FLAT SLAB THICKNESS EFFECT ON T-SHAPED BUILDING AS PER BNBC 2020 BY USING ETABS

A Project and Thesis submitted in partial fulfillment of the requirements for the award of Degree of
Bachelor of Science in Civil Engineering

by

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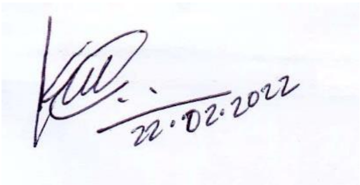
Certification

This is to certify that the following student worked on the project and thesis titled "flat slab thickness effect on T-shaped multistory building as per BNBC 2020 by using ETABS" under my direct supervision and in the laboratories of the Department of Civil Engineering under the faculty of engineering of Daffodil International University in partial fulfillment of the requirements for the bachelor of science in civil engineering degree. The work was presented on March 1st, 2022.

Signature of the candidates



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List of Abbreviations

f_c'	Concrete's compressive strength
f_y	Yield strength of steel
E_s	Modulus of Elasticity
ε_y	strain
ACI	American Concrete Institute
RSM	Response surface methodology
FEMA	Federal Emergency Management Agency (USA)
FRP	Fibre Reinforced Polymer
ETABS	Extended Three-Dimensional Analysis of Building System
BNBC	Bangladesh National Building Code
ACI	American Concrete Institute
T1	Dead load
T2	Live load
TW1	Wind load on the x-direction
TW2	Wind load on the y-direction
TE1	Seismic load in the x-direction
TE2	Seismic load in the y-direction

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ABSTRACT

in this project, an 8-story T-shaped building model was analyzed with various slab thicknesses and column sizes in ETABS software (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) to address the slab thickness effect on the flat slab and to found the minimum slab thickness that can handle the different applied loads without undesired slab deflection. The analyzed model had an overall height of 25.5 m, and story to story height of 3m, and a building plan area of 384 $m^{2.}$ According to BNBC 2020 (BNBC, 2020), 4.8KN/m^2 of live load, 1.2 KN/m^2 of floor finish, and a partition wall of 33% of live load were applied in the model, as well as In Bangladesh Seismic Zone 2, earthquake and wind loads have also been applied from the building's base to the roof. So, the minimum slab thickness that can handle those loads without excessive deflection was discovered to be 250mm with column size 750mm by 750 mm after analyzing different 32 cases. A significant amount of deflection change was also observed when the slab thickness was changed while using the same column, this demonstrates how the slab thickness affects the structure's stability. This research also discovered that there is a column size effect, which gradually increases with column size. However, this column size effect is less than that of the slab effect in terms of deflection and it is greater in large column sections and decreases as the column size section decrease.

CHAPTER 1

INTRODUCTION

1.1 General

Flat slabs are a type of construction that eliminates the usage of beams, which are commonly utilized in traditional ways of construction. The slab sits directly on the column, transferring the load from the slab to the columns and subsequently to the foundation. To support massive loads, the thickness of the slab at the support with the column is raised, resulting in drops, or columns with expanded heads known as column heads or capitals. The absence of a beam results in a plain ceiling, which has a superior architectural appearance and is less vulnerable to fire than when beams are used. A plain ceiling diffuses light more effectively, is easier to install, and requires less formwork. For medium- and high-rise buildings, flat slabs are a common structural element. Because the beams are removed, flat slab construction maximizes interior space and reduces story height. The so-called fly-form is the favored forming system in modern multi-story building construction. If no drop panels or column capitals are utilized, this formwork approach is the most efficient and cost-effective. As a result, a slab of uniform thickness, the flat plate, is produced.

1.2 Advantages and Disadvantages of flat slab

The advantages of using a flat slab

i) A flat slab minimizes the structure's overall height.
ii) These slabs can raise heavy loads.
iii) They don't need as much formwork.
iv) It is simple to install flat slab reinforcement since it may be easily enlarged.
v) Because there are no beams, installing sprinklers, utilities, and another plumbing is simple.
vi) This improves the look and light diffusion.
vii) They can be built in a short amount of time.

The disadvantages of flat slab

i) Large spans are impossible to build with the flat plate approach.

ii) Large mechanical ducting may be obstructed by the use of a drop panel

iii) They should not be used on brick walls (brittle supports).

iv) They should not be used on brick walls (brittle supports).

vi) The flat plate slab's thickness is larger than that of a common RCC two-way slab.

1.3 Scope of the study

My research's main goal is to discover the smallest flat slab thickness that can safely sustain loads to eliminate undesirable slab deflection by using ETABS(*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) with different flat slab thicknesses

1.4 Objective of this study

The major goal of this research is to use FEA packages like ETABS (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) to analyze multistory buildings with various slab thicknesses to find the appropriate slab thickness for flat slab

1.5 Outline of Thesis

In chapter 1 A general concept of the work that has been done as part of this study.

In chapter 2 I discuss what has been done previously and the type of work that has been used in the flat slab thickness effect.

In chapter 3 What I've done is create a model and specify the data needed for analysis.

In chapter 4 the analysis and how it was accomplished, as well as the evaluation results/analysis the outcomes include Max Story displacement, Validation, and deflections.

Chapter 5: This chapter contains the research's major findings as well as recommendations for future work.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

A literature review highlights what competent academics and specialists have published on a certain issue. It's not rare to be asked to write one as a stand-alone piece of work, but it's more common in the context of a publication, report, research, or thesis. The writer's goal in writing a literary review is to express to their reader what knowledge and opinions have been established about a subject, as well as their strengths and faults. Literature reviews are used as a guide for a specific topic. If you just have a limited amount of time to conduct research, literature reviews can be a good place to start. Literature reviews also serve as a solid foundation for the study of a research report. The majority of research tasks necessitate a broad understanding of a variety of topics.

2.2 Overview

The author must discuss what they have learned so far and what they hope to learn in the future through reviewing books. After reading this chapter, the reader should always be convinced that the author's intended research will be critical in furthering that discipline.

2.3 literature review

The papers listed below were published by several other authors in the last few years.

(Robertson, 1997) The effective width method and the equivalent frame method are two structural analysis methods extensively used in practice for the analysis of flat-plate structures subjected to lateral and gravity loads. These models assume a constant slab effective width coefficient, and a constant cracking factor, for an entire span, and often an entire building, without considering variations in slab cracking extent. These analytical models were utilized to examine a half-scale slab-column specimen that had previously been tested. Drift values of 0.5 and 1.5 percent were used in the experiments because they are thought to represent the service and ultimate lateral drift capacities for typical flat slab construction, respectively. At 0.5 and 1.5 percent drift levels, the analytical models were unable to recreate the slab flexural moment distribution seen in the test specimen. For each of the analysis methods, a modified two-beam model is proposed based on observations of the extent of cracking at various parts in the test specimen. The difference between cracking in the positively and negatively moment regions was incorporated into the model by replacing the single beam element with two-beam elements joined at the site of contraflexