x)$ denotes the Reduced Design Spectral Acceleration, calculated by considering the building's fundamental (dominant) natural vibration period in the (T_p^x) considered (X) earthquake direction.

$$m_t = \sum_{i=1}^N m_i \quad (16)$$

S_{DS} refers to the design spectral acceleration coefficient at short periods.

m_t represents the total mass of the building.

Here, m_i is the total mass of the i-th floor slab.

The term Reduced Design Spectral Acceleration refers to the spectral acceleration value adjusted by considering the reduction factors specified in the design process.

$$S_{aR}(T) = \frac{S_{ae}(T)}{R_a(T)} \quad (17)$$

The earthquake load reduction factor, $R_a(T)$ is defined as follows.

$$R_a(T) = \frac{R}{I} \quad T > T_B \quad (18)$$

$$R_a(T) = D + \left(\frac{R}{I} - D\right) \frac{T}{T_B} \quad T \leq T_B \quad (19)$$

2.6.2. Determination of Equivalent Earthquake Loads Acting on the Floors

The calculated total equivalent earthquake load is expressed as the sum of the equivalent earthquake loads acting on the building's floors.

$$V_{tE}^{(X)} = \Delta F_{NE}^{(X)} + \sum_{i=1}^N F_{iE}^{(X)} \quad (20)$$

The additional equivalent earthquake load acting on the N-th (top) floor of the building, DF_{NE}^X shall be determined as follows.

$$\Delta F_{NE}^{(X)} = 0.0075 N V_{tE}^{(X)} \quad (21)$$

The remaining portion of the total equivalent earthquake load, excluding DF_{NE}^X shall be distributed to the building's floors including the N-th floor using the following equation.

$$F_{iE}^{(X)} = (V_{tE}^{(X)} - \Delta F_{NE}^{(X)}) \frac{m_i H_i}{\sum_{j=1}^N m_i H_i} \quad (22)$$

In cases where the floor slabs are Modeled as rigid diaphragms, the equivalent earthquake load $F_{iE}^{(x)}$ calculated using the above equation, shall be applied at the main node of the i-th floor in the considered earthquake direction.

For buildings exhibiting A2 and A3 type irregularities and/or where the floor slabs are not assumed to act as rigid diaphragms including reinforced concrete flat slab systems the floors shall be Modeled using two-dimensional finite elements.

When the floor slabs are Modeled with plate (membrane) finite elements, the equivalent earthquake load acting on the j-th node at the i-th floor shall be calculated using the equation provided below.

$$f_{jE}^{(X)} = \frac{f_{iE}^{(X)}}{m_i} m_j^{(s)} \quad (23)$$

In this context, $m_j^{(s)}$ represents the lumped mass assigned to the j-th node.

$$m_j^{(s)} = \frac{m_j^{(s)}}{g} \quad (24)$$

$$w_j^{(s)} = w_{G,j}^{(s)} + n w_{Q,j}^s \quad (25)$$

Here, $w_{g,j}^s$ and $w_{q,j}^s$ represent, respectively, the combined permanent (dead) load and live load acting on finite element node j. The parameter n denotes the mass participation factor for the live load (see figure 28)

Purpose of Use of the Building	n
Warehouse, warehouse, etc.	0.80
School, student dormitory, sports facility, cinema, theater, concert hall, place of worship, restaurant, store, etc.	0.60
Residential, workplace, hotel, hospital, parking, etc.	0.30

Figure 28. Moving Load Mass Participation Coefficient

The total overturning moment at the base of the building caused by the earthquake loads is calculated using the equation provided below.

$$M_0^{(X)} = \sum_{i=1}^N F_{iE}^{(X)} H_i \quad (26)$$

2.6.3. Determination of the Dominant Natural Vibration Period of the Building.

In all buildings where the Equivalent Seismic Load Method is applied, the dominant natural vibration period of the building in the (X) and (Y) earthquake direction, denoted as $T_p(X)$ and $T_p(Y)$ shall be determined as follows unless a more precise calculation is performed.

$$T_p^{(X)} = 2\pi \sqrt{\frac{\sum_{i=1}^N m_i (d_{fi}^{(X)})^2}{\sum_{i=1}^N F_{fi}^{(X)} (d_{fi}^{(X)})}} \quad (27)$$

Here, F_{fi}^X denotes the fictitious load acting on the i-th floor in the (X) direction.

$$F_{iE}^{(X)} = (V_{tE}^{(X)} - \Delta F_{NE}^{(X)}) \frac{m_i H_i}{\sum_{j=1}^N m_j H_j} \quad (28)$$

In the equation, $V_{tE}^X - \Delta F_{NE}$ shall be replaced with any arbitrary value (for example, 100) for the purpose of determining the result.

The maximum value of the fundamental natural vibration period T_p calculated using the above equation, to be considered in the seismic analysis, shall not exceed 1.4 times the empirical fundamental natural vibration period T_{pA} to be considered in the seismic design calculations.

$$T_{pA} = C_t H_N^{3/4} \quad (29)$$

For buildings with structural systems composed solely of reinforced concrete frames, the coefficient C_t shall be taken as 0.1, for buildings composed of steel frames or braced steel frames, C_t shall be 0.08 and for all other types of buildings, C_t shall be taken as 0.07.

In buildings where the entire seismic effect is resisted by reinforced concrete shear walls, the coefficient C_t is:

$$C_t = \frac{0.1}{\sqrt{A_t}} \leq 0.07 \quad (30)$$

In this expression, C_t the equivalent area

$$A_t = \sum_j A_{wj} \left[0.2 + \left(\frac{l_{wj}}{H_N} \right)^2 \right] \leq \sum_j A_{wj} \quad (31)$$

2.7. Structural Analysis in Accordance with the Principles of TBDY-2018

2.7.1. Building Information

The analyzed workplace buildings are located in Amasya Province, Turkey (Latitude. 40.6502°, Longitude. 35.8286°).

A total of eight distinct buildings were evaluated. Each building is a six-story reinforced concrete (RC) frame structure composed of beams, columns, shear walls, and slabs. While all buildings share the same general structural system, they differ in their specific dimensions for columns, beams, shear walls, and slabs.

The details for each Model are listed in the table 1.

Tablo 1. Structural Dimensions per Model

Model	Columns	Beams	Shear Wall Thickness	Slab Thickness
Model 1	60 cm × 60 cm	50 cm × 30 cm	30 cm	15 cm
Model 2	70 cm × 70 cm	50 cm × 30 cm	30 cm	15 cm
Model 3	75 cm × 75 cm	50 cm × 30 cm	30 cm	15 cm
Model 4	60 cm × 60 cm	60 cm × 30 cm	30 cm	15 cm
Model 5	60 cm × 60 cm	50 cm × 35 cm	30 cm	15 cm
Model 6	60 cm × 60 cm	50 cm × 30 cm	30 cm	12 cm
Model 7	60 cm × 60 cm	50 cm × 30 cm	35 cm	15 cm
Model 8	60 cm × 60 cm	50 cm × 25 cm	25 cm	15 cm

2.7.2 Material Information

Concrete Class:C30

Reinforcing Steel Grade:S420

The local soil class has been determined as:ZB

2.7.3. Loads

Dead Load.

RC Slab weight= 15 cm $\rightarrow 0.15 \times 25 = 3.75 \text{ KN/m}^2$

Ceramic tile covering= $0.03 \times 20 = 0.60 \text{ KN/m}^2$

Leveling= $0.05 \times 22 = 1.1 \text{ KN/m}^2$

Leveling= $0.05 \times 20 = 0.40 \text{ KN/m}^2$

$G_1 = 5.85 \text{ KNm}^2$

Live load=3 KN/m²

Design load = $1.4 \times G + 1.6 \times Q = 1.4 \times 5.85 + 1.6 \times 3.0 = 13 \text{ KN/m}^2$

2.7.4. Setup of the Structural Model and Modal Analysis

The steps to be followed when performing an analysis using the SAP2000 software package are detailed below (see figuresdes 29-54)

Establishing the System Axe

1. The unit system to be used (KN, m, °C) is selected from the lower right corner of the SAP2000 interface.

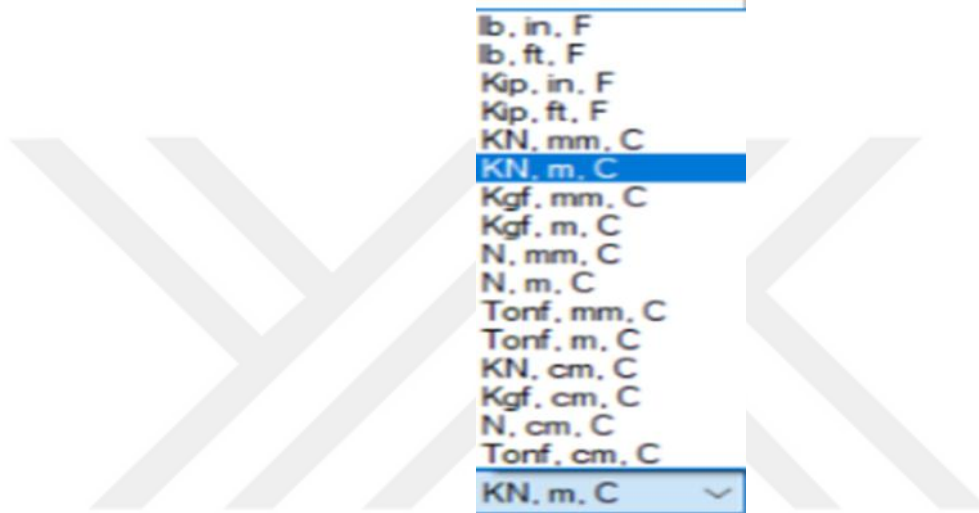


Figure 29. Defining the System of Units

2. from “file” toolbar we select “new Model”.

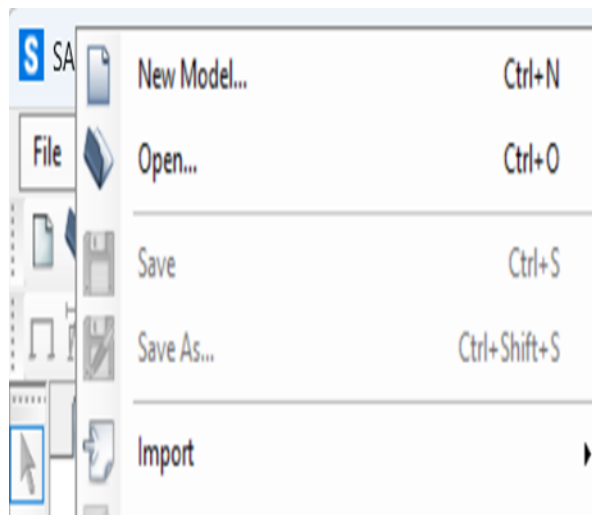


Figure 30. Creating a New Model in SAP2000

3. In the “New Model” window that opens, we select “Grid Only.

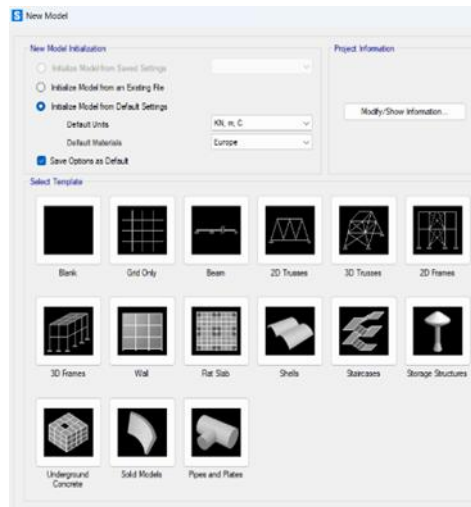


Figure 31. Template Selection

4. After selecting “Grid Only,” enter the number of axes in the X, Y, and Z directions (X direction → 9, Y direction → 11, Z direction → 7) in the “Quick Grid Lines” window, and save the input by clicking the OK button.

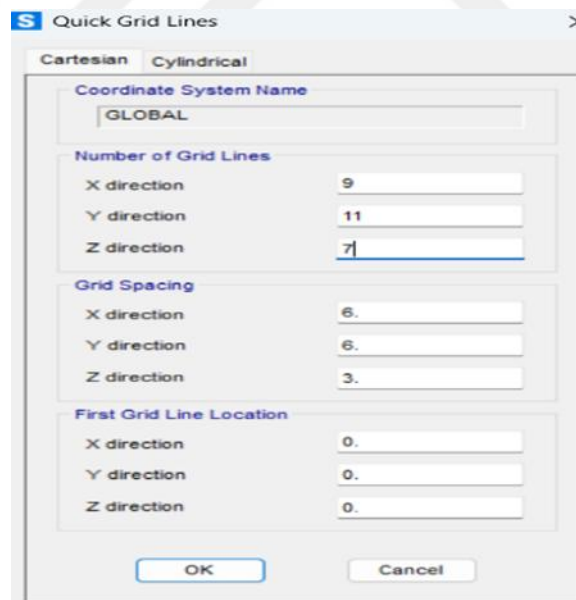


Figure 32. Defining Grid Dimensions

5. To adjust the spacings, double-click with the mouse while the pointer is positioned over an axis line. In the “Define Grid System Data” window, update the coordinates for the A to I axes in the X Grid Data column as (0,

0.65,1.22,1.7,2.65,3.65,5.22,9.42,13.42). Similarly, adjust the coordinates in the Y Grid Data(0, 5.1, 8.6, 11, 13.5, 16.1, 18.7, 21.2, 23.6, 27.1, 32.5) and Z Grid Data sections as specified below.

After entering each coordinate, press ‘Enter,’ and once all modifications are completed, click OK to save the changes.

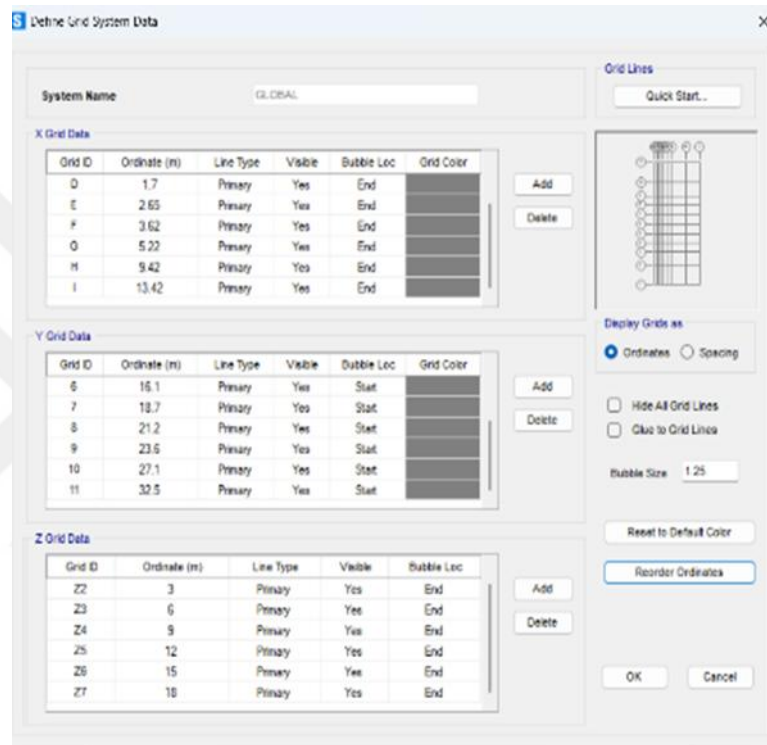


Figure 33. Editing Grid Spacings

6. access the “Materials...” section under the “Define” tab, and add a new material by clicking on ‘Add New Material.’

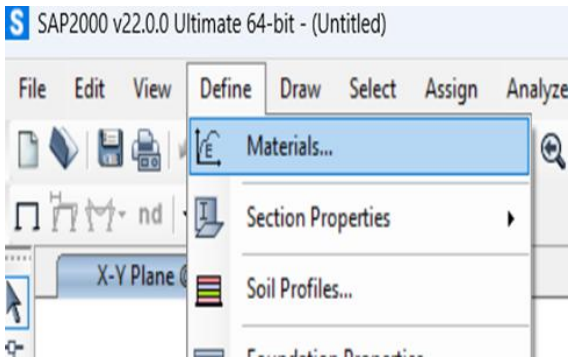


Figure 34. Material Assignment

In the “Add Material Property” window, the Region can be set to User, and the Material Type can be selected as Other.

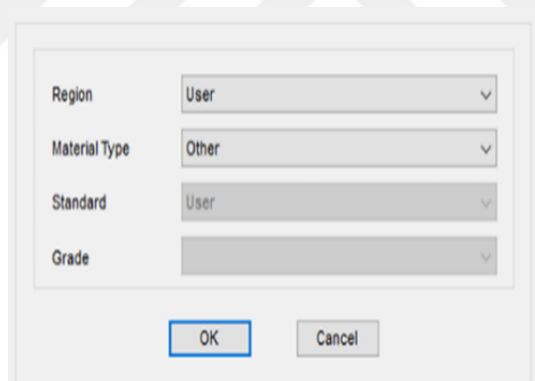


Figure 35. Setting Region and Material Type

The material name (concrete) and its properties are entered in the “Material Property Data” window.



Figure 36. Entering Material Properties

7. From the “Define” tab in the program toolbar, enter through “Section Properties” to “Frame Sections” to open the “Frame Properties” window.
8. In the “Frame Properties” window, click on ‘Add New Property, In the “Add Frame Section Property” window, select Concrete as the material and choose the rectangular section type from the Frame Section Property Type options.

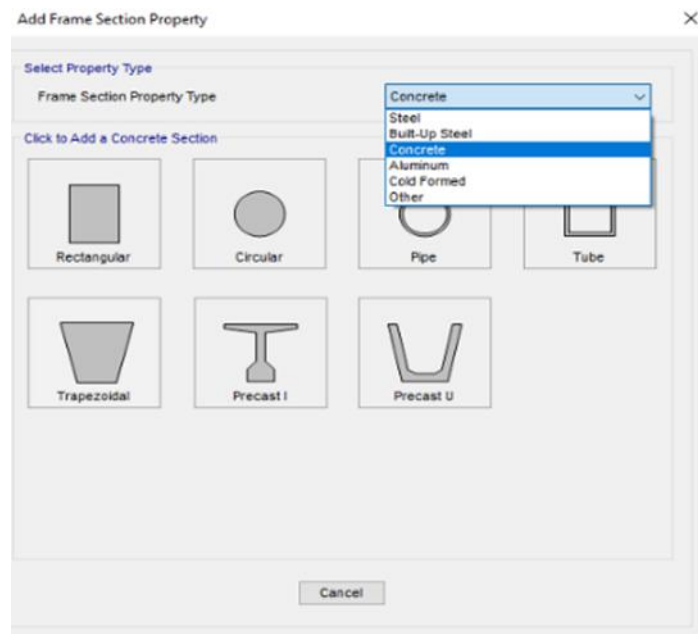


Figure 37. Selection of Concrete Property Type

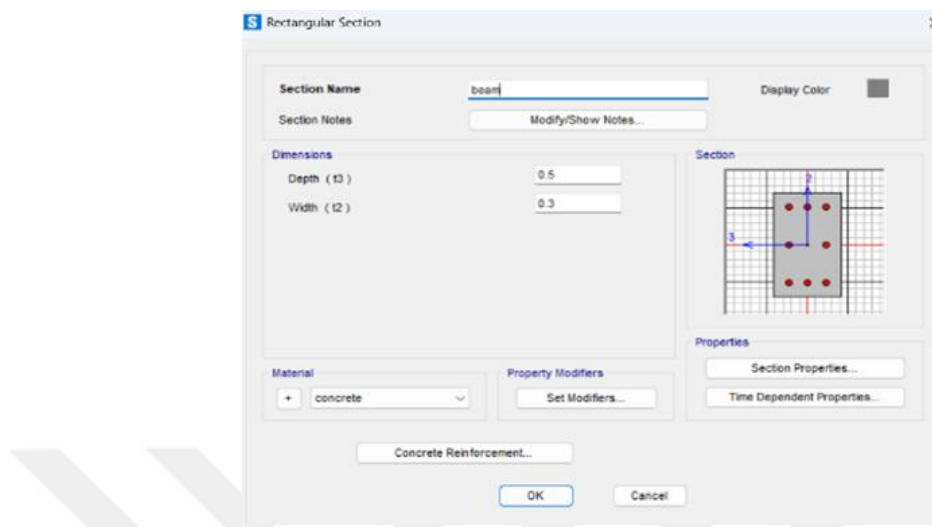


Figure 38. Beam Section Definition and Dimensions

In the “Rectangular Section” window, beam can be assigned as the Section Name. Within this window, the beam dimensions (depth = 0.5 m, width = 0.30 m) in Models 1,2,3,6 and 7, (depth=0.6, width=0.30) in Model 4,(depth=0.5, width=0.35) for Model 5 and (depth=0.5, width=0.25) are entered, and the material CONCRETE is selected.

Important Note. The Effective Section Stiffness Factors for reinforced concrete columns, beams, and slabs shall be defined by opening the “Frame Property/Stiffness Modification Factors” window via the “Set Modifiers” button associated with the relevant section. The Effective Section Stiffness Factors related to bending and shear effects for members, as well as in-plane and out-of-plane effects for slabs, shall be taken from the table below. These factors are applied exclusively in seismic analyses.

Reinforced Concrete Carrier System Element		
<i>Curtain – Flooring (In-Plane)</i>	<i>Axial</i>	<i>Glide</i>
Curtain	0.50	0.50
Basement curtain	0.80	0.50
Flooring	0.25	0.25
<i>Curtain – Flooring (Out of Plane)</i>	<i>Bending</i>	<i>Cut</i>
Curtain	0.25	1.00
Basement curtain	0.50	1.00
Flooring	0.25	1.00
<i>Bar element</i>	<i>Bending</i>	<i>Cut</i>
Vineyard beam	0.15	1.00
Frame beam	0.35	1.00
Frame column	0.70	1.00
Curtain (equivalent rod)	0.50	0.50

Figure 39. Effective Cross-Sectional Rigidity Multipliers of Reinforced Concrete Carrier System Elements

For the section named "beam", the Bending Moment of Inertia Stiffness Factors are defined as follows.

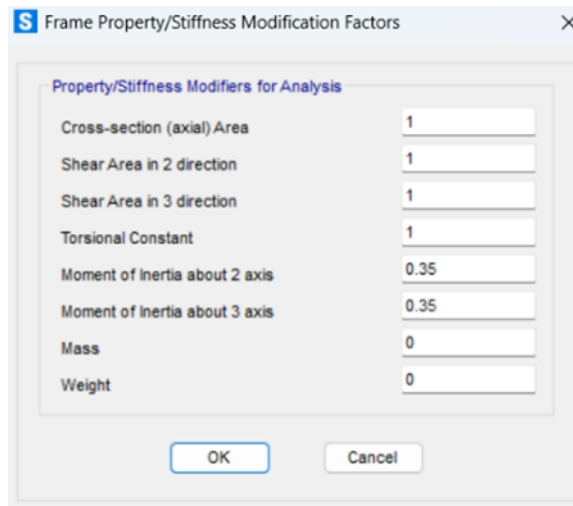


Figure 40. Beam Stiffness Modification

Note. For the bending moment of inertia stiffness factors of all column sections , the values will be defined by opening the "Frame Property/Stiffness Modification Factors" window under the "Set Modifiers" sub-button. In Step (7)'s "Frame

Properties" window, after selecting "Add New Property", the following procedure should be repeated sequentially for each different cross-section.

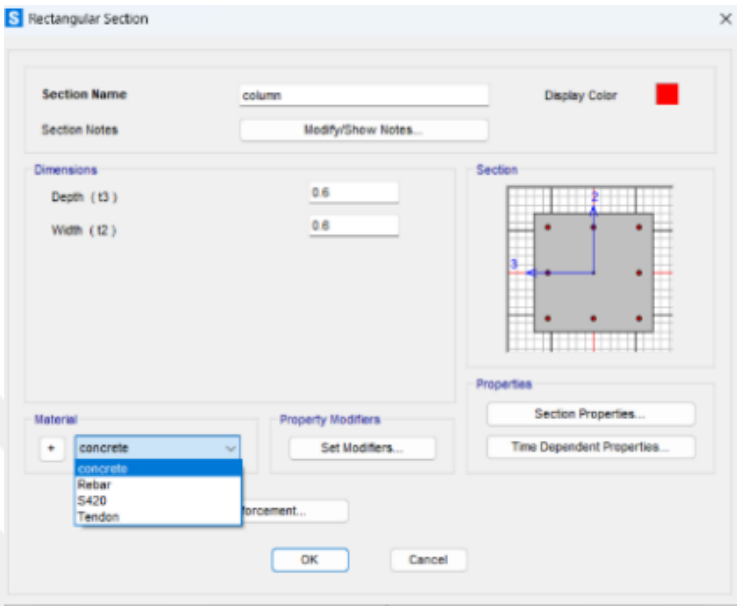


Figure 41. column Section Definition and Dimensions

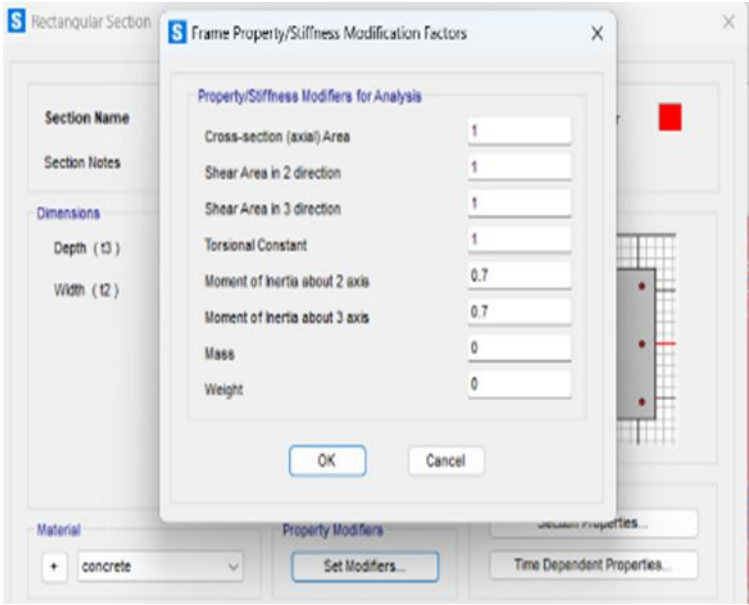


Figure 42. column Stiffness Modification

8) From the "Define" toolbar, sequentially open. "Section Properties" → "Area Sections...", Next, in the "Shell Section Data" window, enter slab as the Section Name and select Shell-Thick for the element type. Complete the remaining information in this window as shown below.

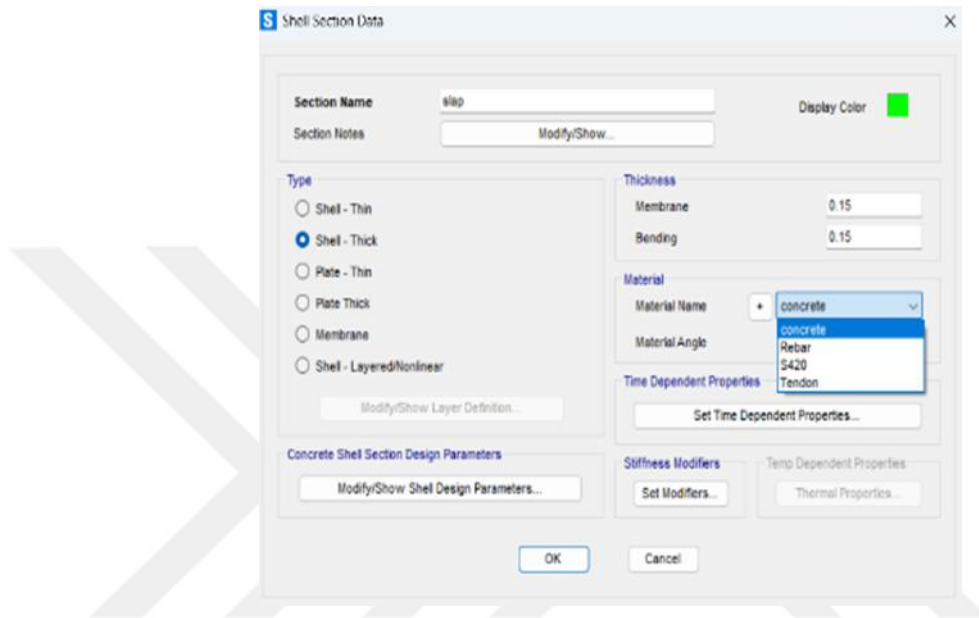


Figure 43. Slab Section Setup

The stiffness modification factors for in-plane axial effects and out-of-plane bending moments of shell-thick sections named slab shall be defined by opening the "Frame Property/Stiffness Modification Factors" window via the Set Modifiers button, and entering the values provided below.

Note. The same steps we did in step (8) when applying shear wall for the bending moment of inertia stiffness factors of all shear walls the values shall be defined by opening the "Frame Property/Stiffness Modification Factors" window under the "Set Modifiers" as shown in figure 44.

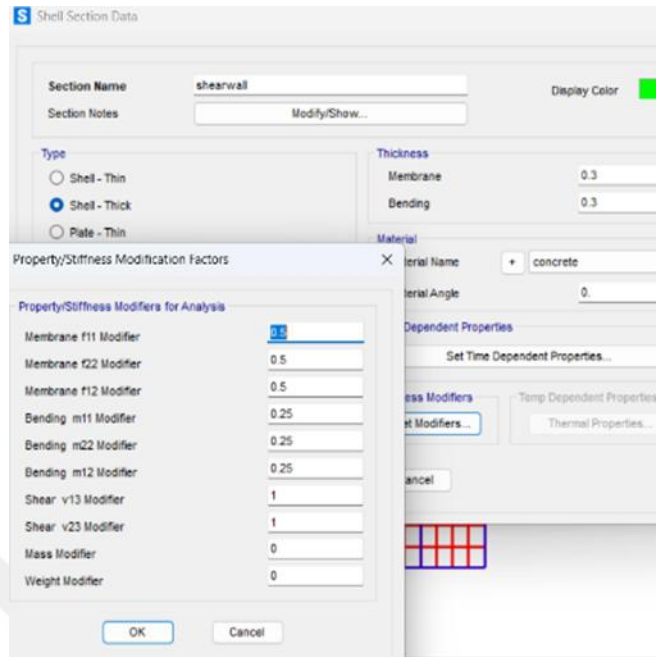


Figure 44. Shear Wall Section Setup

Note. Once the stiffness modification factors for the slab and shear wall elements have been completed, the OK button should be clicked in each sub window to return to the previous window, ensuring that all definitions are individually confirmed and approved.

Model Geometry Creation

a) Drawing the Beams

9. First, switch to the XY plane from the program's toolbar. Then, using the up or down arrow buttons,  navigate to the Z = 3 level. In the left-side Draw tab, use the Quick Draw Frame or Draw Frame shortcut command to open the Properties of Object window, where the beam section is selected. At the Z = 3 level, the beams positioned along each axis are quickly drawn in the XY plane using the mouse.

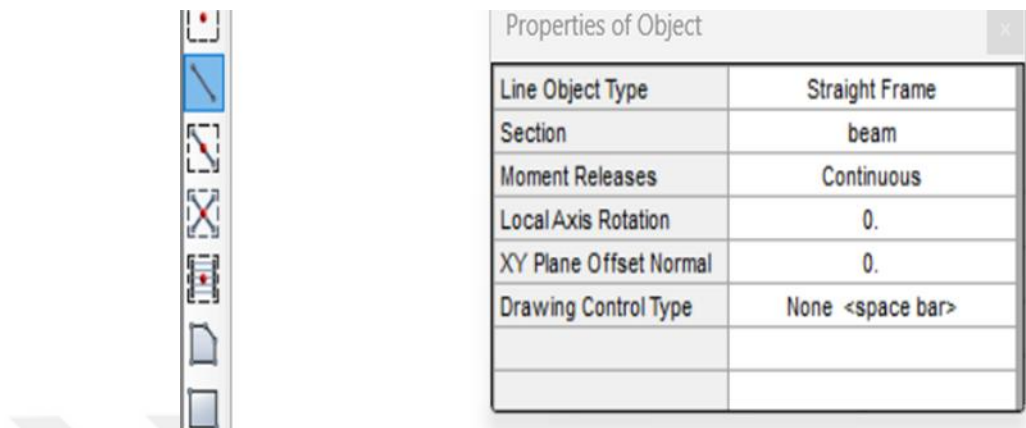


Figure 45. Beam Drawing

b) Drawing the Slabs and Generating the Finite Element Mesh.

10. Select the Draw Rectangular Area or Quick Draw Area shortcut command from the side toolbar. In the opened Properties of Object window, choose slab. For each slab section, create the areas either by marking from the top-left corner to the bottom-right corner or by clicking at the center of each slab using the mouse.

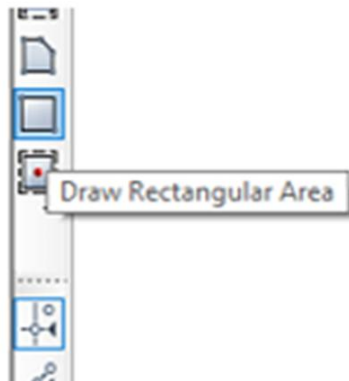


Figure 46. Slab Drawing

11. Each edge of the slabs will be divided into 4 elements to generate the finite element mesh. To do this, click at the center of each slab to select all slabs at the $Z = 3$ level. Then, from the toolbar, navigate to the Edit button, proceed to Edit Areas, and access the Divide Areas command.

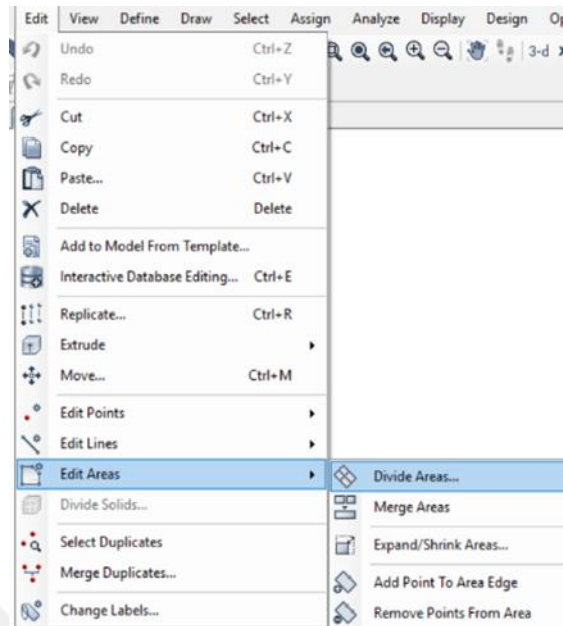


Figure 47. Slab Meshing I

12. Next, in the Divide Selected Areas window, enter 4 for both Along Edge from Point 1 to 2 and Along Edge from Point 1 to 3. Click OK to complete the slab division process. With these division numbers, the mass centers of all floors align precisely with the nodal points of the finite element mesh.

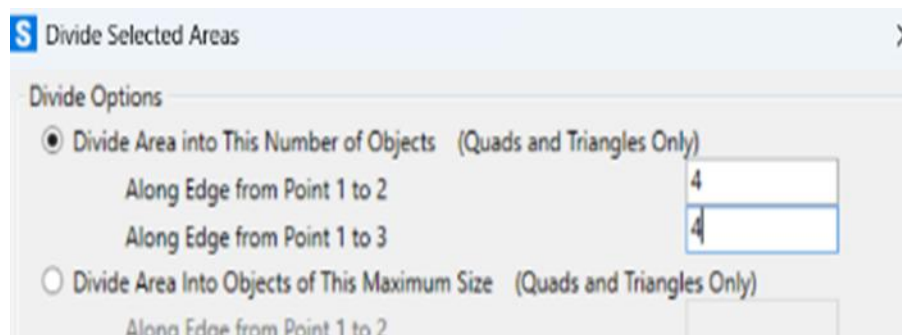


Figure 48. Slab Meshing II

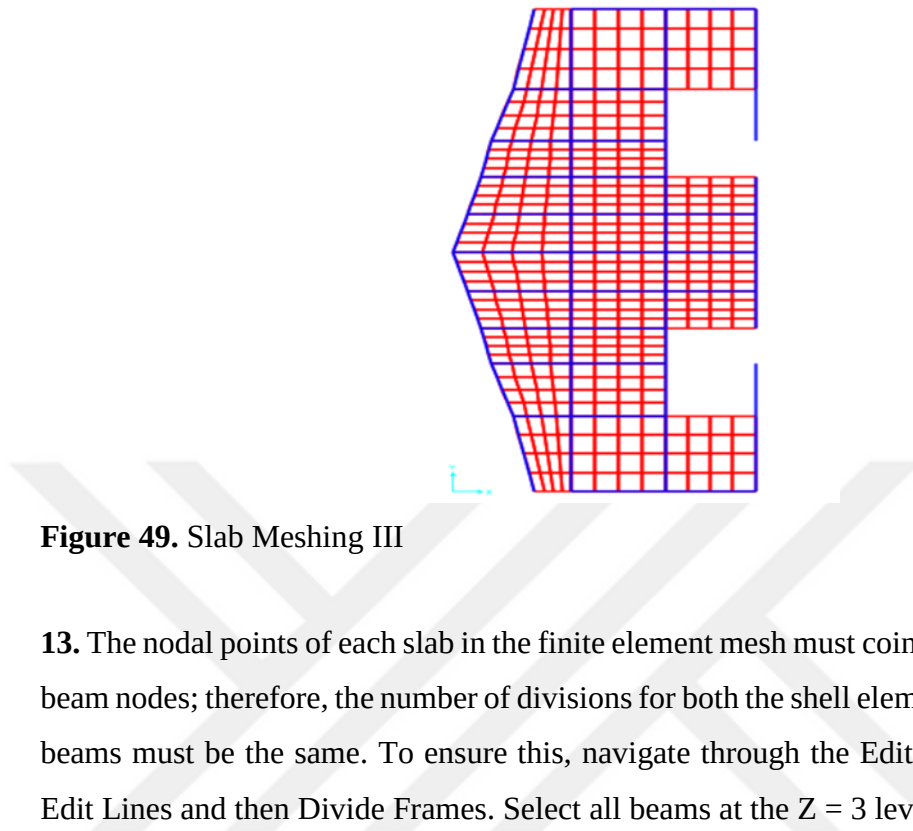


Figure 49. Slab Meshing III

13. The nodal points of each slab in the finite element mesh must coincide with the divided beam nodes; therefore, the number of divisions for both the shell elements and the adjacent beams must be the same. To ensure this, navigate through the Edit toolbar by selecting Edit Lines and then Divide Frames. Select all beams at the $Z = 3$ level.

In the Divide Selected Frames window, enter 2 for Number of Segments and click OK to complete the beam division process.

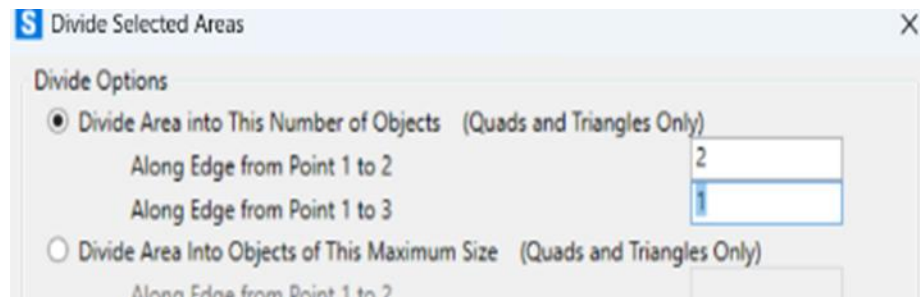


Figure 50. Beam Division

c) Derivation of Similar Floors

14. Since the generated floor plan exhibits identical characteristics across all storeys, the constructed floor Model can be replicated vertically to create the full building Model.

To perform this, all slabs and beams at the $Z = 3$ m level should be selected — either by navigating to Select → Select All under the Select tab or by manually selecting the entire floor layout using the mouse. Subsequently, under the Edit tab, access the Replicate window. In this dialog, choose the Linear replication option, set the translation parameters as $dx = 0$, $dy = 0$, $dz = 3$ m, and input 5 for the Number of replications. This operation will generate 5 additional identical floors, copying the beams and slabs upward at increments of 3 m. Finalize the replication by clicking OK.

d) Drawing of Columns

15. Switch to the XZ plane from the program's toolbar. Using the forward or backward arrow, navigate to grid line 1 (the $Y = 0$ plane). The columns on this plane can be drawn using the Draw Frame or Quick Draw Frame shortcut buttons. For the first-floor columns, select the column section from the Object Properties window and draw the columns with the mouse. Next, select the column section and draw the columns for the second, third up to 7th floor. Repeat the same procedure for the columns along grid lines 2 ($Y = 5.1$) and do same in all grid lines.

e) Drawing of Shear Walls

16. Switch to the XZ plane using the program's toolbar. Navigate using the forward or backward arrow to grid line 1 (corresponding to the $Y = 0$ plane). Using the Draw Wall or Quick Draw Wall shortcut tool, open the Object Properties window and select the previously defined shear wall section. Using the mouse, draw the shear walls along the specified locations for all seven floors. Repeat the same procedure for the walls positioned along grid lines 2 ($Y = 5.1$) ensuring consistency across all stories.

f) Definition of Supports

17. Switch to the XY plane from the program's toolbar, corresponding to the foundation level ($Z = 0$).

Select all nodes at this base level. The selected nodes are then assigned as fixed (encastre) supports using the Assign Joint Restraints shortcut button. Click OK to complete and confirm the support assignment process.

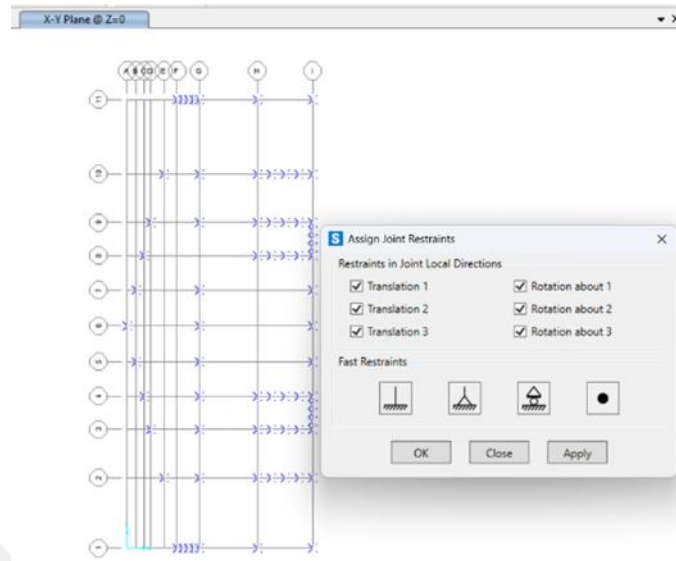


Figure 51. Assigning Fixed Supports

g) Definition and Assignment of Rigid Diaphragms for Each Floor

18. Navigate to Define → Joint Constraints → Define Constraints. In the window that opens, under Choose Constraint Type to Add, select Diaphragm and click the Add New Constraint button. In the Diaphragm Constraint window, define a general diaphragm type DAPH1) and select assign a different diaphragm constraints to each different selected z level. Click OK to save and close the window.

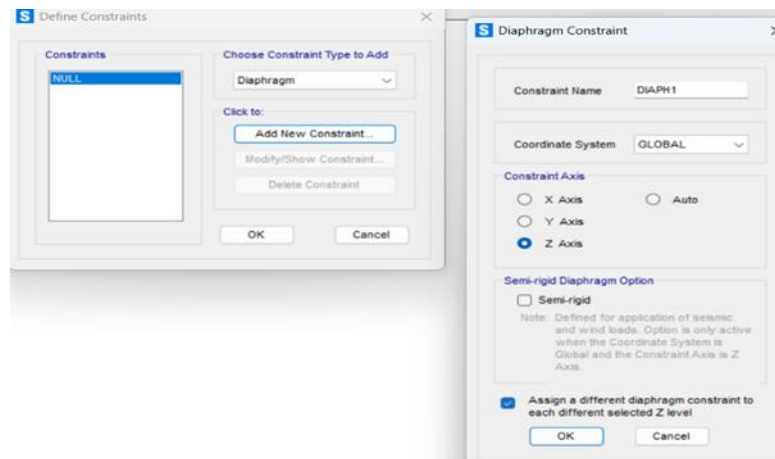


Figure 52. Rigid Diaphragm Setup

h) Assigning Rigid Diaphragms to Each Floor Level

19. Navigate to the XY plane using the main toolbar. Using the navigation buttons, move to the $Z = 3$ m plane, and select nodes on this level (both beam and slab nodes) then move up and select next level and do same in all levels in XY plane. After selection, go to the Assign menu, select Joint, and then Constraints. In the Assign Joint Constraint window, choose the diaphragm defined in Step 16 —DAPH1 — and click Apply to assign the diaphragm constraint(see figures 53 and 44).

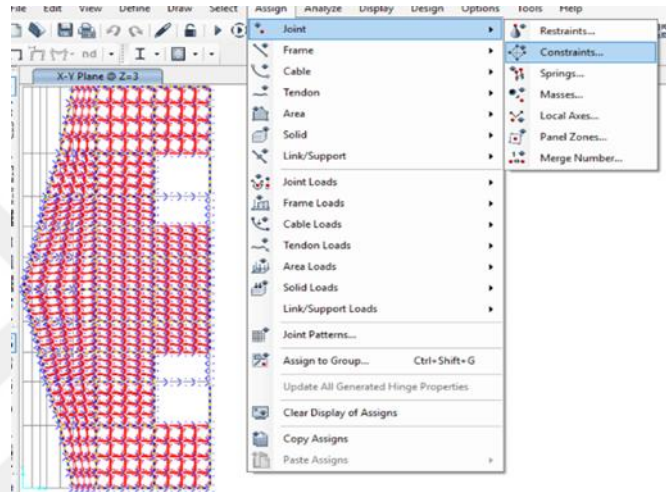


Figure 53. Rigid Diaphragm Setup I

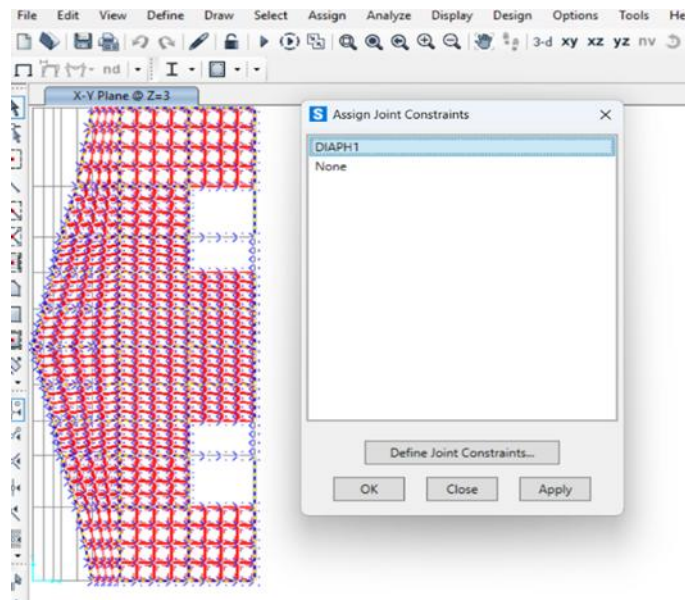


Figure 54. Rigid Diaphragm Setup II

CHAPTER THREE

NUMERICAL METHODS AND APPLICATIONS

In this chapter, the seismic performance analyses of eight distinct 7-story reinforced concrete building Models are presented. All Models are assumed to be located in the city of Amasya, within Amasya Province (latitude 40.6502° N, longitude 35.8286° E), which corresponds to a defined seismic hazard zone according to the Turkish Building Earthquake Code (TBDY-2018).

The analyses are carried out using the Equivalent Seismic Load Method, in line with the seismic parameters provided by the AFAD (Disaster and Emergency Management Authority) reports, as detailed in Chapter Two. Each of the eight Models features varied geometric configurations of structural elements, allowing for a comparative evaluation of their seismic behavior under identical loading and ground motion conditions.

3.1 Analysis Using the Equivalent Seismic Load Method

3.1.1 Calculation of Weights

The floor area is to be 387 m². $Q_i = 387 \cdot q_i$

floor weight $W_i = G_1 + n \cdot q_i$

Calculation are listed in Table 2.

3.1.2. Calculation of Floor Weights

According to TBDY-2018, the live load mass participation coefficient is taken as $n = 0.30$ see figure 55

Purpose of Use of the Building	n
Warehouse, warehouse, etc.	0.80
School, student dormitory, sports facility, cinema, theater, concert hall, place of worship, restaurant, store, etc.	0.60
Residential, workplace, hotel, hospital, parking, etc.	0.30

Figure 55. Moving Load Mass Participation Coefficient

Tablo 2. Floor Weight

Floor no	wi
6	6137.82
5	6253.92
4	6253.92
3	6253.92
2	6253.92
1	6253.92

3.1.3. Calculation of the Period Using Modal Analysis

The period of all Models are calculated using sap2000 (see Tables 3-10)

Table 3. Calculated Periods for Model 1

Model 1				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad2/sec2)
MOD 1	0.622784	1.605693747	10.08887136	101.7853253
MOD 2	0.484603	2.06354615	12.96564285	168.1078945
MOD 3	0.428338	2.334607457	14.66877127	215.1728507
MOD 4	0.172814	5.786569796	36.35809032	1321.910732
MOD 5	0.172417	5.799885186	36.44175338	1328.001389
MOD 6	0.167984	5.952947528	37.40347244	1399.019751
MOD 7	0.167161	5.982242384	37.58753745	1412.822972
MOD 8	0.166002	6.02402933	37.85009257	1432.629508
MOD 9	0.164934	6.063044749	38.09523368	1451.246829
MOD 10	0.164401	6.08270131	38.2187395	1460.672049

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 3, the first vibration periods obtained from the modal analysis are $T_1=0.6228$ sec., $T_2=0.4846$ sec. For this example, $T_p^x= 0.4846$ sec. and $T_p^y=0.6228$ sec. are chosen.

Table 4. Calculated Periods for Model 2

Model 2				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.596107	1.677551096	10.5403644	111.09928
MOD 2	0.476738	2.097586143	13.17952244	173.69981
MOD 3	0.418975	2.386774594	14.99654706	224.89642
MOD 4	0.168646	5.929580838	37.2566552	1388.0584
MOD 5	0.165424	6.045059168	37.98222694	1442.6496
MOD 6	0.164906	6.064060476	38.10161568	1451.7331
MOD 7	0.164052	6.095640642	38.30003972	1466.893
MOD 8	0.163339	6.122239836	38.46716739	1479.723
MOD 9	0.163042	6.133377554	38.53714773	1485.1118
MOD 10	0.162621	6.149251162	38.63688455	1492.8088

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 4, the first vibration periods obtained from the modal analysis are $T_1=0.5961$ sec., $T_2=0.4767$ sec. For this example, $T_p^x= 0.4767$ sec. and $T_p^y=0.5961$ sec. are chosen.

Table 5. Calculated Periods for Model 3

Model 3				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.58394	1.712503707	10.75997813	115.7771293
MOD 2	0.472902	2.114604388	13.28645122	176.529786
MOD 3	0.414151	2.414578137	15.17124187	230.16658
MOD 4	0.167428	5.972702112	37.52759415	1408.320323
MOD 5	0.164634	6.074088868	38.16462593	1456.538672
MOD 6	0.164189	6.090526354	38.2679057	1464.432607
MOD 7	0.163461	6.117685834	38.43855374	1477.522414
MOD 8	0.16286	6.140232092	38.58021606	1488.433071
MOD 9	0.162578	6.150874831	38.64708637	1493.597285
MOD 10	0.157557	6.346916066	39.87884977	1590.322659

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 5, the first vibration periods obtained from the modal analysis are $T_1=0.5839$ sec., $T_2=0.4729$ sec. For this example, $T_p^x=0.4729$ sec. and $T_p^y=0.5839$ sec. are chosen.

Table 6. Calculated Periods for Model 4

Model 4				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.556325	1.797508966	11.29408192	127.5562865
MOD 2	0.455031	2.197651431	13.80825118	190.6678006
MOD 3	0.400902	2.494375199	15.6726216	245.6310679
MOD 4	0.161031	6.209969559	39.01838949	1522.434718
MOD 5	0.143674	6.960186083	43.73213893	1912.499975
MOD 6	0.138747	7.207355624	45.28515096	2050.744897
MOD 7	0.137877	7.252865995	45.57110105	2076.725251
MOD 8	0.136423	7.330165571	46.05678861	2121.227777
MOD 9	0.135252	7.393618709	46.45547644	2158.111291
MOD 10	0.134727	7.422438584	46.63655705	2174.968454

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 6, the first vibration periods obtained from the modal analysis are $T_1=0.5563$ sec., $T_2=0.4550$ sec. For this example, $T_p^x=0.4550$ sec. and $T_p^y=0.5563$ sec. are chosen.

Table 7. Calculated Periods for Model 5

Model 5				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.601198	1.663346158	10.45111214	109.225745
MOD 2	0.475799	2.10172871	13.20555095	174.386576
MOD 3	0.419845	2.381831368	14.96548786	223.9658268
MOD 4	0.169106	5.913467802	37.15541401	1380.52479
MOD 5	0.162023	6.171976532	38.77967226	1503.862981
MOD 6	0.157472	6.350327416	39.90028392	1592.032656
MOD 7	0.156681	6.382374584	40.10164221	1608.141708
MOD 8	0.15544	6.433332226	40.42181852	1633.923412
MOD 9	0.154365	6.478144382	40.7033816	1656.765274
MOD 10	0.15385	6.499823065	40.83959278	1667.872339

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 7, the first vibration periods obtained from the modal analysis are $T_1=0.6011$ sec., $T_2=0.4757$ sec. For this example, $T_p^x= 0.4757$ sec. and $T_p^y=0.6011$ sec. are chosen.

Table 8. Calculated Periods for Model 6

Model 6				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.632552	1.580898065	9.933075494	98.66598877
MOD 2	0.490085	2.040460739	12.82059293	164.3676031
MOD 3	0.432607	2.311566068	14.52399796	210.9465166
MOD 4	0.181052	5.523277179	34.70377402	1204.351931
MOD 5	0.176602	5.662439187	35.5781547	1265.805092
MOD 6	0.17578	5.68892814	35.7445897	1277.675693
MOD 7	0.17467	5.725086162	35.97177725	1293.968759
MOD 8	0.174558	5.728742318	35.99474956	1295.621996
MOD 9	0.173606	5.760163063	36.19217192	1309.873309
MOD 10	0.173063	5.778254459	36.30584352	1318.114273

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 8, the first vibration periods obtained from the modal analysis are $T_1=0.632$ sec., $T_2=0.4901$ sec. For this example, $T_p^x= 0.4901$ sec. and $T_p^y=0.6325$ sec. are chosen.

Table 9. Calculated Periods for Model 7

Model 7				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.601607	1.662214771	10.44400342	109.0772075
MOD 2	0.45894	2.178933883	13.69064536	187.4337703
MOD 3	0.405164	2.468138941	15.50777433	240.4910648
MOD 4	0.171747	5.822529428	36.58403135	1338.39135
MOD 5	0.167193	5.981113157	37.58044231	1412.289644
MOD 6	0.166336	6.011929757	37.77406872	1426.880267
MOD 7	0.165205	6.053081842	38.03263489	1446.481317
MOD 8	0.164778	6.06877481	38.13123672	1453.991214
MOD 9	0.164122	6.093032542	38.28365255	1465.638052
MOD 10	0.163561	6.113926772	38.41493487	1475.707221

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 9, the first vibration periods obtained from the modal analysis are $T_1=0.6016$ sec., $T_2=0.4590$ sec. For this example, $T_p^x=0.4590$ sec. and $T_p^y=0.6016$ sec. are chosen.

Table 10. Calculated Periods for Model 8

Model 8				
mod no	Period(sec)	Frequency cyc/sec	CircFreq(rad/sec)	Eigenvalue(rad ² /sec ²)
MOD 1	0.675435	1.48052832	9.302433787	86.53527436
MOD 2	0.527176	1.896898078	11.91856213	142.0521233
MOD 3	0.467624	2.138469199	13.43639825	180.536798
MOD 4	0.186787	5.3536966	33.63826781	1131.533062
MOD 5	0.186238	5.369459699	33.73731029	1138.206106
MOD 6	0.181918	5.496985378	34.53857776	1192.913354
MOD 7	0.181109	5.521542524	34.69287486	1203.595566
MOD 8	0.179996	5.555678188	34.90735556	1218.523472
MOD 9	0.178963	5.587737196	35.10878825	1232.627012
MOD 10	0.17845	5.60381288	35.20979475	1239.729646

The period values calculated through the modal analysis will be considered in this study. As shown in the Table 10, the first vibration periods obtained from the modal analysis are $T_1=0.754$ sec., $T_2=0.527$ sec. For this example, $T_p^x=0.527$ and $T_p^y=0.6754$ sec. are chosen.

The maximum $T_p(X)$ and $T_p(Y)$ value to be considered in the seismic analysis must not exceed 1.4 times the fundamental natural vibration period, T_{pA} , calculated using the empirical formula expressed in equation 29.

$$T_{pA} = C_t H_N^{3/4}$$

$$T_{pA} = C_t H_N^{3/4} = 0.07 \times 18^{3/4} = 0.611 \text{ sec.}$$

$$T_p^{(x)} = 0.4846 \text{ s} \leq 1.4 T_{pA} = 0.855 \text{ sec.}$$

$$T_p^{(y)} = 0.601607 \leq 1.4 T_{pA} = 0.855 \text{ sec.}$$

periods calculated for all eight Models and evaluations for their compliance with the conditions specified above are presented in table 11.

Table 11. Period Check Summary

MODEL	$T_p^{(x)}$	Comment	$T_p^{(Y)}$	T_{pA}	Comment
1	0.4846	satisfied	0.622784	0.855	satisfied
2	0.596107	satisfied	0.476738	0.855	satisfied
3	0.472902	satisfied	0.58394	0.855	satisfied
4	0.455031	satisfied	0.556325	0.855	satisfied
5	0.475799	satisfied	0.601198	0.855	satisfied
6	0.490085	satisfied	0.632552	0.855	satisfied
7	0.45894	satisfied	0.601607	0.855	satisfied
8	0.527176	satisfied	0.675435	0.855	satisfied

The preconditions are satisfied, and according to Equation 34, the corner periods of the horizontal design spectrum have been determined.

All period values are calculated, and the horizontal elastic design spectrum was computed using the report obtained from AFAD report

For DD2

$$T_A = 0.2 \frac{S_{D1}}{S_{DS}} \quad (32)$$

$$T_A = 0.2 \frac{S_{D1}}{S_{DS}} = 0.2 \frac{0.255}{0.940} = 0.054 \text{ sec.}$$

$$T_B = \frac{S_{D1}}{S_{DS}} \quad (33)$$

$$T_B = \frac{S_{D1}}{S_{DS}} = \frac{0.255}{0.940} = 0.271 \text{ sec.}$$

$$S_{ae}(T) = \frac{S_{D1}}{T_p^{(Y)}} \quad T_B \leq T \leq T_L \quad (34)$$

According to Equation 34, the vertical elastic design spectral acceleration of Y-direction Model 1 is given as follows.

$$S_{ae}(T_p^{(Y)}) = \frac{S_{D1}}{T_p^{(Y)}} \quad T_B \leq T_p^{(Y)} \leq T_L$$

$$S_{ae}(0.6228) = \frac{0.255}{0.6228} = 0.4094$$

According to Equation 34, the vertical elastic design spectral acceleration of X-direction Model 1 is given as follows.

$$S_{ae}(T_p^{(X)}) = \frac{S_{D1}}{T_p^{(Y)}} \quad T_B \leq T_p^{(X)} \leq T_L$$

$$S_{ae}(0.4846) = \frac{0.255}{0.4846} = 0.5262$$

All calculations for eight models are carried out in Excel following the same procedure, and the resulting values are presented in the table 12.

Table 12. DD2 Seismic Parameters per model

DD2				
MODEL	$S_{ae}(T_p^{(X)})$	$S_{ae}(T_p^{(Y)})$	S_{DS}	S_{D1}
1	0.5262	0.4095	0.94	0.255
2	0.42778	0.5349	0.94	0.255
3	0.53922	0.4367	0.94	0.255
4	0.5604	0.4584	0.94	0.255
5	0.53594	0.4242	0.94	0.255
6	0.52032	0.4031	0.94	0.255
7	0.55563	0.4239	0.94	0.255
8	0.48371	0.3775	0.94	0.255

For DD3

$$T_A = 0.2 \frac{S_{D1}}{S_{DS}} = 0.2 \frac{0.095}{0.369} = 0.052 \text{ sec.}$$

$$T_B = \frac{S_{D1}}{S_{DS}} = \frac{0.095}{0.369} = 0.258 \text{ sec.}$$

The vertical elastic design spectral acceleration of Y-direction Model 1 is given as follows.

$$S_{ae}(T_p^{(Y)}) = \frac{S_{D1}}{T_p^{(Y)}} \quad T_B \leq T_p^{(Y)} \leq T_L$$

$$S_{ae}(0.6228) = \frac{0.095}{0.6228} = 0.1525$$

The vertical elastic design spectral acceleration of X-direction Model 1 is given as follows using equation 35.

$$S_{ae}(T_p^{(X)}) = \frac{S_{D1}}{T_p^{(Y)}} \quad T_B \leq T_p^{(X)} \leq T_L$$

$$S_{ae}(0.4846) = \frac{0.095}{0.4846} = 0.1960$$

All calculations for Model 1 across the Eight floors are carried out in Excel and the resulting values are presented in the table 13.

Table 13. DD3 Seismic Parameters per model

DD3				
MODEL	$S_{ae}(T_p^{(X)})$	$S_{ae}(T_p^{(Y)})$	S_{DS}	S_{D1}
1	0.1960	0.1525	0.94	0.255
2	0.1593	0.1992	0.94	0.255
3	0.2009	0.1626	0.94	0.255
4	0.2088	0.1708	0.94	0.255
5	0.1997	0.1580	0.94	0.255
6	0.1938	0.1501	0.94	0.255
7	0.2070	0.1579	0.94	0.255
8	0.1802	0.1407	0.94	0.255

If the building's fundamental vibration period exceeds the horizontal design spectrum corner period T_B , equation 18 shall be used as the basis for determining the earthquake load reduction coefficient

$$R_a(T_p^{(x)}) = \frac{R}{I} \quad T_B < T_p^{(x)}$$

$$R = 7, I = 1$$

$$R_a(T_p^{(x)}) = \frac{7}{1} = 7$$

$$R_a(T_p^{(Y)}) = \frac{R}{I} \quad T_B < T_p^{(Y)} \quad R = 7, I = 1 \quad R_a(T_p^{(Y)}) = \frac{7}{1} = 7$$

All Models are calculated and presented in the table 14.

Table 14. Earthquake Load Reduction Coefficients

MODEL	$S_{ae}(T_p^{(x)})$	$S_{ae}(T_p^{(y)})$	R	I	T_B	D	$R_a(T_p^{(x)})$	$R_a(T_p^{(y)})$
1	0.5262	0.4095	7	1	0.271	2.5	7	7
2	0.42778	0.5349	7	1	0.271	2.5	7	7
3	0.53922	0.4367	7	1	0.271	2.5	7	7
4	0.5604	0.4584	7	1	0.271	2.5	7	7
5	0.53594	0.4242	7	1	0.271	2.5	7	7
6	0.52032	0.4031	7	1	0.271	2.5	7	7
7	0.55563	0.4239	7	1	0.271	2.5	7	7
8	0.48371	0.3775	7	1	0.271	2.5	7	7

The reduced design spectral acceleration is calculated using equation 17 as expressed below.

$$S_{aR}(T_p^{(x)}) = \frac{S_{ae}(T_p^{(x)})}{R_a(T_p^{(x)})} = \frac{0.5262}{7} = 0.0751 \quad S_{aR}(T_p^{(y)}) = \frac{S_{ae}(T_p^{(y)})}{R_a(T_p^{(y)})} = \frac{0.4095}{7} = 0.0585g$$

The calculated reduced horizontal elastic design spectra for all Models are presented in the table 15.

Table 15. reduced horizontal elastic design spectra

MODEL	$S_{ae}(T_p^{(x)})$	$S_{ae}(T_p^{(y)})$	$S_{aR}(T_p^{(x)})$	$S_{aR}(T_p^{(y)})$
1	0.5262	0.4095	0.075172	0.058493
2	0.42778	0.5349	0.061111	0.076412
3	0.53922	0.4367	0.077032	0.062384
4	0.5604	0.4584	0.080057	0.065481
5	0.53594	0.4242	0.076563	0.060593
6	0.52032	0.4031	0.074331	0.05759
7	0.55563	0.4239	0.079375	0.060552
8	0.48371	0.3775	0.069101	0.053933

3.2 Solution Under Equivalent Seismic Loads

For the total equivalent seismic load (base shear force) according to Equation 15.

$$V_{tE}^{(x)} = m_t S_{aR}(T_p^{(x)}) \geq 0.4 m_t I S_{DS} g$$

$$V_{tE}^{(Y)} = m_t S_{aR}(T_p^{(Y)}) \geq 0.4 m_t I S_{DS} g$$

m_t is calculated using equation 16

$$m_t = \sum_{i=1}^N m_i \quad m_t = 3813.192$$

$$V_{tE}^{(x)} = 0.4 \times 3813.192 \times 0.0751 \times 9.81 \geq 0.04 \times 3813.192 \times 1 \times 0.94 \times 9.81$$

$$V_{tE}^{(x)} = 1123.72 \text{ Kn} \leq 1,406.55 \text{ KN} \quad V_{tE}^{(x)} = 1,406.55 \text{ KN}$$

$$V_{tE}^{(Y)} = m_t S_{aR}(T_p^{(Y)}) \geq 0.4 m_t I S_{DS} g$$

$$V_{tE}^{(Y)} = 3813.192 \times 0.0585 \times 9.81 \geq 0.04 \times 3813.192 \times 1 \times 0.94 \times 9.81$$

$$V_{tE}^{(Y)} = 2188.076 \text{ Kn} \geq 1,406.55 \text{ KN}$$

$$V_{tE}^{(Y)} = 2188.076 \text{ KN}$$

The table 16 presents the equivalent seismic loads for all Models, calculated in Excel using the equations 39.

Table 16. equivalent seismic loads per Model

$S_{ae}(T_p^{(x)})$	$S_{ae}(T_p^{(y)})$	$S_{aR}(T_p^{(x)})$	$S_{aR}(T_p^{(y)})$	$V_{tE}^{(x)}$	$V_{tE}^{(Y)}$	limit $V_{tE}^{(x)}$	limit $V_{tE}^{(Y)}$
0.52620392	0.40945175	0.075172	0.058493	2811.99	2188.076	1406.519	1406.519
0.42777555	0.53488499	0.061111	0.076412	2285.997	2858.381	1406.519	1406.519
0.53922377	0.4366887	0.077032	0.062384	2881.567	2333.628	1406.519	1406.519
0.56040138	0.45836516	0.080057	0.065481	2994.739	2449.465	1406.519	1406.519
0.5359406	0.42415311	0.076563	0.060593	2864.022	2266.639	1406.519	1406.519
0.5203179	0.40312891	0.074331	0.05759	2780.536	2154.288	1406.519	1406.519
0.55562819	0.42386475	0.079375	0.060552	2969.231	2265.098	1406.519	1406.519
0.48370943	0.37753448	0.069101	0.053933	2584.903	2017.513	1406.519	1406.519

Determination of Equivalent Earthquake Loads Acting on the Floors
The calculated total equivalent earthquake load is expressed as the sum of the equivalent earthquake loads acting on the building floors as shown in equation 20.

$$V_{tE}^x = \Delta F_{NE}^x + \sum_{i=1}^N F_{NE}^{(x)}$$

The additional equivalent earthquake load acting on the N^{th} floor (top) of the building, ΔF_{NE}^x , will be calculated using equation 21 as follows.

$$\Delta F_{NE}^X = 0.0075 N V_{tE}^x$$

Determination of the equivalent earthquake loads acting on the floors are presented in Table 17.

Table 17. total equivalent seismic loads for top floors

MODEL	floor number	$V_{tE}^{(x)}$	$V_{tE}^{(Y)}$	ΔF_{NE}^X	ΔF_{NE}^Y
1	6	2811.990168	2188.076	126.54	5.6943
2	6	2285.997097	2858.381	102.87	4.6291
3	6	2881.567156	2333.628	129.67	5.8352
4	6	2994.738537	2449.465	134.76	6.0643
5	6	2864.022143	2266.639	128.88	5.7996
6	6	2780.535767	2154.288	125.12	5.6306
7	6	2969.230992	2265.098	133.62	6.0127
8	6	2584.90309	2017.513	116.32	5.2344

The remaining part of the total equivalent earthquake load, excluding $\Delta F_{NE}^{(X)}$ will be distributed to the building floors, including the Nth floor, using equation 28.

$$F_{IE}^X = (V_{tE}^x - \Delta F_{NE}^X) \frac{M_i H_i}{\sum_{i=1}^N M_j H_j}$$

Tables 18-33 presents the total equivalent earthquake loads for all floors in the X and Y directions across the 8 Models, including the top floor, which was calculated previously.

Table 18. EX-direction total equivalent seismic loads for Model 1

EX FOR MODEL NO:1						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	883.5827
5	3	15	6254	637.5	9562.569	642.8025
4	3	12	6254	637.5	7650.055	514.242
3	3	9	6254	637.5	5737.541	385.6815
2	3	6	6254	637.5	3825.028	257.121
1	3	3	6254	637.5	1912.514	128.5605
				3813.2	39949.76	2811.99

Table 19. EY-direction total equivalent seismic loads for Model 1

EY FOR MODEL NO:1						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	687.5366
5	3	15	6253.92	637.5046	9562.569	500.1799
4	3	12	6253.92	637.5046	7650.055	400.1439
3	3	9	6253.92	637.5046	5737.541	300.1079
2	3	6	6253.92	637.5046	3825.028	200.0719
1	3	3	6253.92	637.5046	1912.514	100.036
				3813.193	39949.76	2188.076

Table 20. EX total equivalent seismic loads for Model 2

EX FOR MODEL NO:2						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	718.3053
5	3	15	6254	637.5	9562.569	522.5639
4	3	12	6254	637.5	7650.055	418.0511
3	3	9	6254	637.5	5737.541	313.5384
2	3	6	6254	637.5	3825.028	209.0256
1	3	3	6254	637.5	1912.514	104.5128
				3813.2	39949.76	2285.997

Table 21. EY total equivalent seismic loads for Model 2

EY FOR MODEL NO:2						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	898.1596
5	3	15	6253.92	637.5046	9562.569	653.4071
4	3	12	6253.92	637.5046	7650.055	522.7257
3	3	9	6253.92	637.5046	5737.541	392.0443
2	3	6	6253.92	637.5046	3825.028	261.3629
1	3	3	6253.92	637.5046	1912.514	130.6814
				3813.193	39949.76	2858.381

Table 22. EX total equivalent seismic loads for Model 3

EX FOR MODEL NO:3						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	905.4452
5	3	15	6254	637.5	9562.569	658.7073
4	3	12	6254	637.5	7650.055	526.9659
3	3	9	6254	637.5	5737.541	395.2244
2	3	6	6254	637.5	3825.028	263.4829
1	3	3	6254	637.5	1912.514	131.7415
				3813.2	39949.76	2881.567

Table 23. EY total equivalent seismic loads for Model 3

EY FOR MODEL NO:3						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	733.272
5	3	15	6253.92	637.5046	9562.569	533.4521
4	3	12	6253.92	637.5046	7650.055	426.7617
3	3	9	6253.92	637.5046	5737.541	320.0713
2	3	6	6253.92	637.5046	3825.028	213.3808
1	3	3	6253.92	637.5046	1912.514	106.6904
				3813.193	39949.76	2333.628

Table 24. Ex total equivalent seismic loads for Model 4

EX FOR MODEL NO:4						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	941.0058
5	3	15	6254	637.5	9562.569	684.5776
4	3	12	6254	637.5	7650.055	547.6621
3	3	9	6254	637.5	5737.541	410.7465
2	3	6	6254	637.5	3825.028	273.831
1	3	3	6254	637.5	1912.514	136.9155
				3813.2	39949.76	2994.739

Table 25. EY total equivalent seismic loads for Model 4

EY FOR MODEL NO:4						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	769.6703
5	3	15	6253.92	637.5046	9562.569	559.9317
4	3	12	6253.92	637.5046	7650.055	447.9454
3	3	9	6253.92	637.5046	5737.541	335.959
2	3	6	6253.92	637.5046	3825.028	223.9727
1	3	3	6253.92	637.5046	1912.514	111.9863
				3813.193	39949.76	2449.465

Table 26. EX total equivalent seismic loads for Model 5

EX FOR MODEL NO:5						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	899.9322
5	3	15	6253.92	637.5046	9562.569	654.6967
4	3	12	6253.92	637.5046	7650.055	523.7573
3	3	9	6253.92	637.5046	5737.541	392.818
2	3	6	6253.92	637.5046	3825.028	261.8787
1	3	3	6253.92	637.5046	1912.514	130.9393
				3813.193	39949.76	2864.022

Table 27. EY total equivalent seismic loads for Model 5

EY FOR MODEL NO:5						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	712.2226
5	3	15	6253.92	637.5046	9562.569	518.1388
4	3	12	6253.92	637.5046	7650.055	414.511
3	3	9	6253.92	637.5046	5737.541	310.8833
2	3	6	6253.92	637.5046	3825.028	207.2555
1	3	3	6253.92	637.5046	1912.514	103.6278
				3813.193	39949.76	2266.639

Table 28. EX total equivalent seismic loads for Model 6

FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	873.6991
5	3	15	6254	637.5	9562.569	635.6122
4	3	12	6254	637.5	7650.055	508.4898
3	3	9	6254	637.5	5737.541	381.3673
2	3	6	6254	637.5	3825.028	254.2449
1	3	3	6254	637.5	1912.514	127.1224
				3813.2	39949.76	2780.536

Table 29. EY total equivalent seismic loads for Model 6

FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	676.9196
5	3	15	6253.92	637.5046	9562.569	492.456
4	3	12	6253.92	637.5046	7650.055	393.9648
3	3	9	6253.92	637.5046	5737.541	295.4736
2	3	6	6253.92	637.5046	3825.028	196.9824
1	3	3	6253.92	637.5046	1912.514	98.4912
				3813.193	39949.76	2154.288

Table 30. EX total equivalent seismic loads for Model 7

EX FOR MODEL NO:7						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	932.9909
5	3	15	6254	637.5	9562.569	678.7467
4	3	12	6254	637.5	7650.055	542.9974
3	3	9	6254	637.5	5737.541	407.248
2	3	6	6254	637.5	3825.028	271.4987
1	3	3	6254	637.5	1912.514	135.7493
				3813.2	39949.76	2969.231

Table 31. EY total equivalent seismic loads for Model 7

EY FOR MODEL NO:7						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	711.7384
5	3	15	6253.92	637.5046	9562.569	517.7866
4	3	12	6253.92	637.5046	7650.055	414.2292
3	3	9	6253.92	637.5046	5737.541	310.6719
2	3	6	6253.92	637.5046	3825.028	207.1146

1	3	3	6253.92	637.5046	1912.514	103.5573
				3813.193	39949.76	2265.098

Table 32. EX total equivalent seismic loads for Model 8

EX FOR MODEL NO:8						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^X
6	3	18	6138	625.67	11262.06	441.956
5	3	15	6254	637.5	9562.569	321.521
4	3	12	6254	637.5	7650.055	257.2168
3	3	9	6254	637.5	5737.541	192.9126
2	3	6	6254	637.5	3825.028	128.6084
1	3	3	6254	637.5	1912.514	64.3042
				3813.2	39949.76	1406.519

Table 33. EY total equivalent seismic loads for Model 8

EY FOR MODEL NO:8						
FLOOR NO	h_i	H_i	w_i	m_i	$M_i H_i$	F_{IE}^Y
6	3	18	6137.82	625.6697	11262.06	633.9423
5	3	15	6253.92	637.5046	9562.569	461.1902
4	3	12	6253.92	637.5046	7650.055	368.9522
3	3	9	6253.92	637.5046	5737.541	276.7141
2	3	6	6253.92	637.5046	3825.028	184.4761
1	3	3	6253.92	637.5046	1912.514	92.23804
				3813.193	39949.76	2017.513

Determination of Additional Accidental Eccentricity Effects

The equivalent horizontal earthquake forces shall be applied to mass centers that are shifted by +5% and -5% of the building's plan dimension perpendicular to the considered earthquake direction, in order to account for accidental eccentricity effects during the seismic analysis.

- Defining the Calculated Equivalent Earthquake Loads in SAP2000

Before performing the equivalent earthquake load analysis, the pre-assigned diaphragms for the floor slabs must be deleted. The rigid diaphragms should then be redefined by repeating steps 16 and 17 from the Model setup phase.

To define the equivalent earthquake loads and additional accidental eccentricities in SAP2000, the following steps should be followed.

After completing the modal analysis, unlock the Model by clicking the appropriate icon to enable the reanalysis of the building under the effect of equivalent earthquake forces (see figures 56-63)

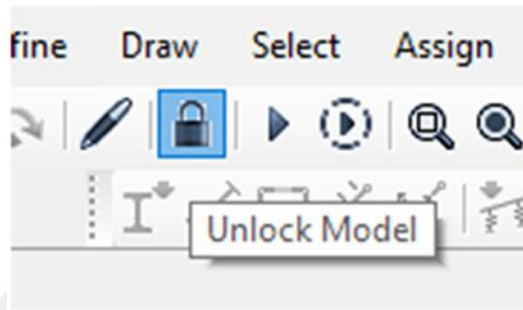


Figure 56. Preparing Model for Seismic Load Reanalysis

Access the Define tab and proceed to Load Patterns to input the earthquake load definitions.

For the equivalent earthquake loading in the X direction (EXP), select the Quake load type and choose User Loads from the Auto Lateral Load Pattern options.

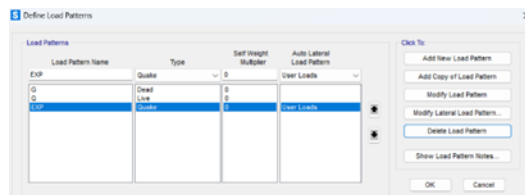


Figure 57. Setting Up Quake Load Type for EXP Direction

The load pattern names EXP are assigned for +5% eccentricity and EXN for –5% eccentricity. To define the equivalent earthquake loads, the Modify Lateral Load Pattern section is accessed.

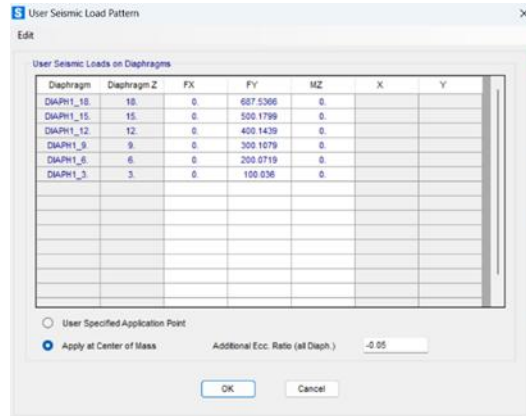


Figure 61. EYN Load Pattern Definition

The program was executed, and the minimum and maximum displacements in the X and Y directions were obtained at each floor diaphragm's corner nodes. The top, bottom, and center of the structure were then analyzed under the EXP, EXN, EYP, and EYN load cases to record the extreme displacements, with U1 values corresponding to the X direction and U2 values corresponding to the Y direction.

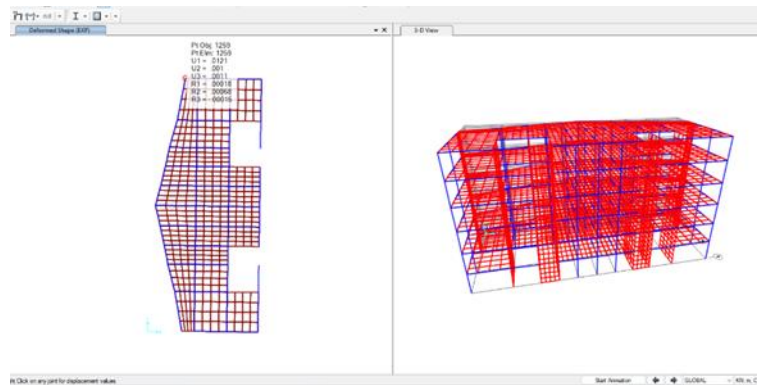


Figure 62. Displacements Under Seismic Load

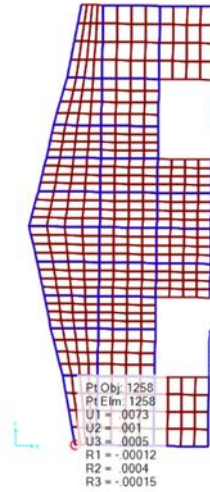


Figure 63. Displacements Under Seismic Loads II

The maximum and minimum displacements for the EXP load case on Floor 6 of Model 1 were 0.0121 and 0.0073, respectively. Similar EXP, EXN, EYP, and EYN displacements were calculated for each floor in all eight Models, and the results are summarized in the tables 34-41.

Tables 34 to 41 summarizes the peak $(d_i)_{min}$ and $(d_i)_{min}$ displacements for each floors of 8 Models in all four seismic loading directions.

Table 34. Floor Displacements for Model 1

EXP			EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$	floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0121	0.0073	6	0.0121	0.0072
5	0.0096	0.0057	5	0.0096	0.0057
4	0.0071	0.00242	4	0.0071	0.0041
3	0.0046	0.0027	3	0.0046	0.0026
2	0.0024	0.0014	2	0.0024	0.0014
1	0.0008	0.0004	1	0.0008	0.0004
EYP			EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$	floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0119	0.0095	6	0.0129	0.0092
5	0.0101	0.0081	5	0.0101	0.0078
4	0.0079	0.0063	4	0.0086	0.0062
3	0.0056	0.0044	3	0.0055	0.0043
2	0.0032	0.0026	2	0.0034	0.0025
1	0.0011	0.0009	1	0.0012	0.0009

Table 35. Floor Displacements for Model 2

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0094	0.0058		6	0.0095	0.0057
5	0.0075	0.0046		5	0.0075	0.0045
4	0.0055	0.0033		4	0.0056	0.0033
3	0.0036	0.0021		3	0.0036	0.0021
2	0.0019	0.0011		2	0.0019	0.0011
1	0.0006	0.0003		1	0.0006	0.0003
EYP				EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0143	0.0117		6	0.0154	0.0113
5	0.0121	0.0099		5	0.0121	0.0096
4	0.0095	0.0077		4	0.0102	0.0075
3	0.0066	0.0054		3	0.0071	0.0052
2	0.0038	0.0031		2	0.0037	0.003
1	0.00133	0.0011		1	0.0014	0.001

Table 36. Floor Displacements for Model 3

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0116	0.0072		6	0.0117	0.0071
5	0.0092	0.0057		5	0.0093	0.0056
4	0.0068	0.0042		4	0.0069	0.0041
3	0.0044	0.0027		3	0.0045	0.0026
2	0.0023	0.0014		2	0.0024	0.0013
1	0.0007	0.0004		1	0.0007	0.0004
EYP				EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0112	0.0093		6	0.0121	0.009
5	0.0095	0.009		5	0.0102	0.0076
4	0.0074	0.0061		4	0.0074	0.0059
3	0.0052	0.0042		3	0.0055	0.0041
2	0.0029	0.0024		2	0.0031	0.00023
1	0.001	0.0008		1	0.001	0.0008

Table 37. Floor Displacements for Model 4

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0122	0.0074		6	0.0123	0.0073
5	0.0097	0.0058		5	0.0098	0.0057
4	0.0071	0.0042		4	0.0072	0.0042
3	0.0046	0.0027		3	0.0047	0.0027
2	0.0024	0.0014		2	0.0025	0.0014
1	0.0008	0.0004		1	0.0008	0.0004
EYP				EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0121	0.0097		6	0.0131	0.0093
5	0.0103	0.0081		5	0.0111	0.0079
4	0.0081	0.0064		4	0.0087	0.0062
3	0.0056	0.0045		3	0.0061	0.0044
2	0.0032	0.0026		2	0.0035	0.0025
1	0.0011	0.0009		1	0.0012	0.0009

Table 38. Floor Displacements for Model 5

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0118	0.0072		6	0.0118	0.0071
5	0.0094	0.0057		5	0.0094	0.0056
4	0.0069	0.0041		4	0.0055	0.003
3	0.0045	0.0027		3	0.0046	0.0026
2	0.0024	0.0014		2	0.0024	0.0014
1	0.0008	0.0004		1	0.0008	0.0004
EYP				EYN		
floor no	dimax	dimin		floor no	dimax	dimin
6	0.0143	0.0117		6	0.0123	0.0089
5	0.0121	0.0099		5	0.0104	0.0076
4	0.0095	0.0077		4	0.00082	0.006
3	0.0066	0.0054		3	0.0058	0.0042
2	0.0038	0.0031		2	0.0033	0.0025
1	0.00133	0.0011		1	0.0012	0.0009

Table 39. Floor Displacements for Model 6

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0122	0.0074		6	0.0123	0.0073
5	0.0097	0.0058		5	0.0098	0.0057
4	0.0071	0.0042		4	0.0072	0.0042
3	0.0046	0.0027		3	0.0047	0.0027
2	0.0024	0.0014		2	0.0025	0.0014
1	0.0008	0.0004		1	0.0008	0.0004
EYP				EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0114	0.0093		6	0.0131	0.0093
5	0.0097	0.0079		5	0.0111	0.0079
4	0.0077	0.0062		4	0.0087	0.0062
3	0.0054	0.0044		3	0.0061	0.0044
2	0.0032	0.0025		2	0.0035	0.0025
1	0.0011	0.0009		1	0.0012	0.0009

Table 40. Floor Displacements for Model 7

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0115	0.0068		6	0.0115	0.0068
5	0.0091	0.0054		5	0.0091	0.0053
4	0.0067	0.0039		4	0.0067	0.0039
3	0.0043	0.0025		3	0.0044	0.0025
2	0.0023	0.0013		2	0.0023	0.0013
1	0.0007	0.0004		1	0.0007	0.0004
EYP				EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0115	0.009		6	0.0125	0.0088
5	0.0097	0.0076		5	0.0105	0.0074
4	0.0076	0.0059		4	0.0082	0.0058
3	0.0053	0.0042		3	0.0057	0.0041
2	0.0031	0.0024		2	0.0033	0.0024
1	0.0011	0.0009		1	0.0011	0.0008

Table 41. Floor Displacements for Model 8

EXP				EXN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0071	0.0043		6	0.0071	0.0043
5	0.0057	0.0034		5	0.0057	0.0034
4	0.0042	0.0025		4	0.0042	0.0024
3	0.0027	0.0016		3	0.0027	0.0016
2	0.0014	0.0008		2	0.0014	0.0008
1	0.0004	0.0003		1	0.0005	0.0003
EYP				EYN		
floor no	$(d_i)_{max}$	$(d_i)_{min}$		floor no	$(d_i)_{max}$	$(d_i)_{min}$
6	0.0129	0.0105		6	0.0139	0.0101
5	0.011	0.0089		5	0.0118	0.0089
4	0.0086	0.0069		4	0.0093	0.0068
3	0.0061	0.0049		3	0.0065	0.0047
2	0.0035	0.0028		2	0.0037	0.0027
1	0.0012	0.001		1	0.0013	0.001

The displacement tables show a clear Drift increase from lower to upper floors, as expected. Variations between EXP, EXN, EYP, and EYN remain small, indicating balanced seismic behavior in both directions. Across all eight Models, peak displacements rise modestly with changes in geometry and stiffness, yet stay within acceptable limits. These results confirm a stable, well-distributed lateral response under all eccentricity cases.

Recommendation: For buildings with symmetric geometry in both the X and Y directions, it is generally sufficient to conduct irregularity checks using the +5% eccentricity load cases in both directions. However, since the building analyzed in this study lacks symmetry along both the X and Y axes, irregularity checks are required in both directions using the $\pm 5\%$ eccentricity load cases. The procedures and outcomes of these checks are further elaborated and clarified in Chapter 4.

CHAPTER FOUR

COMPARATIVE ANALYSIS OF RESULTS

This chapter presents a comprehensive evaluation of key seismic irregularities — including torsional behavior, soft-story conditions, and interstory drift — as well as an assessment of second-order effects. The main objective is to systematically identify and assess potential structural weaknesses that may compromise the building's seismic performance..

Using SAP2000, all checks are conducted under $\pm 5\%$ eccentricity load cases in both the X and Y directions, and the results are critically compared against relevant code requirements. This comparative analysis not only highlights the most critical irregularities present in the structure but also quantifies the influence of second-order effects on the overall seismic demand. Ultimately, the findings provide valuable insights into the building's seismic resilience and inform recommendations for improving performance under earthquake loading.

4.1 Torsional Irregularity Check

4.1.1 Torsional Irregularity Check for Model 1

Table 42. Model 1 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0121	0.0073	0.0025	0.0016	0.00205	1.2195	Torsional irregular
5	0.0096	0.0057	0.0025	0.0015	0.002	1.25	Torsional irregular
4	0.0071	0.0042	0.0025	0.0015	0.002	1.25	Torsional irregular
3	0.0046	0.0027	0.0022	0.0013	0.00175	1.2571	Torsional irregular
2	0.0024	0.0014	0.0016	0.001	0.0013	1.2307	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.3333	Torsional irregular

Table 42 for Model 1 under EXP (X-direction) shows displacement data across six floors. The maximum displacement $(d_i)_{max}$ at Floor 6 is 0.0121 m, while the minimum $(d_i)_{min}$ is 0.0073 m. The η_{bi} values, ranging from 1.2195 to 1.3333, indicate torsional irregularity across all floors. All floors are classified as "Torsional irregular" due to $\eta_{bi} > 1.2$.

Table 43. Model 1 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0121	0.0072	0.0025	0.0015	0.002	1.25	Torsional irregular
5	0.0096	0.0057	0.0025	0.0016	0.00205	1.2195	Torsional irregular
4	0.0071	0.0041	0.0025	0.0015	0.002	1.25	Torsional irregular
3	0.0046	0.0026	0.0022	0.0012	0.0017	1.2948	Torsional irregular
2	0.0024	0.0014	0.0016	0.001	0.0013	1.2307	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.3333	Torsional irregular

Model 1 under EXN loading (see Table 43) shows max displacement of 0.0121 m and min 0.0072 m at Floor 6. Drift ranges from 0.0015 m to 0.0025 m, avg 0.002 m. Torsional irregularity ratio (η_{bi}) exceeds 1.2 on all floors, indicating torsional irregularity according to condition given in Turkish Earthquake Code.

Table 44. Model 1 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0119	0.0095	0.0018	0.0014	0.0016	1.125	Regular
5	0.0101	0.0081	0.0022	0.0018	0.002	1.1	Regular
4	0.0079	0.0063	0.0023	0.0019	0.0021	1.095238	Regular
3	0.0056	0.0044	0.0024	0.0018	0.0021	1.142857	Regular
2	0.0032	0.0026	0.0021	0.0017	0.0019	1.105263	Regular
1	0.0011	0.0009	0.0011	0.0009	0.001	1.1	Regular

Model 1 under EYP loading (see Table 44) shows Floor 6 displacement ranging from 0.0095 m to 0.0119 m, with average drift 0.0016 m.

Torsional irregularity is within limits ($\eta_{bi} \leq 1.2$) except at Floor 3 ($\eta_{bi} = 1.43$), indicating localized irregularity.

Table 45. Model 1 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0129	0.0092	0.0028	0.0014	0.0021	1.333333	Torsional irregular
5	0.0101	0.0078	0.0015	0.0016	0.00155	0.967742	Regular
4	0.0086	0.0062	0.0031	0.0019	0.0025	1.24	Torsional irregular
3	0.0055	0.0043	0.0021	0.0018	0.00195	1.076923	Regular
2	0.0034	0.0025	0.0022	0.0016	0.0019	1.157895	Regular
1	0.0012	0.0009	0.0012	0.0009	0.00105	1.142857	Regular

Model 1 under EYN loading (see Table 45) shows Floor 6 displacement between 0.0092 m and 0.0129 m, with an average inter-story Drift of 0.0021 m..

Torsional irregularity appears on Floors 4 and 6 ($\eta_{bi} > 1.2$), indicating significant torsional effects from structural asymmetry.

4.1.2 Torsional Irregularity Chck for Model 2

Table 46. Model 2 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0094	0.0058	0.0019	0.0012	0.00155	1.225806	Torsional irregular
5	0.0075	0.0046	0.002	0.0013	0.00165	1.212121	Torsional irregular
4	0.0055	0.0033	0.0019	0.0012	0.00155	1.225806	Torsional irregular
3	0.0036	0.0021	0.0017	0.001	0.00135	1.259259	Torsional irregular
2	0.0019	0.0011	0.0013	0.0008	0.00105	1.238095	Torsional irregular
1	0.0006	0.0003	0.0006	0.0003	0.00045	1.333333	Torsional irregular

Model 2 under EXP loading (see Table 46) shows Floor 6 displacement between 0.0058 m and 0.0094 m, with an average inter-story Drift of 0.00155 m.

Torsional irregularity exists on all floors ($\eta_{bi} > 1.2$), indicating asymmetry in stiffness or mass in the X-direction.

Table 47. Model 2 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0095	0.0057	0.002	0.0012	0.0016	1.25	Torsional irregular
5	0.0075	0.0045	0.0019	0.0012	0.00155	1.225806	Torsional irregular
4	0.0056	0.0033	0.002	0.0012	0.0016	1.25	Torsional irregular
3	0.0036	0.0021	0.0017	0.001	0.00135	1.259259	Torsional irregular
2	0.0019	0.0011	0.0013	0.0008	0.00105	1.238095	Torsional irregular
1	0.0006	0.0003	0.0006	0.0003	0.00045	1.333333	Torsional irregular

Model 2 under EXN loading (see Table 47) shows Floor 6 displacement between 0.0057 m and 0.0095 m, with an average inter-story Drift of 0.0016 m.

Torsional irregularity is present on all floors ($\eta_{bi} > 1.2$), suggesting asymmetry in stiffness or mass in the X-direction.

Table 48. Model 2 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0143	0.0117	0.0022	0.0018	0.002	1.1	Regular
5	0.0121	0.0099	0.0026	0.0022	0.0024	1.083333	Regular
4	0.0095	0.0077	0.0029	0.0023	0.0026	1.115385	Regular
3	0.0066	0.0054	0.0028	0.0023	0.00255	1.098039	Regular
2	0.0038	0.0031	0.00247	0.002	0.002235	1.105145	Regular
1	0.00133	0.0011	0.00133	0.0011	0.001215	1.09465	Regular

Model 2 under EYP loading (see Table 48) shows Floor 6 displacement between 0.0117 m and 0.0143 m, with an average inter-story Drift of 0.002 m.

Torsional irregularity ratios ($\eta_{bi} < 1.2$) across all floors indicate torsional regularity in the Y-direction per TBDY-2018.

Table 49. Model 2 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0154	0.0113	0.0033	0.0017	0.0025	1.32	Torsional irregular
5	0.0121	0.0096	0.0019	0.0021	0.002	0.95	Regular
4	0.0102	0.0075	0.0031	0.0023	0.0027	1.148148	Regular
3	0.0071	0.0052	0.0034	0.0022	0.0028	1.214286	Torsional irregular
2	0.0037	0.003	0.0023	0.002	0.00215	1.069767	Regular
1	0.0014	0.001	0.0014	0.001	0.0012	1.166667	Regular

Model 2 under EYN loading (see Table 49) shows Floor 6 displacement between 0.0113 m and 0.0154 m, with an average inter-story Drift of 0.0025 m.

Floors 3, 4, and 6 exhibit torsional irregularity ($\eta_{bi} > 1.2$), indicating significant torsional effects likely from structural asymmetry.

4.1.3 Torsional Irregularity Check for Model 3

Table 50. Model 3 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0116	0.0072	0.0024	0.0015	0.00195	1.230769	Torsional irregular
5	0.0092	0.0057	0.0024	0.0015	0.00195	1.230769	Torsional irregular
4	0.0068	0.0042	0.0024	0.0015	0.00195	1.230769	Torsional irregular
3	0.0044	0.0027	0.0021	0.0013	0.0017	1.235294	Torsional irregular
2	0.0023	0.0014	0.0016	0.001	0.0013	1.230769	Torsional irregular
1	0.0007	0.0004	0.0007	0.0004	0.00055	1.272727	Torsional irregular

Model 3 under EXP loading (see Table 40) shows Floor 6 displacement between 0.0072 m and 0.0116 m, with an average inter-story Drift of 0.00195 m.

Torsional irregularity ratios ($\eta_{bi} > 1.2$) across all floors indicate torsional irregularity according to TBDY-2018.

Table 51. Model 3 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0117	0.0071	0.0024	0.0015	0.00195	1.230769	Torsional irregular
5	0.0093	0.0056	0.0024	0.0015	0.00195	1.230769	Torsional irregular
4	0.0069	0.0041	0.0024	0.0015	0.00195	1.230769	Torsional irregular
3	0.0045	0.0026	0.0021	0.0013	0.0017	1.235294	Torsional irregular
2	0.0024	0.0013	0.0017	0.0009	0.0013	1.307692	Torsional irregular
1	0.0007	0.0004	0.0007	0.0004	0.00055	1.272727	Torsional irregular

Model 3 under EXN loading (see Table 51) shows Floor 6 displacement between 0.0071 m and 0.0117 m, with an average inter-story Drift of 0.00195 m. torsional irregularity ratios ($\eta_{bi} > 1.2$) across all floors indicate torsional irregularity according to TBDY-2018.

Table 52. Model 3 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0112	0.0093	0.0017	0.0003	0.001	1.7	Torsional irregular
5	0.0095	0.009	0.0021	0.0029	0.0025	0.84	Regular
4	0.0074	0.0061	0.0022	0.0019	0.00205	1.073171	Regular
3	0.0052	0.0042	0.0023	0.0018	0.00205	1.121951	Regular
2	0.0029	0.0024	0.0019	0.0016	0.00175	1.085714	Regular
1	0.001	0.0008	0.001	0.0008	0.0009	1.111111	Regular

Model 3 under EYP loading (see Table 52) shows Floor 6 displacement between 0.0093 m and 0.0112 m, with an average inter-story Drift of 0.001 m. torsional irregularity occurs only at Floor 6 ($\eta_{bi} = 1.7$), while other floors remain regular ($\eta_{bi} \leq 1.2$), indicating localized torsional effects in the Y-direction per TBDY-2018.

Table 53. Model 3 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0121	0.009	0.0019	0.0014	0.00165	1.151515	Regular
5	0.0102	0.0076	0.0028	0.0017	0.00225	1.244444	Torsional irregular
4	0.0074	0.0059	0.0019	0.0018	0.00185	1.027027	Regular
3	0.0055	0.0041	0.0024	0.00387	0.003135	0.76555	Regular
2	0.0031	0.00023	0.0021	0.00057	0.000765	2.745098	Torsional irregular
1	0.001	0.0008	0.001	0.0008	0.0009	1.111111	Regular

Model 3 under EYN loading (see Table 53) shows Floor 6 displacement between 0.009 m and 0.0121 m, with an average inter-story Drift of 0.00165 m.

Floors 2 ($\eta_{bi} = 2.75$) and 5 ($\eta_{bi} = 1.24$) are torsionally irregular, while other floors are regular, indicating localized torsional effects in the Y-direction per TBDY-2018.

4.1.4 Torsional Irregularity Check for Model 4

Table 54. Model 4 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0111	0.0069	0.0022	0.0015	0.00185	1.189189	Regular
5	0.0089	0.0054	0.0023	0.0014	0.00185	1.243243	Torsional irregular
4	0.0066	0.004	0.0022	0.0014	0.0018	1.222222	Torsional irregular
3	0.0044	0.0026	0.0021	0.0012	0.00165	1.272727	Torsional irregular
2	0.0023	0.0014	0.0016	0.001	0.0013	1.230769	Torsional irregular
1	0.0007	0.0004	0.0007	0.0004	0.00055	1.272727	Torsional irregular

Model 4 under EXP loading (see Table 54) shows Floor 6 displacement between 0.0069 m and 0.0111 m, with an average inter-story Drift of 0.00185 m.

Floors 1–5 are torsionally irregular ($\eta_{bi} > 1.2$), while Floor 6 is regular ($\eta_{bi} \leq 1.2$), indicating varying torsional effects in the X-direction per TBDY-2018.

Table 55. Model 4 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	(d_i)	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0112	0.0068	0.0022	0.0014	0.0018	1.222222	Torsional irregular
5	0.009	0.0054	0.0023	0.0014	0.00185	1.243243	Torsional irregular
4	0.0067	0.004	0.0023	0.0014	0.00185	1.243243	Torsional irregular
3	0.0044	0.0026	0.0021	0.0013	0.0017	1.235294	Torsional irregular
2	0.0023	0.0013	0.0015	0.0009	0.0012	1.25	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.333333	Torsional irregular

Model 4 under EXN loading (see Table 55) shows Floor 6 displacement between 0.0068 m and 0.0112 m, with an average inter-story Drift of 0.0018 m.

Torsional irregularity is present on all floors ($\eta_{bi} > 1.2$) according to TBDY-2018.

Table 56. Model 4 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0104	0.0088	0.0014	0.0013	0.00135	1.037037	Regular
5	0.009	0.0075	0.0018	0.0015	0.00165	1.090909	Regular
4	0.0072	0.006	0.0021	0.0018	0.00195	1.076923	Regular
3	0.0051	0.0042	0.0021	0.0017	0.0019	1.105263	Regular
2	0.003	0.0025	0.0019	0.0016	0.00175	1.085714	Regular
1	0.0011	0.0009	0.0011	0.0009	0.001	1.1	Regular

Model 4 under EYP loading (see Table 56) shows Floor 6 displacement between 0.0088 m and 0.0104 m, with an average inter-story Drift of 0.00135 m. Torsional irregularity ratios are below 1.2 across all floors, indicating torsional regularity in the Y-direction per TBDY-2018.

Table 57. Model 4 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0112	0.0084	0.0015	0.0012	0.00135	1.111111	Regular
5	0.0097	0.0072	0.002	0.0014	0.0017	1.176471	Regular
4	0.0077	0.0058	0.0022	0.0017	0.00195	1.128205	Regular
3	0.0055	0.0041	0.0023	0.0017	0.002	1.15	Regular
2	0.0032	0.0024	0.002	0.0015	0.00175	1.142857	Regular
1	0.0012	0.0009	0.0012	0.0009	0.00105	1.142857	Regular

Model 4 under EYN loading (see Table 57) shows Floor 6 displacement between 0.0084 m and 0.0112 m, with an average inter-story Drift of 0.00135 m.

Torsional irregularity ratios are below 1.2 across all floors, indicating torsional regularity in the Y-direction per TBDY-2018.

4.1.5 Torsional Irregularity Check for Model 5

Table 58. Model 5 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0118	0.0072	0.0024	0.0015	0.00195	1.230769	Torsional irregular
5	0.0094	0.0057	0.0025	0.0016	0.00205	1.219512	Torsional irregular
4	0.0069	0.0041	0.0024	0.0014	0.0019	1.263158	Torsional irregular
3	0.0045	0.0027	0.0021	0.0013	0.0017	1.235294	Torsional irregular
2	0.0024	0.0014	0.0016	0.001	0.0013	1.230769	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.333333	Torsional irregular

Model 5 under EXP loading (see Table 58) shows Floor 6 displacement between 0.0072 m and 0.0118 m, with an average inter-story Drift of 0.00195 m.

Torsional irregularity is present on all floors ($\eta_{bi} > 1.2$) according to TBDY-2018.

Table 59. Model 5 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0118	0.0071	0.0024	0.0015	0.00195	1.230769	Torsional irregular
5	0.0094	0.0056	0.0039	0.0026	0.00325	1.2	Torsional irregular
4	0.0055	0.003	0.0009	0.0004	0.00065	1.384615	Torsional irregular
3	0.0046	0.0026	0.0022	0.0012	0.0017	1.294118	Torsional irregular
2	0.0024	0.0014	0.0016	0.001	0.0013	1.230769	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.333333	Torsional irregular

Model 5 under EXN loading (see Table 59) shows Floor 6 displacement between 0.0071 m and 0.0118 m, with an average inter-story Drift of 0.00195 m.

Torsional irregularity is present on all floors ($\eta_{bi} > 1.2$) according to TBDY-2018.

Table 60. Model 5 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0114	0.0093	0.0017	0.0014	0.00155	1.096774	Regullar
5	0.0097	0.0079	0.002	0.0017	0.00185	1.081081	Regullar
4	0.0077	0.0062	0.0023	0.0018	0.00205	1.121951	Regullar
3	0.0054	0.0044	0.0022	0.0019	0.00205	1.073171	Regullar
2	0.0032	0.0025	0.0021	0.0016	0.00185	1.135135	Regullar
1	0.0011	0.0009	0.0011	0.0009	0.001	1.1	Regullar

For the six-story structure under EYP loading (see Table 60), Floor 6 displacement ranges from 0.0093 m to 0.0114 m, with an average inter-story drift of 0.00155 m

The height-to-base index (η_{bi}) ranges from 1.073 to 1.135, all below 1.2, indicating no torsional irregularity and consistent stiffness and mass distribution.

Table 61. Model 5 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0123	0.0089	0.0019	0.0013	0.0016	1.1875	Regular
5	0.0104	0.0076	0.00958	0.0016	0.00559	1.71377 5	Torsional irregular
4	0.00082	0.006	- 0.00498	0.0018	- 0.00159	3.13207 5	Torsional irregular
3	0.0058	0.0042	0.0025	0.0017	0.0021	1.19047 6	Regular
2	0.0033	0.0025	0.0021	0.0016	0.00185	1.13513 5	Regular
1	0.0012	0.0009	0.0012	0.0009	0.00105	1.14285 7	Regular

For the six-story structure under EYN loading (see Table 61), Floor 6 displacement ranges from 0.0089 m to 0.0123 m, with an average inter-story drift of 0.0016 m.

Torsional irregularity ($\eta_{bi} > 1.2$) occurs on Floors 4 and 5, while Floors 1, 2, 3, and 6 remain regular. Negative drifts on Floor 4 suggest possible Modeling or load application issues.

4.1.6 Torsional Irregularity Check for Model 6

Table 62. Model 6 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0122	0.0074	0.0025	0.0016	0.00205	1.219512	Torsional irregular
5	0.0097	0.0058	0.0026	0.0016	0.0021	1.238095	Torsional irregular
4	0.0071	0.0042	0.0025	0.0015	0.002	1.25	Torsional irregular
3	0.0046	0.0027	0.0022	0.0013	0.00175	1.257143	Torsional irregular
2	0.0024	0.0014	0.0016	0.001	0.0013	1.230769	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.333333	Torsional irregular

Model 6 under EXP loading (see Table 62) shows Floor 6 displacement between 0.0074 m and 0.0122 m, with an average inter-story Drift of 0.00205 m.

Torsional irregularity ratios ($\eta_{bi} > 1.2$) on all floors indicate torsional irregularity per TBDY-2018.

Table 63. Model 6 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0123	0.0073	0.0025	0.0016	0.00205	1.21951 2	Torsional irregular
5	0.0098	0.0057	0.0026	0.0015	0.00205	1.26829 3	Torsional irregular
4	0.0072	0.0042	0.0025	0.0015	0.002	1.25	Torsional irregular
3	0.0047	0.0027	0.0022	0.0013	0.00175	1.25714 3	Torsional irregular
2	0.0025	0.0014	0.0017	0.001	0.00135	1.25925 9	Torsional irregular
1	0.0008	0.0004	0.0008	0.0004	0.0006	1.33333 3	Torsional irregular

For the six-story structure under EXN loading (see Table 63), Floor 6 displacement ranges from 0.0073 m to 0.0123 m, with an average inter-story Drift of 0.00205 m.

Torsional irregularity ratios ($\eta_{bi} > 1.2$) on all floors indicate torsional irregularity up to TBDY 2018, with no negative Drifts observed, showing consistent structural response in the X-direction.

Table 64. Model 6 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0121	0.0097	0.0018	0.0016	0.0017	1.058824	Regular
5	0.0103	0.0081	0.0022	0.0017	0.00195	1.128205	Regular
4	0.0081	0.0064	0.0025	0.0019	0.0022	1.136364	Regular
3	0.0056	0.0045	0.0024	0.0019	0.00215	1.116279	Regular
2	0.0032	0.0026	0.0021	0.0017	0.0019	1.105263	Regular
1	0.0011	0.0009	0.0011	0.0009	0.001	1.1	Regular

For the six-story structure under EYN loading (see Table 64), the displacement on Floor 6 ranges from 0.0093 m to 0.0131 m, with an average inter-story Drift of 0.0017 m. torsional irregularity ratios ($\eta_{bi} > 1.2$) on all floors indicate torsional irregularity up to TBDY 2018.

Table 65. Model 6 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0131	0.0093	0.002	0.0014	0.0017	1.176471	Regular
5	0.0111	0.0079	0.0024	0.0017	0.00205	1.170732	Regular
4	0.0087	0.0062	0.0026	0.0018	0.0022	1.181818	Regular
3	0.0061	0.0044	0.0026	0.0019	0.00225	1.155556	Regular
2	0.0035	0.0025	0.0023	0.0016	0.00195	1.179487	Regular
1	0.0012	0.0009	0.0012	0.0009	0.00105	1.142857	Regular

For the six-story structure under EYN loading (see Table 65), the displacement on Floor 6 ranges from 0.0093 m to 0.0131 m, with an average inter-story Drift of 0.0017 m.

Torsional irregularity ratios ($\eta_{bi} < 1.2$) on all floors indicate regular behavior up to TBDY 2018.

4.1.7 Torsional Irregularity Check for Model 7

Table 66. Model 7 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0115	0.0068	0.0024	0.0014	0.0019	1.263158	Torsional irregular
5	0.0091	0.0054	0.0024	0.0015	0.00195	1.230769	Torsional irregular
4	0.0067	0.0039	0.0024	0.0014	0.0019	1.263158	Torsional irregular
3	0.0043	0.0025	0.002	0.0012	0.0016	1.25	Torsional irregular
2	0.0023	0.0013	0.0016	0.0009	0.00125	1.28	Torsional irregular
1	0.0007	0.0004	0.0007	0.0004	0.00055	1.272727	Torsional irregular

For Model 7 under EXP loading (see Table 66), the displacement on Floor 6 ranges from 0.0068 m to 0.0115 m, with an average inter-story drift of 0.0019 m.

Torsional irregularity ratios ($\eta_{bi} > 1.2$) on all floors indicate torsional irregularity up to TBDY 2018.

Table 67. Model 7 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0115	0.0068	0.0024	0.0015	0.00195	1.230769	Torsional irregular
5	0.0091	0.0053	0.0024	0.0014	0.0019	1.263158	Torsional irregular
4	0.0067	0.0039	0.0023	0.0014	0.00185	1.243243	Torsional irregular
3	0.0044	0.0025	0.0021	0.0012	0.00165	1.272727	Torsional irregular
2	0.0023	0.0013	0.0016	0.0009	0.00125	1.28	Torsional irregular
1	0.0007	0.0004	0.0007	0.0004	0.00055	1.272727	Torsional irregular

For Model 7 under EXN loading (see Table 67), the displacement on Floor 6 ranges from 0.0068 m to 0.0115 m, with an average inter-story drift of 0.00195 m.

Torsional irregularity ratios ($\eta_{bi} > 1.2$) on all floors indicate torsional irregularity up to TBDY 2018.

Table 68. Model 7 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0115	0.009	0.0018	0.0014	0.0016	1.125	Regular
5	0.0097	0.0076	0.0021	0.0017	0.0019	1.105263	Regular
4	0.0076	0.0059	0.0023	0.0017	0.002	1.15	Regular
3	0.0053	0.0042	0.0022	0.0018	0.002	1.1	Regular
2	0.0031	0.0024	0.002	0.0015	0.00175	1.142857	Regular
1	0.0011	0.0009	0.0011	0.0009	0.001	1.1	Regular

For Model 7 under EYN loading (see Table 68), the displacement on Floor 6 ranges from 0.0088 m to 0.0125 m, with an average inter-story drift of 0.0017 m.

Torsional irregularity ratios ($\eta_{bi} < 1.2$) on all floors indicate torsional regularity up to TBDY 2018.

Table 69. Model 7 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0125	0.0088	0.002	0.0014	0.0017	1.176471	Regular
5	0.0105	0.0074	0.0023	0.0016	0.00195	1.179487	Regular
4	0.0082	0.0058	0.0025	0.0017	0.0021	1.190476	Regular
3	0.0057	0.0041	0.0024	0.0017	0.00205	1.170732	Regular
2	0.0033	0.0024	0.0022	0.0016	0.0019	1.157895	Regular
1	0.0011	0.0008	0.0011	0.0008	0.00095	1.157895	Regular

For Model 7 under EYN loading (see Table 69), the displacement on Floor 6 ranges from 0.0088 m to 0.0125 m, with an average inter-story drift of 0.0017 m. Torsional irregularity ratios ($\eta_{bi} < 1.2$) on all floors indicate torsional regularity up to TBDY 2018.

4.1.8 Torsional Irregularity Check for Model 8

Table 70. Model 8 EXP for torsional irregularity

EXP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0071	0.0043	0.0014	0.0009	0.00115	1.217391	Torsional irregular
5	0.0057	0.0034	0.0015	0.0009	0.0012	1.25	Torsional irregular
4	0.0042	0.0025	0.0015	0.0009	0.0012	1.25	Torsional irregular
3	0.0027	0.0016	0.0013	0.0008	0.00105	1.238095	Torsional irregular
2	0.0014	0.0008	0.001	0.0005	0.00075	1.333333	Torsional irregular
1	0.0004	0.0003	0.0004	0.0003	0.00035	1.142857	Regular

For Model 8 under EXP loading (see Table 70), the displacement on Floor 6 ranges from 0.0043 m to 0.0071 m, with an average inter-story drift of 0.00115 m. Torsional irregularity ratios ($\eta_{bi} > 1.2$) on Floors 2 to 6 indicate torsional irregularity up to TBDY 2018, while Floor 1 is regular.

Table 71. Model 8 EXN for torsional irregularity

EXN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0071	0.0043	0.0014	0.0009	0.00115	1.217391	Torsional irregular
5	0.0057	0.0034	0.0015	0.001	0.00125	1.2	Torsional irregular
4	0.0042	0.0024	0.0015	0.0008	0.00115	1.304348	Torsional irregular

3	0.0027	0.0016	0.0013	0.0008	0.00105	1.238095	Torsional irregular
2	0.0014	0.0008	0.0009	0.0005	0.0007	1.285714	Torsional irregular
1	0.0005	0.0003	0.0005	0.0003	0.0004	1.25	Torsional irregular

For Model 8 under EXN loading conditions(see table 71), The on floor displacement on floor 6 ranges from 0.0043 m to 0.0071 m, with average inter-story drift of 0.00115 m.

Torsional irregularity ratios ($\eta_{bi} > 1.2$) on all floors indicate torsional irregularity up to TBDY 2018. No negative Drifts are observed. This reinforces recurring torsional challenges in X-directional loading across Models 6, 7, and 8.

Table 72. Model 8 EYP for torsional irregularity

EYP							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0129	0.0105	0.0019	0.0016	0.00175	1.085714	Regular
5	0.011	0.0089	0.0024	0.002	0.0022	1.090909	Regular
4	0.0086	0.0069	0.0025	0.002	0.00225	1.111111	Regular
3	0.0061	0.0049	0.0026	0.0021	0.00235	1.106383	Regular
2	0.0035	0.0028	0.0023	0.0018	0.00205	1.121951	Regular
1	0.0012	0.001	0.0012	0.001	0.0011	1.090909	Regular

For Model 8 under EYP loading (see Table 72), Floor 6 displacement ranges from 0.0105 m to 0.0129 m, with an average inter-story Drift of 0.00175 m.

Torsional irregularity ratios remain below 1.2, indicating regular behavior per TBDY 2018.

Table 73. Model 8 EYN for torsional irregularity

EYN							
floor no	$(d_i)_{max}$	$(d_i)_{min}$	$(\Delta i)_{max}$	$(\Delta i)_{min}$	$(\Delta i)_{avg}$	η_{bi}	Comment
6	0.0139	0.0101	0.0021	0.0012	0.00165	1.272727	Torsional irregular
5	0.0118	0.0089	0.0025	0.0021	0.0023	1.086957	Regular
4	0.0093	0.0068	0.0028	0.0021	0.00245	1.142857	Regular
3	0.0065	0.0047	0.0028	0.002	0.0024	1.166667	Regular
2	0.0037	0.0027	0.0024	0.0017	0.00205	1.170732	Regular
1	0.0013	0.001	0.0013	0.001	0.00115	1.130435	Regular

For Model 8 under EYN loading (see Table 73), Floor 6 displacement ranges from 0.0101 m to 0.0139 m, with an average inter-story drift of 0.00165 m.

Torsional irregularity occurs at Floor 6 ($\eta_{bi} > 1.2$), while Floors 1–5 remain regular per TBDY 2018.

4.2. Soft Floor Check

4.2.1 Soft Floor Check For Model 1

Table 74. Model 1 EXP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00205	0.000683	0	1.025	Regular
5	3	0.002	0.000667	0.9756098	1	Regular
4	3	0.002	0.000667	1	1.14286	Regular
3	3	0.00175	0.000583	0.875	1.34615	Regular
2	3	0.0013	0.000433	0.7428571	2.16667	Irregular
1	3	0.0006	0.0002	0.4615385	0	Regular

For Model 1 under EXP loading (see Table 74), average inter-story drift ranges from 0.0006 m to 0.00205 m, with drift ratios $((\Delta_i)_{avg}/h_i)$ between 0.0002 and 0.000683.

Stiffness irregularity occurs at Floor 2 ($\eta_{ki} = 2.166 > 2$), indicating stiffness discontinuity per TBDY 2018, while other floors remain regular.

Table 75. Model 1 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.002	0.000667	0	0.97561	Regular
5	3	0.00205	0.000683	1.025	1.025	Regular
4	3	0.002	0.000667	0.9756098	1.17647	Regular
3	3	0.0017	0.000567	0.85	1.30769	Regular
2	3	0.0013	0.000433	0.7647059	2.16667	Irregular
1	3	0.0006	0.0002	0.4615385	0	Regular

For Model 1 under EXN loading (see Table 75), average inter-story drift ranges from 0.0006 m to 0.00205 m, with drift ratios $((\Delta_i)_{avg}/h_i)$ between 0.0002 and 0.000683. Stiffness irregularity is observed at Floor 2 ($\eta_{ki} = 2.166 > 2$), indicating a stiffness discontinuity per TBDY 2018, while other floors remain regular.

Table 76. Model 1 EYP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0016	0.000533	0	0.8	Regular
5	3	0.002	0.000667	1.25	0.95238	Regular
4	3	0.0021	0.0007	1.05	1	Regular
3	3	0.0021	0.0007	1	1.10526	Regular
2	3	0.0019	0.000633	0.9047619	1.9	Regular
1	3	0.001	0.000333	0.5263158	0	Regular

Model 1 under EYP loading (see Table 76) shows average inter-story Driffts ranging from 0.001 m to 0.0021 m, with Drifft ratios ≤ 0.0007 . Stiffness irregularity ratios (η_{ki}) are mostly ≤ 2 , indicating no stiffness irregularity per TBDY 2018.

Table 77. Model 1 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0021	0.0007	0	1.35484	Regular
5	3	0.00155	0.000517	0.7380952	0.62	Regular
4	3	0.0025	0.000833	1.6129032	1.28205	Regular
3	3	0.00195	0.00065	0.78	1.02632	Regular
2	3	0.0019	0.000633	0.974359	1.80952	Regular
1	3	0.00105	0.00035	0.5526316	0	Regular

Model 1 under EYN loading (see Table 77) shows average inter-story Driffts ranging from 0.00105 m to 0.0025 m, with Drifft ratios up to 0.00083. Stiffness irregularity ratios (η_{ki}) are mostly ≤ 2 , indicating no stiffness irregularity per TBDY 2018.

4.2.2 Soft Floor Check For Model 2

Table 78. Model 2 EXP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / (\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i / (\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00155	0.000517	0	0.939394	Regular
5	3	0.00165	0.00055	1.064516	1.064516	Regular
4	3	0.00155	0.000517	0.939394	1.148148	Regular
3	3	0.00135	0.00045	0.870968	1.285714	Regular
2	3	0.00105	0.00035	0.777778	2.333333	Irregular
1	3	0.00045	0.00015	0.428571	0	Regular

Model 2 under EXP shows Drift ratios up to 0.00055 (see Table 78).

Floor 2 stiffness irregularity ratio is 2.333, exceeding 2, indicating stiffness irregularity per TBDY 2018 and other floors are regular.

Table 79. Model 2 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / (\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i / (\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0016	0.000533	0	1.032258	Regular
5	3	0.00155	0.000517	0.96875	0.96875	Regular
4	3	0.0016	0.000533	1.032258	1.185185	Regular
3	3	0.00135	0.00045	0.84375	1.285714	Regular
2	3	0.00105	0.00035	0.777778	2.333333	Irregular

Model 2 under EXN shows drift ratios up to 0.000533 (see Table 79).

Floor 2 stiffness irregularity ratio is 2.333, exceeding 2, indicating stiffness irregularity per TBDY 2018.

Other floors are regular.

Table 80. Model 2 EYP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / (\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{bi} = \Delta_i/h_i / (\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.002	0.000667	0	0.833333	Regular
5	3	0.0024	0.0008	1.2	0.923077	Regular
4	3	0.0026	0.000867	1.083333	1.019608	Regular
3	3	0.00255	0.00085	0.980769	1.14094	Regular

2	3	0.002235	0.000745	0.876471	1.839506	Regular
1	3	0.001215	0.000405	0.543624	0	Regular

Model 2 under EYP shows Drift ratios up to 0.000667(see table 80).

All floors have stiffness irregularity ratios $(\eta_{ki}) \leq 2$, indicating no stiffness irregularity per TBDY 2018.

No significant stiffness discontinuity is observed in the Y-direction.

Table 81. Model 2 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0025	0.000833	0	1.25	Regular
5	3	0.002	0.000667	0.8	0.740741	Regular
4	3	0.0027	0.0009	1.35	0.964286	Regular
3	3	0.0028	0.000933	1.037037	1.302326	Regular
2	3	0.00215	0.000717	0.767857	1.791667	Regular
1	3	0.0012	0.0004	0.55814	0	Regular

Model 2 under EYN shows Drift ratios up to 0.00093(see table 81).

All floors have stiffness irregularity ratios $(\eta_{ki}) \leq 2$, indicating no stiffness irregularity per TBDY 2018.

4.2.3 Soft Floor Check For Model 3

Table 82. Model 3 EXP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00195	0.00065	0	1	Regular
5	3	0.00195	0.00065	1	1	Regular
4	3	0.00195	0.00065	1	1.14706	Regular
3	3	0.0017	0.000567	0.8717949	1.30769	Regular
2	3	0.0013	0.000433	0.7647059	2.36364	Irregular
1	3	0.00055	0.000183	0.4230769	0	Regular

Table 82 presents the soft story evaluation results for Model 3 under EXP loading. Based on the $(\Delta_i)_{avg}/h_i$ and η_{ki} ratios, Floor 2 exceeds typical thresholds, indicating soft story irregularity, while the other floors remain within regular limits.

Table 83. Model 3 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00195	0.00065	0	1	Regular
5	3	0.00195	0.00065	1	1	Regular
4	3	0.00195	0.00065	1	1.14706	Regular
3	3	0.0017	0.000567	0.8717949	1.30769	Regular
2	3	0.0013	0.000433	0.7647059	2.36364	Irregular
1	3	0.00055	0.000183	0.4230769	0	Regular

Model 3 under EXN loading(see table 83) shows drift ratios up to 0.00065 (see table 83).

Floor 2 has a stiffness irregularity ratio (η_{ki}) of 2.36, exceeding 2, indicating stiffness irregularity per TBDY 2018.

Other floors are regular ($\eta_{ki} \leq 2$).

Table 84. Model 3 EYP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.001	0.000333	0	0.4	Regular
5	3	0.0025	0.000833	2.5	1.21951	Irregular
4	3	0.00205	0.000683	0.82	1	Regular
3	3	0.00205	0.000683	1	1.17143	Regular
2	3	0.00175	0.000583	0.8536585	1.94444	Regular
1	3	0.0009	0.0003	0.5142857	0	Regular

Model 3 under EYP loading shows Drift ratios up to 0.00083 (see table 84).

Floor 5 has stiffness irregularity ($\eta_{ki} = 2.5$), others are regular. Indicates stiffness discontinuity between Floors 4 and 5.

Table 85. Model 3 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00165	0.00055	0	0.73333	Regular
5	3	0.00225	0.00075	1.3636364	1.21622	Regular
4	3	0.00185	0.000617	0.8222222	0.59011	Regular
3	3	0.003135	0.001045	1.6945946	4.09804	Irregular
2	3	0.000765	0.000255	0.2440191	0.85	Regular
1	3	0.0009	0.0003	1.1764706	0	Regular

Model 3 under EYN loading shows Drift ratios up to 0.00105 (see table 85).

Floor 3 has stiffness irregularity ($\eta_{ki}= 4.1$), others are regular.

4.2.4 Soft Floor Check For Model 4

Table 86. Model 3 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00185	0.000617	0	1	Regular
5	3	0.00185	0.000617	1	1.027778	Regular
4	3	0.0018	0.0006	0.972973	1.090909	Regular
3	3	0.00165	0.00055	0.916667	1.269231	Regular
2	3	0.0013	0.000433	0.787879	2.363636	Irregular
1	3	0.00055	0.000183	0.423077	0	Regular

Model 4 under EXP shows Drift ratios up to 0.00062 as shown in table 86.

Floor 2 has stiffness irregularity ($\eta_{ki}= 2.36$) per TBDY 2018, others are regular.

Indicates stiffness discontinuity between Floors 1 and 2 in X-direction.

Table 87. Model 4 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0018	0.0006	0	0.972973	Regular
5	3	0.00185	0.000617	1.027778	1	Regular
4	3	0.00185	0.000617	1	1.088235	Regular

3	3	0.0017	0.000567	0.918919	1.416667	Regular
2	3	0.0012	0.0004	0.705882	2	Regular
1	3	0.0006	0.0002	0.5	0	Regular

Model 4 under EXN loading(see table 87) shows average displacement ratios $((\Delta_i)_{avg}/h_i)$ from 0.0002 to 0.00062.

All floors have stiffness irregularity ratios $(\eta_{ki}) \leq 2$. indicating no stiffness irregularity per TBDY 2018.

Table 88. Model 4 EYP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00135	0.00045	0	0.818182	Regular
5	3	0.00165	0.00055	1.222222	0.846154	Regular
4	3	0.00195	0.00065	1.181818	1.026316	Regular
3	3	0.0019	0.000633	0.974359	1.085714	Regular
2	3	0.00175	0.000583	0.921053	1.75	Regular
1	3	0.001	0.000333	0.571429	0	Regular

Model 4 under EYP loading(see table 88) shows average displacement ratios $((\Delta_i)_{avg}/h_i)$ from 0.00033 to 0.00065.

Torsional irregularity ratios (η_{ki}) range from 0 to 1.75, but all are below the 2 threshold according to Turkish earthquake code 2018.

Therefore, soft floor behavior is regular across all floors.

Table 89. Model 4 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00135	0.00045	0	0.794118	Regular
5	3	0.0017	0.000567	1.259259	0.871795	Regular
4	3	0.00195	0.00065	1.147059	0.975	Regular
3	3	0.002	0.000667	1.025641	1.142857	Regular

2	3	0.00175	0.000583	0.875	1.666667	Regular
1	3	0.00105	0.00035	0.6	0	Regular

For Model 4 under EYN loading(see table 89) the displacement-to-height ratio $((\Delta_i)_{avg}/h_i)$ ranges from 0.00035 (Floor 1) to 0.00067 (Floor 3).

The torsional irregularity ratio (η_{ki}) ranges from 0 (Floors 1 and 6) to 1.67 (Floor 2).

Since all η_{ki} values are below the 2 limit per TBDY 2018, torsional behavior is regular across all floors.

4.2.5 Soft Floor Check For Model 5

Table 90. Model 5 EXP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00195	0.00065	0	0.95122	Regular
5	3	0.00205	0.000683	1.0512821	1.07895	Regular
4	3	0.0019	0.000633	0.9268293	1.11765	Regular
3	3	0.0017	0.000567	0.8947368	1.30769	Regular
2	3	0.0013	0.000433	0.7647059	2.16667	Irregular
1	3	0.0006	0.0002	0.4615385	0	Regular

Under EXP (see table 90) Floor 2 shows stiffness irregularity $(\eta_{ki} = 2.17 > 2)$ per TBDY 2018. Other floors are regular, indicating a stiffness discontinuity at Floor 2.

Table 91. Model 5 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00195	0.00065	0	0.6	Regular
5	3	0.00325	0.001083	1.6666667	5	Irregular
4	3	0.00065	0.000217	0.2	0.38235	Regular
3	3	0.0017	0.000567	2.6153846	1.30769	Irregular
2	3	0.0013	0.000433	0.7647059	2.16667	Irregular
1	3	0.0006	0.0002	0.4615385	0	Regular

Under EXN (see table 91) Floors 3, 5, and 2 show stiffness irregularity with h_{ki} values of 2.62, 1.67, and 2.17 respectively, all exceeding 2 per TBDY 2018. Other floors are regular. This indicates multiple stiffness discontinuities in the structure.

Table 92. Model 5 EYP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00155	0.000517	0	0.83784	Regular
5	3	0.00185	0.000617	1.1935484	0.90244	Regular
4	3	0.00205	0.000683	1.1081081	1	Regular
3	3	0.00205	0.000683	1	1.10811	Regular
2	3	0.00185	0.000617	0.902439	1.85	Regular
1	3	0.001	0.000333	0.5405405	0	Regular

Under EYP (see table 92), all floors show stiffness irregularity ratios (η_{ki}) below 2 per TBDY 2018, indicating regular stiffness behavior throughout the structure.

Table 93. Model 5 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0016	0.000533	0	0.28623	Regular
5	3	0.00559	0.001863	3.49375	-3.51572	Irregular
4	3	-0.00159	-0.00053	-0.2844365	-0.75714	Regular
3	3	0.0021	0.0007	-1.3207547	1.13514	Regular
2	3	0.00185	0.000617	0.8809524	1.7619	Regular
1	3	0.00105	0.00035	0.5675676	0	Regular

Under EYN (see table 93), Floor 5 shows stiffness irregularity with $h_{ki} = 3.49$, exceeding the 2 limit per TBDY 2018. Other floors have $\eta_{ki} \leq 2$, indicating regular stiffness behavior.

4.2.6 Soft Floor Check For Model 6

Table 94. Model 6 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00205	0.000683	0	0.97619	Regular
5	3	0.0021	0.0007	1.02439	1.05	Regular
4	3	0.002	0.000667	0.952381	1.142857	Regular
3	3	0.00175	0.000583	0.875	1.346154	Regular
2	3	0.0013	0.000433	0.742857	2.166667	Irregular
1	3	0.0006	0.0002	0.461538	0	Regular

Table 94 shows that Model 6 under EYN loading exhibits stiffness irregularity at the 2nd floor ($\eta_{ki} = 2.17 > 2.0$), indicating a soft-story condition that may compromise the seismic performance at that level.

Table 95. Model 6 EXP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00205	0.000683	0	1	Regular
5	3	0.00205	0.000683	1	1.025	Regular
4	3	0.002	0.000667	0.97561	1.142857	Regular
3	3	0.00175	0.000583	0.875	1.296296	Regular
2	3	0.00135	0.00045	0.771429	2.25	Irregular
1	3	0.0006	0.0002	0.444444	0	Regular

Table 95 shows that Model 6 under EXP loading exhibits stiffness irregularity at the 2nd floor ($\eta_{ki} = 2.25 > 2.0$), indicating a soft-story condition that may compromise the seismic performance at that level.

Table 96. Model 6 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0017	0.000567	0	0.871795	Regular
5	3	0.00195	0.00065	1.147059	0.886364	Regular
4	3	0.0022	0.000733	1.128205	1.023256	Regular
3	3	0.00215	0.000717	0.977273	1.131579	Regular
2	3	0.0019	0.000633	0.883721	1.9	Regular
1	3	0.001	0.000333	0.526316	0	Regular

Table 96 shows that Model 6 under EXN loading does not exhibit stiffness irregularity, as all η_{ki} values remain below the 2.0 limit, indicating regular soft-story behavior across all floors.

Table 97. Model 6 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0017	0.000567	0	0.829268	Regular
5	3	0.00205	0.000683	1.205882	0.931818	Regular
4	3	0.0022	0.000733	1.073171	0.977778	Regular

3	3	0.00225	0.00075	1.022727	1.153846	Regular
2	3	0.00195	0.00065	0.866667	1.857143	Regular
1	3	0.00105	0.00035	0.538462	0	Regular

Table 97 shows that Model 6 under EYN loading exhibits no stiffness irregularity, with all η_{ki} values below the 2.0 limit, indicating regular soft-story behavior throughout the structure.

4.2.7 Soft Floor Check For Model 7

Table 98. Model 7 EXP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	Comment
6	3	0.0019	0.000633	0	0.97436	Regular
5	3	0.00195	0.00065	1.0263158	1.02632	Regular
4	3	0.0019	0.000633	0.974359	1.1875	Regular
3	3	0.0016	0.000533	0.8421053	1.28	Regular
2	3	0.00125	0.000417	0.78125	2.27273	Irregular
1	3	0.00055	0.000183	0.44	0	Regular

Table 98 shows that Model 7 under EXP loading exhibits stiffness irregularity at the 2nd floor ($\eta_{ki} = 2.27 > 2.0$), indicating a soft-story condition that may affect the seismic performance at that level.

Table 99. Model 7 EXN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	Comment
6	3	0.00195	0.00065	0	1.02632	Regular
5	3	0.0019	0.000633	0.974359	1.02703	Regular
4	3	0.00185	0.000617	0.9736842	1.12121	Regular
3	3	0.00165	0.00055	0.8918919	1.32	Regular
2	3	0.00125	0.000417	0.7575758	2.27273	Irregular
1	3	0.00055	0.000183	0.44	0	Regular

Table 99 shows that Model 7 under EXN loading exhibits stiffness irregularity at the 2nd floor ($\eta_{ki} = 2.27 > 2.0$), indicating a soft-story condition that may impact seismic performance at that level.

Table 100. Model 7 EYP for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0016	0.000533	0	0.84211	Regular
5	3	0.0019	0.000633	1.1875	0.95	Regular
4	3	0.002	0.000667	1.0526316	1	Regular
3	3	0.002	0.000667	1	1.14286	Regular
2	3	0.00175	0.000583	0.875	1.75	Regular
1	3	0.001	0.000333	0.5714286	0	Regular

Table 100 shows that Model 7 under EYP loading does not exhibit stiffness irregularity, with all η_{ki} values below the 2.0 limit, indicating regular soft-story behavior across all floors.

Table 101. Model 7 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.0017	0.000567	0	0.87179	Regular
5	3	0.00195	0.00065	1.1470588	0.92857	Regular
4	3	0.0021	0.0007	1.0769231	1.02439	Regular
3	3	0.00205	0.000683	0.9761905	1.07895	Regular
2	3	0.0019	0.000633	0.9268293	2	Regular
1	3	0.00095	0.000317	0.5	0	Regular

Table 101 shows that Model 7 under EYN loading does not exhibit stiffness irregularity, with all η_{ki} values at or below the 2.0 limit, indicating regular soft-story behavior throughout the structure.

4.2.8 Soft Floor Check For Model 8

Table 102. Model 8 Exp for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	Comment
6	3	0.00115	0.000383	0	0.958333	Regular
5	3	0.0012	0.0004	1.043478	1	Regular
4	3	0.0012	0.0004	1	1.142857	Regular
3	3	0.00105	0.00035	0.875	1.4	Regular
2	3	0.00075	0.00025	0.714286	2.142857	Irregular
1	3	0.00035	0.000117	0.466667	0	Regular

Table 102 shows that Model 8 under EXP loading exhibits stiffness irregularity at the 2nd floor ($\eta_{ki} = 2.14 > 2.0$), indicating a soft-story condition that may affect seismic performance at that level.

Table 103. Model 8 Exn for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	$\eta_{ki} = \Delta_i/h_i / \Delta_{i+1}/h_{i+1}$	Comment
6	3	0.00115	0.000383	0	0.92	Regular
5	3	0.00125	0.000417	1.086957	1.086957	Regular
4	3	0.00115	0.000383	0.92	1.095238	Regular
3	3	0.00105	0.00035	0.913043	1.5	Regular
2	3	0.0007	0.000233	0.666667	1.75	Regular
1	3	0.0004	0.000133	0.571429	0	Regular

Table 103 shows that Model 8 under EXN loading does not exhibit stiffness irregularity, with all η_{ki} values below the 2.0 limit, indicating regular soft-story behavior across all floors.

Table 104. Model 8 Eyp for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00175	0.000583	0	0.795455	Regular
5	3	0.0022	0.000733	1.257143	0.977778	Regular
4	3	0.00225	0.00075	1.022727	0.957447	Regular
3	3	0.00235	0.000783	1.044444	1.146341	Regular
2	3	0.00205	0.000683	0.87234	1.863636	Regular
1	3	0.0011	0.000367	0.536585	0	Regular

Table 104 shows that Model 8 under EYP loading does not exhibit stiffness irregularity, with all η_{ki} values below the 2.0 limit, indicating regular soft-story behavior throughout the building.

Table 105. Model 8 EYN for soft floor

floor no	h_i	$(\Delta_i)_{avg}$	$(\Delta_i)_{avg}/h_i$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	$\eta_{ki} = \Delta_i/h_i)_{avg}/\Delta_{i+1}/h_{i+1})_{avg}$	Comment
6	3	0.00165	0.00055	0	0.717391	Regular
5	3	0.0023	0.000767	1.393939	0.938776	Regular
4	3	0.00245	0.000817	1.065217	1.020833	Regular
3	3	0.0024	0.0008	0.979592	1.170732	Regular
2	3	0.00205	0.000683	0.854167	1.782609	Regular
1	3	0.00115	0.000383	0.560976	0	Regular

Table 105 shows that Model 8 under EYN loading does not exhibit stiffness irregularity, with all η_{ki} values below the 2.0 limit, indicating regular soft-story behavior throughout the structure.

4.3 Interstory Drift Control

4.3.1 Interstory Drift Control For Model 1

Table 106. Model 1 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0121	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0096	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0071	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Model 1 under EXP loading (see table 106) shows that the relative interstory Drifts at all floors remain below the limit value of 0.008. This indicates that the building satisfies the seismic Drift control requirements and maintains structural integrity during lateral displacement.

Table 107. Model 1 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0121	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0096	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0071	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Model 1 under EXN loading (see table 107) shows that the relative interstory Drifts at all floors remain below the limit value of 0.008.

Table 108. Model 1 EYP for interstory drift control

Flo.or no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0119	0.0018	0.0126	3	0.372549	0.001564706	regular
5	0.0101	0.0022	0.0154	3	0.142857	0.000733333	regular
4	0.0079	0.0023	0.0161	3	0.142857	0.000766667	regular
3	0.0056	0.0024	0.0168	3	0.142857	0.0008	regular
2	0.0032	0.0021	0.0147	3	0.142857	0.0007	regular
1	0.0011	0.0011	0.0077	3	0.142857	0.000366667	regular

Table 108 shows Model 1 under EYP loading has relative interstory Drifts below the 0.008 limit, indicating satisfactory seismic Drift control.

Table 109. Model 1 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0129	0.0028	0.0196	3	0.372549	0.002433987	regular
5	0.0101	0.0015	0.0105	3	0.142857	0.0005	regular
4	0.0086	0.0031	0.0217	3	0.142857	0.001033333	regular
3	0.0055	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0034	0.0022	0.0154	3	0.142857	0.000733333	regular
1	0.0012	0.0012	0.0084	3	0.142857	0.0004	regular

Table 109 shows Model 1 under EYN loading has relative interstory drifts below the 0.008 limit, indicating effective seismic Drift control throughout the building.

4.3.2 Interstory Drift Control For Model 2

Table 110. Model 2 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0094	0.0019	0.0133	3	0.372549	0.001651634	regular
5	0.0075	0.002	0.014	3	0.142857	0.000666667	regular
4	0.0055	0.0019	0.0133	3	0.142857	0.000633333	regular
3	0.0036	0.0017	0.0119	3	0.142857	0.000566667	regular
2	0.0019	0.0013	0.0091	3	0.142857	0.000433333	regular
1	0.0006	0.0006	0.0042	3	0.142857	0.0002	regular

Table 110 shows Model 2 under EXP loading has relative interstory drifts below the 0.008 limit, confirming adequate seismic Drift control at all floors.

Table 111. Model 2 EXN for interstory Drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0121	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0096	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0071	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 111 shows Model 2 under EXN loading has relative interstory drifts below the 0.008 limit, indicating satisfactory seismic Drift control across all floors.

Table 112. Model 2 EYP for interstory Drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0121	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0096	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0071	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 112 shows Model 2 under EYP loading has relative interstory drifts below the 0.008 limit, confirming effective seismic Drift control throughout the building.

Table 113. Model 2 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0121	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0096	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0071	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 113 shows Model 2 under EYN loading has relative interstory drifts below the 0.008 limit, indicating proper seismic Drift control at all floors.

4.3.3 Interstory Drift Control For Model 3

Table 114. Model 3 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0116	0.0024	0.0168	3	0.372549	0.002086275	regular
5	0.0092	0.0024	0.0168	3	0.142857	0.0008	regular
4	0.0068	0.0024	0.0168	3	0.142857	0.0008	regular
3	0.0044	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0023	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0007	0.0007	0.0049	3	0.142857	0.000233333	regular

Table 114 shows that Model 3 under EXP loading has relative interstory drifts below the 0.008 limit at all floors, indicating satisfactory seismic Drift control.

Table 115. Model 3 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0117	0.0024	0.0168	3	0.372549	0.002086275	regular
5	0.0093	0.0024	0.0168	3	0.142857	0.0008	regular
4	0.0069	0.0024	0.0168	3	0.142857	0.0008	regular
3	0.0045	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0024	0.0017	0.0119	3	0.142857	0.000566667	regular
1	0.0007	0.0007	0.0049	3	0.142857	0.000233333	regular

Table 115 shows that Model 3 under EXN loading has relative interstory Drifts below the 0.008 limit at all floors, indicating effective seismic drift control throughout the building.

Table 116. Model 3 EYP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0112	0.0017	0.0119	3	0.372549	0.001477778	regular
5	0.0095	0.0021	0.0147	3	0.142857	0.0007	regular
4	0.0074	0.0022	0.0154	3	0.142857	0.000733333	regular
3	0.0052	0.0023	0.0161	3	0.142857	0.000766667	regular
2	0.0029	0.0019	0.0133	3	0.142857	0.000633333	regular
1	0.001	0.001	0.007	3	0.142857	0.000333333	regular

Table 116 shows that Model 3 under EYP loading has relative interstory drifts below the 0.008 limit at all floors, confirming proper seismic Drift control throughout the structure.

Table 117. Model 3 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0121	0.0019	0.0133	3	0.372549	0.001651634	regular
5	0.0102	0.0028	0.0196	3	0.142857	0.000933333	regular
4	0.0074	0.0019	0.0133	3	0.142857	0.000633333	regular
3	0.0055	0.0024	0.0168	3	0.142857	0.0008	regular
2	0.0031	0.0021	0.0147	3	0.142857	0.0007	regular
1	0.001	0.001	0.007	3	0.142857	0.000333333	regular

Table 117 shows that Model 3 under EYN loading has relative interstory drifts below the 0.008 limit at all floors, indicating satisfactory seismic Drift control throughout the building.

4.3.4 Interstory Drift Control For Model 4

Table 118. Model 4 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0111	0.0022	0.0154	3	0.372549	0.001912418	regular
5	0.0089	0.0023	0.0161	3	0.142857	0.000766667	regular
4	0.0066	0.0022	0.0154	3	0.142857	0.000733333	regular
3	0.0044	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0023	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0007	0.0007	0.0049	3	0.142857	0.000233333	regular

Table 118 shows that Model 4 under EXP loading has relative interstory Drifts below the 0.008 limit at all floors, indicating effective seismic drift control throughout the structure.

Table 119. Model 4 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0112	0.0022	0.0154	3	0.372549	0.001912418	regular
5	0.009	0.0023	0.0161	3	0.142857	0.000766667	regular
4	0.0067	0.0023	0.0161	3	0.142857	0.000766667	regular
3	0.0044	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0023	0.0015	0.0105	3	0.142857	0.0005	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 119 shows that Model 4 under EXN loading has relative interstory Drifts below the 0.008 limit at all floors, indicating proper seismic Drift control throughout the building.

Table 120. Model 4 EYP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0104	0.0014	0.0098	3	0.372549	0.001216993	regular
5	0.009	0.0018	0.0126	3	0.142857	0.0006	regular
4	0.0072	0.0021	0.0147	3	0.142857	0.0007	regular
3	0.0051	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.003	0.0019	0.0133	3	0.142857	0.000633333	regular
1	0.0011	0.0011	0.0077	3	0.142857	0.000366667	regular

Table 120 shows that Model 4 under EYP loading has relative interstory Drifts below the 0.008 limit at all floors, confirming effective seismic Drift control throughout the building.

Table 121. Model 4 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0112	0.0015	0.0105	3	0.372549	0.001303922	regular
5	0.0097	0.002	0.014	3	0.142857	0.000666667	regular
4	0.0077	0.0022	0.0154	3	0.142857	0.000733333	regular
3	0.0055	0.0023	0.0161	3	0.142857	0.000766667	regular
2	0.0032	0.002	0.014	3	0.142857	0.000666667	regular
1	0.0012	0.0012	0.0084	3	0.142857	0.0004	regular

Table 121 shows that Model 4 under EYN loading has relative interstory drifts below the 0.008 limit at all floors, indicating satisfactory seismic Drift control throughout the structure.

4.3.5 Interstory Drift Control For Model 5

Table 122. Model 5 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0118	0.0024	0.0168	3	0.372549	0.002086275	regular
5	0.0094	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0069	0.0024	0.0168	3	0.142857	0.0008	regular
3	0.0045	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 122 shows that Model 5 under EXP loading has relative interstory drifts below the 0.008 limit at all floors, confirming effective seismic Drift control throughout the building.

Table 123. Model 5 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0118	0.0024	0.0168	3	0.372549	0.002086275	regular
5	0.0094	0.0039	0.0273	3	0.142857	0.0013	regular
4	0.0055	0.0009	0.0063	3	0.142857	0.0003	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 123 shows that Model 5 under EXN loading has relative interstory drifts below the 0.008 limit at all floors, indicating satisfactory seismic Drift control throughout the building.

Table 2. Model 5 EYP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0114	0.0017	0.0119	3	0.372549	0.001477778	regular
5	0.0097	0.002	0.014	3	0.142857	0.000666667	regular
4	0.0077	0.0023	0.0161	3	0.142857	0.000766667	regular
3	0.0054	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0032	0.0021	0.0147	3	0.142857	0.0007	regular
1	0.0011	0.0011	0.0077	3	0.142857	0.000366667	regular

Table 124 shows that Model 5 under EYP loading has relative interstory drifts below the 0.008 limit at all floors, confirming effective seismic Drift control throughout the structure.

Table 3. Model 5 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0123	0.0019	0.0133	3	0.372549	0.001651634	regular
5	0.0104	0.00958	0.06706	3	0.142857	0.003193333	regular
4	0.00082	-0.00498	-0.03486	3	0.142857	-0.00166	regular
3	0.0058	0.0025	0.0175	3	0.142857	0.000833333	regular
2	0.0033	0.0021	0.0147	3	0.142857	0.0007	regular
1	0.0012	0.0012	0.0084	3	0.142857	0.0004	regular

Table 125 shows that Model 5 under EYN loading has relative interstory drifts below the 0.008 limit at all floors, indicating effective seismic Drift control despite some irregular average displacements at floors 4 and 5.

4.3.6 Interstory Drift Control For Model 6

Table 126. Model 6 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0122	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0097	0.0026	0.0182	3	0.142857	0.000866667	regular
4	0.0071	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0046	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0024	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 126 shows that Model 6 under EXP loading maintains relative interstory drifts well below the 0.008 limit across all floors, confirming satisfactory Drift control and structural regularity.

Table 127. Model 6 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0123	0.0025	0.0175	3	0.372549	0.002173203	regular
5	0.0098	0.0026	0.0182	3	0.142857	0.000866667	regular
4	0.0072	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0047	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0025	0.0017	0.0119	3	0.142857	0.000566667	regular
1	0.0008	0.0008	0.0056	3	0.142857	0.000266667	regular

Table 127 indicates that Model 6 under EXN loading keeps relative interstory drifts well below the 0.008 limit at all floors, ensuring effective drift control and structural regularity.

Table 48. Model 6 EYP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0121	0.0018	0.0126	3	0.372549	0.001564706	regular
5	0.0103	0.0022	0.0154	3	0.142857	0.000733333	regular
4	0.0081	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0056	0.0024	0.0168	3	0.142857	0.0008	regular
2	0.0032	0.0021	0.0147	3	0.142857	0.0007	regular
1	0.0011	0.0011	0.0077	3	0.142857	0.000366667	regular

Table 128 shows that Model 6 under EYP loading maintains relative interstory drifts well below the 0.008 limit for all floors, confirming the building's structural regularity and adequate Drift control.

Table 5. Model 6 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0131	0.002	0.014	3	0.372549	0.001738562	regular
5	0.0111	0.0024	0.0168	3	0.142857	0.0008	regular
4	0.0087	0.0026	0.0182	3	0.142857	0.000866667	regular
3	0.0061	0.0026	0.0182	3	0.142857	0.000866667	regular
2	0.0035	0.0023	0.0161	3	0.142857	0.000766667	regular
1	0.0012	0.0012	0.0084	3	0.142857	0.0004	regular

Table 129 indicates that Model 6 under EYN loading exhibits relative interstory Drifts well below the 0.008 limit across all floors, confirming the structure's satisfactory Drift performance and regularity.

4.3.7 Interstory Drift Control For Model 7

Table 130. Model 7 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0115	0.0024	0.0168	3	0.372549	0.002086275	regular
5	0.0091	0.0024	0.0168	3	0.142857	0.0008	regular
4	0.0067	0.0024	0.0168	3	0.142857	0.0008	regular
3	0.0043	0.002	0.014	3	0.142857	0.000666667	regular
2	0.0023	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0007	0.0007	0.0049	3	0.142857	0.000233333	regular

Table 130 shows that Model 7 under EXP loading maintains interstory relative displacements well below the 0.008 limit for all floors, indicating compliance with drift control criteria and overall structural regularity.

Table 131. Model 7 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0115	0.0024	0.0168	3	0.372549	0.002086275	regular
5	0.0091	0.0024	0.0168	3	0.142857	0.0008	regular
4	0.0067	0.0023	0.0161	3	0.142857	0.000766667	regular
3	0.0044	0.0021	0.0147	3	0.142857	0.0007	regular
2	0.0023	0.0016	0.0112	3	0.142857	0.000533333	regular
1	0.0007	0.0007	0.0049	3	0.142857	0.000233333	regular

Table 131 indicates that Model 7 under EXN loading maintains interstory relative displacements well within the limit of 0.008 for all floors. This confirms that the building

satisfies the Drift control requirements and is classified as regular in terms of interstory Drift.

Table 132. Model 7 EYP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0115	0.0018	0.0126	3	0.372549	0.001564706	regular
5	0.0097	0.0021	0.0147	3	0.142857	0.0007	regular
4	0.0076	0.0023	0.0161	3	0.142857	0.000766667	regular
3	0.0053	0.0022	0.0154	3	0.142857	0.000733333	regular
2	0.0031	0.002	0.014	3	0.142857	0.000666667	regular
1	0.0011	0.0011	0.0077	3	0.142857	0.000366667	regular

Table 132 shows that Model 7 under EYP loading has interstory relative displacements well below the 0.008 limit across all floors. Therefore, the building meets the interstory Drift control criteria and is classified as regular for all levels.

Table 133. Model 7 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0125	0.002	0.014	3	0.372549	0.001738562	regular
5	0.0105	0.0023	0.0161	3	0.142857	0.000766667	regular
4	0.0082	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0057	0.0024	0.0168	3	0.142857	0.0008	regular
2	0.0033	0.0022	0.0154	3	0.142857	0.000733333	regular
1	0.0011	0.0011	0.0077	3	0.142857	0.000366667	regular

Table 133 indicates that Model 7 under EYN loading has interstory relative displacements well below the 0.008 limit for all floors. Hence, the building satisfies the interstory Drift control requirements and is considered regular throughout.

4.3.8 Interstory Drift Control For Model 8

Table 134. Model 8 EXP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	$d_{\max}$	h_i	λ	Relative displacement	Comment
6	0.0071	0.0014	0.0098	3	0.372549	0.001216993	regular
5	0.0057	0.0015	0.0105	3	0.142857	0.0005	regular
4	0.0042	0.0015	0.0105	3	0.142857	0.0005	regular
3	0.0027	0.0013	0.0091	3	0.142857	0.000433333	regular
2	0.0014	0.001	0.007	3	0.142857	0.000333333	regular
1	0.0004	0.0004	0.0028	3	0.142857	0.000133333	regular

Table 134 shows that Model 8 under EXP loading has interstory relative displacements significantly below the 0.008 limit for all floors. This indicates that the building meets the interstory Drift control criteria and is classified as regular.

Table 135. Model 8 EXN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0071	0.0014	0.0098	3	0.372549	0.001216993	regular
5	0.0057	0.0015	0.0105	3	0.142857	0.0005	regular
4	0.0042	0.0015	0.0105	3	0.142857	0.0005	regular
3	0.0027	0.0013	0.0091	3	0.142857	0.000433333	regular
2	0.0014	0.0009	0.0063	3	0.142857	0.0003	regular
1	0.0005	0.0005	0.0035	3	0.142857	0.000166667	regular

Table 135 indicates that Model 8 under EXN loading exhibits interstory relative displacements well below the 0.008 limit on all floors. Therefore, the building complies with the interstory Drift control requirements and is classified as regular.

Table 136. Model 8 EYP for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0129	0.0019	0.0133	3	0.372549	0.001651634	regular
5	0.011	0.0024	0.0168	3	0.142857	0.0008	regular
4	0.0086	0.0025	0.0175	3	0.142857	0.000833333	regular
3	0.0061	0.0026	0.0182	3	0.142857	0.000866667	regular
2	0.0035	0.0023	0.0161	3	0.142857	0.000766667	regular
1	0.0012	0.0012	0.0084	3	0.142857	0.0004	regular

Table 136 shows that Model 8 under EYP loading has interstory relative displacements significantly below the 0.008 limit across all floors. This confirms that the building meets the interstory Drift control criteria and is classified as regular.

Table 137. Model 8 EYN for interstory drift control

floor no	$(d_i)_{\max}$	$(\Delta_i)_{\text{avg}}$	dimax	hi	λ	Relative displacement	Comment
6	0.0139	0.0021	0.0147	3	0.372549	0.00182549	regular
5	0.0118	0.0025	0.0175	3	0.142857	0.000833333	regular
4	0.0093	0.0028	0.0196	3	0.142857	0.000933333	regular
3	0.0065	0.0028	0.0196	3	0.142857	0.000933333	regular
2	0.0037	0.0024	0.0168	3	0.142857	0.0008	regular
1	0.0013	0.0013	0.0091	3	0.142857	0.000433333	regular

Table 137 shows that Model 8 under EYN loading maintains relative interstory displacements well below the limit of 0.008 for all floors. Therefore, the building satisfies the interstory Drift control requirements and is classified as regular.

4.4 2nd Order Effect

4.4.1 2nd Order Effect For Model 1

Table 138. Model 1 EXP for 2nd order effect

floor no	$d_{i,max}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0121	625.67	6137.8	883.5827	3	0.1708	0.085714286	consider
5	0.0096	637.5	6253.9	642.8025	3	0.1862	0.085714286	consider
4	0.0071	637.5	6253.9	514.242	3	0.1722	0.085714286	consider
3	0.0046	637.5	6253.9	385.6815	3	0.1487	0.085714286	consider
2	0.0024	637.5	6253.9	257.121	3	0.1164	0.085714286	consider
1	0.0008	637.5	6253.9	128.5605	3	0.0776	0.085714286	do not consider

Table 138 Model 1 (EXP), $\theta_{II,I}$ values exceed the TBDY 2018 limit (0.0857) on most floors, requiring 2nd-order analysis. Only the 1st floor meets the stability condition.

Table 139. Model 1 EXN for 2nd order effect

floor no	$d_{i,max}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0121	625.67	6137.8	883.5827	3	0.1708	0.085714286	consider
5	0.0096	637.5	6253.9	642.8025	3	0.1862	0.085714286	consider
4	0.0071	637.5	6253.9	514.242	3	0.1722	0.085714286	consider
3	0.0046	637.5	6253.9	385.6815	3	0.1487	0.085714286	consider
2	0.0024	637.5	6253.9	257.121	3	0.1164	0.085714286	consider
1	0.0008	637.5	6253.9	128.5605	3	0.0776	0.085714286	do not consider

Table 139 Model 1 (EXN), second-order effects considered for all floors except the first ($\theta_{II,I} = 0.0776$), as multiple levels exceed the TBDY 2018 stability limit ($\theta_{II,I} > 0.0857$)

Table 140. Model 1 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	COMMENT
6	0.0121	625.67	6137.8	883.5827	3	0.1708	0.085714286	consider
5	0.0096	637.5	6253.9	642.8025	3	0.1862	0.085714286	consider
4	0.0071	637.5	6253.9	514.242	3	0.1722	0.085714286	consider
3	0.0046	637.5	6253.9	385.6815	3	0.1487	0.085714286	consider
2	0.0024	637.5	6253.9	257.121	3	0.1164	0.085714286	consider
1	0.0008	637.5	6253.9	128.5605	3	0.0776	0.085714286	do not consider

Table 140 EXN direction, only the ground floor ($\theta=0.0776$) satisfies TBDY 2018 stability requirements, while all upper floors require second-order analysis ($\theta_{II,I}=0.1164-0.1862$).

Table 141. Model 1 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0129	625.67	6137.8	687.5366	3	0.234	0.085714286	consider
5	0.0101	637.5	6253.9	500.1799	3	0.2518	0.085714286	consider
4	0.0086	637.5	6253.9	400.1439	3	0.268	0.085714286	consider
3	0.0055	637.5	6253.9	300.1079	3	0.2285	0.085714286	consider
2	0.0034	637.5	6253.9	200.0719	3	0.2119	0.085714286	consider
1	0.0012	637.5	6253.9	100.036	3	0.1496	0.085714286	consider

Table 141 EYN direction, every floor level ($\theta_{II,I}=0.1496-0.268$) surpasses the TBDY 2018 stability threshold (0.0857), mandating second-order effects consideration throughout the structure.

4.4.2 2nd Order Effect For Model 2

Table142. Model 2 EXP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0094	625.6697	6137.82	718.305	3	0.1632	0.085714286	consider
5	0.0075	637.5046	6253.92	522.564	3	0.179	0.085714286	consider
4	0.0055	637.5046	6253.92	418.051	3	0.164	0.085714286	consider
3	0.0036	637.5046	6253.92	313.538	3	0.1432	0.085714286	consider
2	0.0019	637.5046	6253.92	209.026	3	0.1133	0.085714286	consider
1	0.0006	637.5046	6253.92	104.513	3	0.0716	0.085714286	do not consider

Table 142 all floors except the 1st ($\theta_{II,I} = 0.0716$) exceed stability limits ($\theta_{II,I} = 0.1133-0.1790 > 0.0857$), requiring second-order analysis per TBDY 2018.

Table 143. Model 2 EXN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0095	625.6697	6137.82	718.305	3	0.1649	0.085714286	consider
5	0.0075	637.5046	6253.92	522.564	3	0.179	0.085714286	consider
4	0.0056	637.5046	6253.92	418.051	3	0.167	0.085714286	consider
3	0.0036	637.5046	6253.92	313.538	3	0.1432	0.085714286	consider
2	0.0019	637.5046	6253.92	209.026	3	0.1133	0.085714286	consider
1	0.0006	637.5046	6253.92	104.513	3	0.0716	0.085714286	do not consider

Table 143 model 2 EXN. Only 1st floor ($\theta_{II,I} = 0.0716$) meets stability requirements. Upper floors ($\theta_{II,I} > 0.0857$) need second-order analysis per TBDY 2018.

Table 144. Model 2 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0143	625.6697	6137.82	898.16	3	0.1985	0.085714286	consider
5	0.0121	637.5046	6253.92	653.407	3	0.2309	0.085714286	consider
4	0.0095	637.5046	6253.92	522.726	3	0.2266	0.085714286	consider
3	0.0066	637.5046	6253.92	392.044	3	0.2099	0.085714286	consider
2	0.0038	637.5046	6253.92	261.363	3	0.1813	0.085714286	consider
1	0.00133	637.5046	6253.92	130.681	3	0.1269	0.085714286	consider

TBDY 2018 requires second-order analysis for Model 2 EYP, with $\theta_{II,I}$ values (0.1269-0.2309) surpassing the 0.0857 stability limit on all floors(see Table 144).

Table 145. Model 2 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0017	0.0154	6137.82	898.16	3	0.0236	0.085714286	consider
5	0.0021	0.0121	6253.92	653.407	3	0.0401	0.085714286	consider
4	0.0023	0.0102	6253.92	522.726	3	0.0549	0.085714286	consider
3	0.0022	0.0071	6253.92	392.044	3	0.07	0.085714286	consider
2	0.002	0.0037	6253.92	261.363	3	0.0954	0.085714286	consider
1	0.001	0.0014	6253.92	130.681	3	0.0954	0.085714286	do not consider

Table 145 model 2 EYN. Floor 1 ($\theta_{II,I} = 0.0954$) marked consider despite exceeding limit; Floors 2 to 6 show mixed compliance with TBDY 2018.

4.4.3 2nd Order Effect For Model 3

Table 146. Model 3 EXP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0116	625.67	6137.8	905.4452	3	0.1597	0.085714286	consider
5	0.0092	637.5	6253.9	658.7073	3	0.1742	0.085714286	consider
4	0.0068	637.5	6253.9	526.9659	3	0.1609	0.085714286	consider
3	0.0044	637.5	6253.9	395.2244	3	0.1388	0.085714286	consider
2	0.0023	637.5	6253.9	263.4829	3	0.1088	0.085714286	consider
1	0.0007	637.5	6253.9	131.7415	3	0.0663	0.085714286	do not consider

Table 146 model 3 EXP. Floor 1 ($\theta_{II,I} = 0.066$) complies with TBDY 2018 ($\theta_{II,I} \leq 0.0857$), while Floors 2-6 ($\theta_{II,I} = 0.1088-0.1742$) require second-order analysis due to stability limit exceedance.

Table 147. Model 3 EXN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0116	625.67	6137.8	905.4452	3	0.1597	0.085714286	COMMENT
5	0.0092	637.5	6253.9	658.7073	3	0.1742	0.085714286	consider
4	0.0068	637.5	6253.9	526.9659	3	0.1609	0.085714286	consider
3	0.0044	637.5	6253.9	395.2244	3	0.1388	0.085714286	consider
2	0.0023	637.5	6253.9	263.4829	3	0.1088	0.085714286	consider
1	0.0007	637.5	6253.9	131.7415	3	0.0663	0.085714286	do not consider

Table 147 Model 3 EXN. Only Floor 1 ($\theta_{II,I} = 0.066$) satisfies TBDY 2018 stability limits ($\theta_{II,I} \leq 0.0857$); Floors 2-6 ($\theta_{II,I} = 0.1088-0.1760$) require second-order analysis.

Table 148. Model 3 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0112	625.67	6137.8	733.272	3	0.1905	0.085714286	consider
5	0.0095	637.5	6253.9	533.4521	3	0.2221	0.085714286	consider
4	0.0074	637.5	6253.9	426.7617	3	0.2162	0.085714286	consider
3	0.0052	637.5	6253.9	320.0713	3	0.2026	0.085714286	consider
2	0.0029	637.5	6253.9	213.3808	3	0.1695	0.085714286	consider
1	0.001	637.5	6253.9	106.6904	3	0.1169	0.085714286	do not consider

TBDY 2018 mandates second-order analysis for Model 3 EYP as all floors ($\theta_{II,I} = 0.1169-0.2221$) surpass stability limits ($\theta_{II,I} > 0.0857$) (see Table 148)

Table 149. Model 3 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0121	625.67	6137.8	733.272	3	0.2058	0.085714286	consider
5	0.0102	637.5	6253.9	533.4521	3	0.2384	0.085714286	consider
4	0.0074	637.5	6253.9	426.7617	3	0.2162	0.085714286	consider
3	0.0055	637.5	6253.9	320.0713	3	0.2143	0.085714286	consider
2	0.0031	637.5	6253.9	213.3808	3	0.1812	0.085714286	consider
1	0.001	637.5	6253.9	106.6904	3	0.1169	0.085714286	do not consider

Table 149 model 3 EYN stability coefficients ($\theta_{II,I}$ =0.1169-0.2384) all exceed TBDY 2018 limits (0.0857), mandating second-order analysis throughout the structure.

4.4.4 2nd order effect for model 4

Table 150. Model 4 EXP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0015	0.0111	6137.82	941.006	3	0.0199	0.085714286	do not consider
5	0.0014	0.0089	6253.92	684.578	3	0.0255	0.085714286	do not consider
4	0.0014	0.0066	6253.92	547.662	3	0.0319	0.085714286	do not consider
3	0.0012	0.0044	6253.92	410.747	3	0.0364	0.085714286	do not consider
2	0.001	0.0023	6253.92	273.831	3	0.0455	0.085714286	do not consider
1	0.0004	0.0007	6253.92	136.916	3	0.0364	0.085714286	do not consider

Table 150 model 4 EXP. Floors 1 to 6 all marked do not consider and remain well below the limit ($\theta_{II,I} \leq 0.0857$), showing full compliance with TBDY 2018 stability requirements.

Table 151. Model 4 EXN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0014	0.0112	6137.82	941.006	3	0.0186	0.085714286	do not consider
5	0.0014	0.009	6253.92	684.578	3	0.0255	0.085714286	do not consider
4	0.0014	0.0067	6253.92	547.662	3	0.0319	0.085714286	do not consider
3	0.0013	0.0044	6253.92	410.747	3	0.0395	0.085714286	do not consider
2	0.0009	0.0023	6253.92	273.831	3	0.041	0.085714286	do not consider
1	0.0004	0.0008	6253.92	136.916	3	0.0364	0.085714286	do not consider

Table 151 model 4 EXN. Floors 1–6 all marked do not consider, staying well below the limit and fully meeting TBDY 2018 stability requirements.

Table 6. Model 4 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	COMMENT
6	0.0013	0.0104	6137.82	769.67	3	0.0211	0.085714286	do not consider
5	0.0015	0.009	6253.92	559.932	3	0.0334	0.085714286	do not consider
4	0.0018	0.0072	6253.92	447.945	3	0.0501	0.085714286	do not consider
3	0.0017	0.0051	6253.92	335.959	3	0.0631	0.085714286	do not consider
2	0.0016	0.003	6253.92	223.973	3	0.0891	0.085714286	consider
1	0.0009	0.0011	6253.92	111.986	3	0.1002	0.085714286	consider

Table 152 model 4 under EYP loading. Floors 1–2 exceed the stability threshold and are labeled irregular, while Floors 3–6 remain regular with no stability concerns.

Table 153. Model 4 EYN for 2nd order effect

floor no	Diavg	dimax	wi	vt(Kn)	hi	F	Indicator condition	COMMENT
6	0.0012	0.0112	6137.82	769.67	3	0.0194	0.085714286	do not consider
5	0.0014	0.0097	6253.92	559.932	3	0.0312	0.085714286	do not consider
4	0.0017	0.0077	6253.92	447.945	3	0.0473	0.085714286	do not consider
3	0.0017	0.0055	6253.92	335.959	3	0.0631	0.085714286	do not consider
2	0.0015	0.0032	6253.92	223.973	3	0.0835	0.085714286	do not consider
1	0.0009	0.0012	6253.92	111.986	3	0.1002	0.085714286	consider

Table 153 model 4 under EYN loading floor 1 exceeds the stability threshold and is labeled irregular, while Floors 2–6 remain regular with no stability concerns.

4.4.5 2nd Order Effect For Model 5

Table 154. Model 5 EXP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0118	625.67	6137.8	899.9322	3	0.1635	0.085714286	consider
5	0.0094	637.5	6253.9	654.6967	3	0.179	0.085714286	consider
4	0.0069	637.5	6253.9	523.7573	3	0.1643	0.085714286	consider
3	0.0045	637.5	6253.9	392.818	3	0.1428	0.085714286	consider
2	0.0024	637.5	6253.9	261.8787	3	0.1143	0.085714286	consider
1	0.0008	637.5	6253.9	130.9393	3	0.0762	0.085714286	do not consider

Table 154 model 5 under EXP loading. Floors 2–6 exceed the stability threshold and require second-order effects to be considered, while Floor 1 remains below the limit and does not require it.

Table 155. Model 5 EXN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0118	625.67	6137.8	899.9322	3	0.1635	0.085714286	consider
5	0.0094	637.5	6253.9	654.6967	3	0.179	0.085714286	consider
4	0.0055	637.5	6253.9	523.7573	3	0.1309	0.085714286	consider
3	0.0046	637.5	6253.9	392.818	3	0.146	0.085714286	consider
2	0.0024	637.5	6253.9	261.8787	3	0.1143	0.085714286	consider
1	0.0008	637.5	6253.9	130.9393	3	0.0762	0.085714286	do not consider

Table 155 model 5 under EXN loading. Floors 2–6 exceed the stability threshold and require second-order effects, while Floor 1 stays below the limit and does not require them.

Table 156. Model 5 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0114	625.67	6137.8	712.2226	3	0.1996	0.085714286	consider
5	0.0097	637.5	6253.9	518.1388	3	0.2334	0.085714286	consider
4	0.0077	637.5	6253.9	414.511	3	0.2316	0.085714286	consider
3	0.0054	637.5	6253.9	310.8833	3	0.2166	0.085714286	consider
2	0.0032	637.5	6253.9	207.2555	3	0.1925	0.085714286	consider
1	0.0011	637.5	6253.9	103.6278	3	0.1324	0.085714286	do not consider

Table 156 model 5 under EYP loading. Floors 2–6 exceed the stability threshold and require second-order effects, while Floor 1 stays below the limit and does not require them.

Table 157. Model 5 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0123	625.67	6137.8	712.2226	3	0.2153	0.085714286	consider
5	0.0104	637.5	6253.9	518.1388	3	0.2503	0.085714286	consider
4	0.0008	637.5	6253.9	414.511	3	0.0247	0.085714286	consider
3	0.0058	637.5	6253.9	310.8833	3	0.2326	0.085714286	consider
2	0.0033	637.5	6253.9	207.2555	3	0.1985	0.085714286	consider
1	0.0012	6253.9	6253.9	103.6278	3	0.1444	0.085714286	do not consider

Table 157 model 5 under EYN loading. Floors 2–6 exceed the stability threshold and require second-order effects, while Floor 1 remains below the limit and does not require them.

4.4.6 2nd Order Effect For Model 6

Table 158. Model 6 EXP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0016	0.0122	6137.82	873.699	3	0.0228	0.085714286	do not consider
5	0.0016	0.0097	6253.92	635.612	3	0.0314	0.085714286	do not consider
4	0.0015	0.0071	6253.92	508.49	3	0.0368	0.085714286	do not consider
3	0.0013	0.0046	6253.92	381.367	3	0.0425	0.085714286	do not consider
2	0.001	0.0024	6253.92	254.245	3	0.049	0.085714286	do not consider
1	0.0004	0.0008	6253.92	127.122	3	0.0392	0.085714286	do not consider

Table 158 model 6 under EXP loading. all floors $\theta_{II,I}$ show well below the threshold (0.0857), so second-order effects do not need to be considered; the building behaves regularly under this loading.

Table 159. Model 6 EXN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0016	0.0123	6137.82	873.699	3	0.0228	0.085714286	do not consider
5	0.0015	0.0098	6253.92	635.612	3	0.0294	0.085714286	do not consider
4	0.0015	0.0072	6253.92	508.49	3	0.0368	0.085714286	do not consider
3	0.0013	0.0047	6253.92	381.367	3	0.0425	0.085714286	do not consider
2	0.001	0.0025	6253.92	254.245	3	0.049	0.085714286	do not consider
1	0.0004	0.0008	6253.92	127.122	3	0.0392	0.085714286	do not consider

Table 159 model 6 under EXN loading. all floors have $\theta_{II,I}$ values below the 0.0857 threshold, indicating regular behavior with no need to account for second-order effects under this loading case.

Table 160. Model 6 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0016	0.0121	6137.82	676.92	3	0.0295	0.085714286	do not consider
5	0.0017	0.0103	6253.92	492.456	3	0.043	0.085714286	do not consider
4	0.0019	0.0081	6253.92	393.965	3	0.0601	0.085714286	do not consider
3	0.0019	0.0056	6253.92	295.474	3	0.0802	0.085714286	do not consider
2	0.0017	0.0032	6253.92	196.982	3	0.1076	0.085714286	consider
1	0.0009	0.0011	6253.92	98.4912	3	0.1139	0.085714286	consider

Table 160 model 6 EYP. Only Floors 1-2 require second-order analysis; upper floors are stable. Max displacement. 12.1 mm at roof.

Table 161. Model 6 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0014	0.0131	6137.82	676.92	3	0.0258	0.085714286	do not consider
5	0.0017	0.0111	6253.92	492.456	3	0.043	0.085714286	do not consider
4	0.0018	0.0087	6253.92	393.965	3	0.057	0.085714286	do not consider
3	0.0019	0.0061	6253.92	295.474	3	0.0802	0.085714286	do not consider
2	0.0016	0.0035	6253.92	196.982	3	0.1013	0.085714286	consider
1	0.0009	0.0012	6253.92	98.4912	3	0.1139	0.085714286	consider

Lower floors exhibit stability concerns requiring second-order analysis, while upper floors remain stable.((see Table 161)

4.4.7 2nd Order Effect For Model 7

Table 162. Model 7 EXP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0115	625.67	6137.8	932.9909	3	0.1537	0.085714286	consider
5	0.0091	637.5	6253.9	678.7467	3	0.1672	0.085714286	consider
4	0.0067	637.5	6253.9	542.9974	3	0.1539	0.085714286	consider
3	0.0043	637.5	6253.9	407.248	3	0.1317	0.085714286	consider
2	0.0023	637.5	6253.9	271.4987	3	0.1056	0.085714286	consider
1	0.0007	637.5	6253.9	135.7493	3	0.0643	0.085714286	do not consider

Floor 7 EXP Only Floor 1 meets stability limits ($\theta_{II,I} \leq 0.0857$). Floors 2-6 require second-order analysis as shown in floor 162.

Table 163. Model 7 EXN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0115	625.67	6137.8	932.9909	3	0.1537	0.085714286	consider
5	0.0091	637.5	6253.9	678.7467	3	0.1672	0.085714286	consider
4	0.0067	637.5	6253.9	542.9974	3	0.1539	0.085714286	consider
3	0.0044	637.5	6253.9	407.248	3	0.1347	0.085714286	consider
2	0.0023	637.5	6253.9	271.4987	3	0.1056	0.085714286	consider
1	0.0007	637.5	6253.9	135.7493	3	0.0643	0.085714286	do not consider

Table 163 model 7 under EXN. All floors except the 1st exceed the stability limit, requiring second-order analysis per TBDY 2018.

Table 164. Model 7 EYP for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0115	625.67	6137.8	711.7384	3	0.2015	0.085714286	consider
5	0.0097	637.5	6253.9	517.7866	3	0.2336	0.085714286	consider
4	0.0076	637.5	6253.9	414.2292	3	0.2288	0.085714286	consider
3	0.0053	637.5	6253.9	310.6719	3	0.2127	0.085714286	consider
2	0.0031	637.5	6253.9	207.1146	3	0.1866	0.085714286	consider
1	0.0011	637.5	6253.9	103.5573	3	0.1324	0.085714286	do not consider

Table 164 model 7 under EYP. All floors except the 1st exceed the stability limit, requiring second-order analysis per TBDY 2018.

Table 165. Model 7 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0125	625.67	6137.8	711.7384	3	0.219	0.085714286	consider
5	0.0105	637.5	6253.9	517.7866	3	0.2529	0.085714286	consider
4	0.0082	637.5	6253.9	414.2292	3	0.2468	0.085714286	consider
3	0.0057	637.5	6253.9	310.6719	3	0.2288	0.085714286	consider
2	0.0033	637.5	6253.9	207.1146	3	0.1987	0.085714286	consider
1	0.0011	637.5	6253.9	103.5573	3	0.1324	0.085714286	do not consider

Table 165 model 7 under EYN. All floors except the 1st exceed the stability limit, requiring second-order analysis per TBDY 2018.

4.4.8 2nd Order Effect For Model 8

Table 166. Model 8 EXP for 2nd order effect

floor no	$d_{i,max}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0009	0.0071	625.6697	441.956	3	0.0254	0.085714286	do not consider
5	0.0009	0.0057	637.5046	321.521	3	0.0349	0.085714286	do not consider
4	0.0009	0.0042	637.5046	257.217	3	0.0436	0.085714286	do not consider
3	0.0008	0.0027	637.5046	192.913	3	0.0517	0.085714286	do not consider
2	0.0005	0.0014	637.5046	128.608	3	0.0485	0.085714286	do not consider
1	0.0003	0.0004	637.5046	64.3042	3	0.0582	0.085714286	do not consider

Table 166 model 8 under EXP. All floors show stability coefficients well below the limit, so second-order effects are not required; the structure behaves regularly under this loading.

Table 167. Model 8 EXN for 2nd order effect

floor no	$d_{i,max}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0009	0.0071	6137.82	441.956	3	0.0254	0.085714286	do not consider
5	0.001	0.0057	6253.92	321.521	3	0.0388	0.085714286	do not consider
4	0.0008	0.0042	6253.92	257.217	3	0.0388	0.085714286	do not consider
3	0.0008	0.0027	6253.92	192.913	3	0.0517	0.085714286	do not consider
2	0.0005	0.0014	6253.92	128.608	3	0.0485	0.085714286	do not consider
1	0.0003	0.0005	6253.92	64.3042	3	0.0582	0.085714286	do not consider

Table 167 model 8 under EXN. All floors have stability coefficients below the limit, so second-order effects are not needed; the building behaves regularly under this loading.

Table 168. Model 8 EYP for 2nd order effect

floor no	$d_{i,max}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0016	0.0129	6137.82	633.942	3	0.0315	0.085714286	do not consider
5	0.002	0.011	6253.92	461.19	3	0.0541	0.085714286	do not consider
4	0.002	0.0086	6253.92	368.952	3	0.0676	0.085714286	do not consider
3	0.0021	0.0061	6253.92	276.714	3	0.0946	0.085714286	consider
2	0.0018	0.0035	6253.92	184.476	3	0.1217	0.085714286	consider
1	0.001	0.0012	6253.92	92.238	3	0.1352	0.085714286	consider

Table 168 model 8 under EYP. Floors 1 to 3 exceed stability limits and require second-order analysis, while floors 4 to 6 are within limits do not require.

Table 169. Model 8 EYN for 2nd order effect

floor no	$d_{i_{max}}$	m_i	w_i	V_t (Kn)	h_i	$\theta_{II,I}$	Indicator condition	Comment
6	0.0012	0.0139	6137.82	633.942	3	0.0236	0.085714286	do not consider
5	0.0021	0.0118	6253.92	461.19	3	0.0568	0.085714286	do not consider
4	0.0021	0.0093	6253.92	368.952	3	0.071	0.085714286	do not consider
3	0.002	0.0065	6253.92	276.714	3	0.0901	0.085714286	consider
2	0.0017	0.0037	6253.92	184.476	3	0.1149	0.085714286	consider
1	0.001	0.0013	6253.92	92.238	3	0.1352	0.085714286	consider

Table 169 model 8 under EYN (Y-direction, negative loading). Floors 1 to 3 exceed stability limits and require second-order analysis; floors 4 to 6 are within limits and do not.

CHAPTER FIVE

SUMMARY OF RESULTS

5.1 Summarized result of torsional irregularity

Table 170. Summary of Torsional Irregularities

MODEL	EXP	EXN	EYP	EYN
1	Torsional irregular	T. irregular	Regular	Regular floor (1,2,3 and 5)
2	Torsional irregular	T. irregular	Regular	Regular floor (1,2,4 and 5)
3	Torsional irregular	T. irregular	Regular floors(1 to 5)	Regular floor (1,3,4 and 6)
4	T.irregular floors (1 to5)	T. irregular	Regular	Regular
5	Torsional irregular	T. irregular	Rular	Regular floor(2,3 and 6)
6	Torsional irregular	T. irregular	Regular	Regular
7	Torsional irregular	T. irregular	regular	Regular
8	T.irregular floors (2 to6)	T. irregular	regular	Regular

Looking at the summarized results in Table 170, we can see that Model 3 performs best, showing regular behavior across most floors and load cases. This makes it the preferred option when aiming for stable seismic performance. In contrast, Models 4 and 8 show clear torsional irregularities on multiple floors, which raises concerns about their resilience under earthquake loads. Overall, Models with fewer irregularities and more consistent behavior are better suited for ensuring safety and minimizing seismic risks.

5.2 Summarized result of soft floors

Table 171. Summary Of Soft Floors

MODEL	EXP	EXN	EYP	EYN
1	Floor 2 irregular	Floor 2 irregular	Regular	Regular
2	Floor 2 irregular	Floor 2 Irregular	Regular	Regular
3	Floor 2 irregular	Floor 2 irregular	floor 5 irregular	Regular floor 3
4	Floor 2 irregular	Regular	Regular	Regular
5	Floor 2 irregular	Floor(2 and 3) irrigular	Rular	Regular floor 5
6	Floor 2 irregular	Floor 2 irregular	Regular	Regular
7	Floor 2 irregular	Floor 2 irregular.	regular	Regular
8	Floor 2 irregular 2 to6)	regular	regular	Regular

From Table171, we see that floor 2 shows soft floor irregularity in most Models, especially under EXP and EXN. Model 4 performs the best with mostly regular behavior, while Model 5 shows more irregularity, making it less preferred. Overall, strengthening lower floors is key for better seismic performance.

5.3 Summarized result of interstory Drift control

Table 172. Summary Of Soft Floors

MODEL	EXP	EXN	EYP	EYN
1	Regular	Regular	Regular	Regular
2	Regular	Regular	Regular	Regular
3	Regular	Regular	Regular	Regular
4	Regular	Regular	Regular	Regular
5	Regula	Regula	Regula	Regula
6	Regular	Regular	Regular	Regular
7	Regular	Regular	Regular	Regular
8	Regular	Regular	Regular	Regular

As shown in Table 172, all Models meet the interstory drift control limits under all load cases, indicating no irregularity. This suggests that, in terms of Drift behavior, all Models perform satisfactorily and comply well with code requirements.

5.4 Summarized result of 2nd order effect

Table 173. Summary 2nd Order Effect

MODEL	EXP	EXN	EYP	EYN
1	Consider floors(2-6)	Consider floors(2-6)	consider	consider
2	Consider floors(2-6)	Consider floors(2-6)	consider	Consider(1-2)
3	Consider floors(2-6)	Consider floors(2-6)	Consider floors(2-6)	Consider floors(2-6)
4	Do not consider	Do not consider	Consider(1-2)	Consider in floors 1
5	Consider floors(2-6)	Consider floors(2-6)	Consider floors(2-6)	Consider floors(2-6)
6	Do not consider	Do not consider	Regular Consider(1-2)	Consider(1-2)
7	Regular Consider floors(2-6)	Regular Consider floors(2-6)	Consider floors(2-6)	Consider floors(2-6)
8	Do not consider	Do not consider	Consider floors(1, and 3)	Consider (1,2 and 3)

Based on the summarized results in Table 173, several Models (such as Models 1, 2, 3, 5, and 7) show that second-order (P- Δ) effects need to be considered in most upper floors under all load cases, highlighting their sensitivity to geometric nonlinearity. In contrast, Models 4, 6, and 8 generally do not require second-order considerations, indicating better

CONCLUSION AND RECOMMENDATIONS

This thesis examined the influence of geometric configuration on the seismic performance of reinforced concrete (RC) buildings through the analysis of 8 structural models using SAP2000, in accordance with the Turkish Seismic Code. The models were analyzed using linear static and dynamic methods. The results show that geometry plays a vital role in seismic behavior. Structures with regular and symmetrical layouts performed significantly better under seismic loading, showing reduced torsional irregularities, more uniform displacement patterns, and improved energy dissipation. In contrast, buildings with irregular configurations such as asymmetric floor plans, eccentric shear walls, or non-uniform column spacing exhibited larger lateral displacements, increased torsional responses, and higher stress concentrations, which could lead to greater seismic vulnerability and potential failure. Dynamic response parameters such as base shear, fundamental period, mode shapes, and inter-story drift were all affected by geometric changes. Irregular geometries led to longer natural periods and greater displacements, while optimized forms demonstrated better control over drift and lateral forces. The Turkish Seismic Code provided a reliable and detailed framework, aligning well with performance-based design principles and offering practical guidance for evaluating structural safety using linear analysis techniques. Optimizing the geometric arrangement of structural components is essential for improving earthquake resilience. A well-planned configuration not only ensures compliance with code requirements but also enhances overall structural safety and efficiency. These insights are especially valuable for engineers, architects, and researchers committed to designing earthquake-resistant RC buildings. Future studies should incorporate nonlinear time history analyses using real earthquake records to gain a more realistic understanding of structural behavior under strong ground motions. Comparing the Turkish Seismic Code with international standards such as Eurocode 8, ASCE 7, IS 1893, and NZS 1170.5 could highlight differences in design philosophy and identify areas for improvement. Including soil-structure interaction models would increase the accuracy of results, particularly in taller or irregular buildings. Expanding the scope to include complex structures such as high-rises, podium buildings, or those with mass irregularities would provide deeper insight into how these features influence seismic response. Investigating the use of innovative materials like high-

strength or fiber-reinforced concrete, or hybrid steel-RC systems, could offer alternative strategies for enhancing seismic performance. Applying machine learning or optimization algorithms to the dataset may help identify ideal geometries for seismic safety. Developing a parametric design tool that integrates modeling, code checks, and analysis could streamline the design process and support more informed decision-making in seismic engineering.



REFERENCES

- Abdel-Raheem, K. A., Abdel Raheem, S. E., Soghair, H. M., and Ahmed, M. H. (2010). Evaluation of seismic performance of multistory buildings designed according to Egyptian code. *JES. Journal of Engineering Sciences*, 38(2), 381-402.
- Adhav, A., Gawande, G., Vishwakarma, S., Dhapekar, K., and Moon, N. (2019). Comparative study of analysis and design of building using indian standards (IS), European norms (EN) and American concrete institute (ACI). *Int J Res Appl Sci Eng Technol*, 7, 1436-1442.
- Ahmad, M. M., Elahi, A., and Barbhuiya, S. (2023). Comparative Analysis of Reinforced Concrete Beam Behaviour: Conventional Model vs. Artificial Neural Network Predictions. *Materials*, 16(24), 7642.
- Akkar, S., and Bommer, J. J. (2007). Prediction of elastic displacement response spectra in Europe and the MiDdle East. *Earthquake Engineering and Structural Dynamics*, 36(10), 1275-1301.
- Algott, I. H., and Kafri, G. M. A. (2023). Comparative Study of Reinforced Concrete Design of Short Columns between BS 8110 and ACI 318-11 (Codes). *Sirte University Scientific Journal*, 13(1), 46-54.
- Amulu, C. P., and Ezeagu, C. A. (2017). Experimental and analytical comparison of torsion, bending moment and shear forces in reinforced concrete beams using BS 8110, euro code 2 and ACI 318 provisions. *Nigerian Journal of Technology*, 36(3), 705-711.
- Araújo, D. L., Silva Neto, A. P., Lobo, F. A., and El Debs, M. K. (2016). Comparative analysis of design models for concrete corbels. *Revista IBRACON de Estruturas e Materiais*, 9, 435-470.
- Arroyo, O., Barros, J., and Ramos, L. (2018). Comparison of the reinforced-concrete seismic provisions of the design codes of the United States, Colombia, and Ecuador for low-rise frames. *Earthquake Spectra*, 34(2), 441-458.
- Bashir, S. (2014). Design of Short Columns According to ACI 318-11 and BS 8110-97: A Comparative Study Based on Conditions in Nigeria (Doctoral dissertation, Near East University).
- Bernard, E. S., Amin, A., and Gilbert, R. I. (2020). Assessment of MC2010 and AS3600 models for estimating instantaneous flexural crack widths in fibre reinforced concrete members. *Engineering Structures*, 208, 110271.
- Bhavsar, M. J., Choksi, K. N., Bhatt, S. K., and Shah, S. K. (2014). Comparative study of typical RCC building using Indian standards and Euro standards under seismic

forces. *International Journal of Scientific and Research Publications*, 4(12), 1-4.

- Caterino, N., Di Cristo, V., and Ceroni, F. (2024). Strength capacity of RC beams without shear reinforcement: Numerical analysis and comparisons with code provisions. *Engineering Structures*, 317, 118634.
- Ergün, A., Kırac, N., and Başaran, V. (2015). The evaluation of structural properties of reinforced concrete building designed according to pre-modern code considering seismic performance. *Engineering Failure Analysis*, 58, 184-191.
- Fragomeni, S., & Loo, Y. C. (2003). Asian concrete model code (ACMC) and Australian concrete structures standard (AS3600) compared. *Australian Journal of Structural Engineering*, 4(3), 177-185.
- Gowrishankar, P. (2018). Critical Review of Reinforced Concrete Design Codes and Their Relevance to the United Arab Emirates (Master's thesis, The British University in Dubai).
- Gullu, M. F., and Mohammed, F. S. (2021). Investigating the reliability of shear strength equations in TS500 and ACI318-19. *Journal of Structural Engineering*, 4(2), 057-067.
- Hamrat, M., Boulekbache, B., Tahenni, T., Chemrouk, M., and Amziane, S. (2022). Experimental study of deflection of steel fibre reinforced concrete beams: comparison of different design codes. *European Journal of Environmental and Civil Engineering*, 26(6), 2057-2073
- Hassan, A., and Pal, S. (2018). Effect of soil condition on seismic response of isolated base buildings. *International Journal of Advanced Structural Engineering*, 10(3), 249-261.
- Izhar, T., and Dagar, R. (2018). Comparison of reinforced concrete member design methods of various countries. *International Journal of Civil Engineering and Technology (IJCIET)*, 9(4), 637-646.
- Izhar, T., Bano, S., & Mumtaz, N. (2019). Comparative study on analysis and design of reinforced concrete building under seismic forces for different codal guidelines. *Int J Trend Sci Res Dev*, 3(4), 536-551.
- Jayasinghe, T., Gunawardena, T., and Mendis, P. (2021). A comparative study on minimum shear reinforcement provisions in codes of practice for reinforced concrete beams. *Case Studies in Construction Materials*, 15, e00617.
- Jayasinghe, T., Gunawardena, T., and Mendis, P. (2022). Assessment of shear strength of reinforced concrete beams without shear reinforcement: A comparative study between codes of practice and artificial neural network. *Case Studies in Construction Materials*, 16, e01102.

- Kabashi, N., Avdyli, B., Krasniqi, E., and Këpuska, A. (2020). Comparative approach to flexural behavior of reinforced beams with GFRP, CFRP, and steel bars. *Civil Engineering Journal*, 6(1), 50-59.
- Kiani, A., Yang, T. Y., KheyroDdin, A., Kafi, M. A., and Naderpour, H. (2024, March). Quantification of seismic performance factors of mixed concrete/steel buildings using the FEMA P695 methodology. In *Structures* (Vol. 61, p. 106144). Elsevier.
- Kuan, A., Bruun, E. P., Bentz, E. C., and Collins, M. P. (2020). Alternative design procedures for torsion in ACI 318-19: a comparative study. *Am Concr Inst Spec Publ SP-344*, 64-91.
- Kunwar, S., Thapa, D., Paudel, A., and Shrestha, A. (2024). Discover Civil Engineering. Discover, 1, 117.
- Kurç, Ö., Kayışoğlu, B., Lüleş, A., and Özcebe, G. (2011). A comparative study on structural wall design approach of 2007 Turkish earthquake code. *Teknik Dergi*, 22(110), 1477-1497.
- Landingin, J., Rodrigues, H., Varum, H., Arêde, A., and Costa, A. (2013). Comparative analysis of RC irregular buildings designed according to different seismic design codes.
- Lee, Y. H., Kim, M. S., Lee, J., and Scanlon, A. (2013). Comparison of minimum thickness provisions for concrete beams in building codes and standards. *Canadian Journal of Civil Engineering*, 40(7), 595-602.
- Li, H., Pan, Z., Yang, Y., Wang, X., Tang, H., Ma, F., and Zheng, L. (2024). Predicting Residual Flexural Strength of Corroded Prestressed Concrete Beams: Comparison of Chinese Code, Eurocode and ACI Standard. *Buildings*, 14(7), 2047.
- Nwofor, T., Sule, S., and Eme, D. B. (2015). A comparative study of Bs8110 and Eurocode 2 standards for design of a continuous reinforced concrete beam. *International journal of civil engineering and technology*, 6(5), 76-84.
- Nwoji, C. U., and Ugwu, A. I. (2017). Comparative Study of BS 8110 and Eurocode 2 in structural design and analysis. *Nigerian Journal of Technology*, 36(3), 758-766.
- Oussadou, S. E. (2021). Comparison of the Provisions of ACI318-19 Code and Eurocode on the Structural Design and Cost Analysis, of a High-Rise Concrete Building Subjected to Seismic and Wind Forces (Master's thesis, The British University in Dubai).
- Özmen, C. (2008). A comparative structural and architectural analysis of earthquake resistant design principles applied in reinforced concrete residential buildings in Turkey (Doctoral dissertation, Middle East Technical University (Turkey)).

- Pacheco, J., De Brito, J., Chastre, C., and Evangelista, L. (2019). Uncertainty models of reinforced concrete beams in bending: Code comparison and recycled aggregate incorporation. *Journal of Structural Engineering*, 145(4), 04019013.
- Rajeev, A., Meena, N. K., and Pallav, K. (2019). Comparative study of seismic design and performance of OMRF building using Indian, British, and European codes. *Infrastructures*, 4(4), 71.
- Resatoglu, R., and Hamed, M. (2019). Comparative study of Different Seismic Codes for Reinforced Concrete Buildings in Northern Cyprus Using Static and Dynamic Methods. *Journal of Engineering Science and Technology*, 14(3), 1314-1329.
- Santos, s., giarlelis, c., traykova, m., lima, s., bucur, c., and orrala, w. comparative study of some Seismic codes for building design regarding criteria for non-linear methods of analysis.
- Sezen, H., Whittaker, A. S., Elwood, K. J., and Mosalam, K. M. (2003). Performance of reinforced concrete buildings during the August 17, 1999 Kocaeli, Turkey earthquake, and seismic design and construction practise in Turkey. *Engineering Structures*, 25(1), 103-114.
- Suliman, M., and Lu, L. (2024). A Comparative Study of Seismic Performance Evaluation of Reinforced Concrete Frame Structures Using Chinese and African Seismic Codes. *Advances in Civil Engineering*, 2024(1), 5588833.
- Tabsh, S. W. (2013). Comparison between reinforced concrete designs based on the ACI 318 and BS 8110 codes. *Structural Engineering and Mechanics*, 48(4), 467-477.
- Tafheem, Z., Jihan, J. I., Samdane, T., Islam, M. Z., and Tarin, A. S. M. (2016). earthquake response analysis of a multistoried rc building under equivalent static and dynamic loading as per bangladesh national building code 2006. *Malaysian Journal of Civil Engineering*, 28(1).
- Uzel, A. (2019). Evaluation of TS500-2000 Shear Strength Provisions for Deep Beams. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 23(2), 338-342.
- Workeluel, N., Saha, P., Matiyas, S., and Mohanty, T. (2023). A comparative study on analysis and design of RC C elevated water tank using different country codes. *Materials Today: Proceedings*.
- Yang, K. H., and Ashour, A. F. (2008). Code modelling of reinforced-concrete deep beams. *Magazine of Concrete Research*, 60(6), 441-454.
- Zhang, L., Hu, H., Fang, Y., and Qiang, Z. (2021). Code compliance in reinforce concrete design: A comparative study of USA code (ACI) and Chinese code (GB). *Advances in Civil Engineering*, 2021(1), 5517332.

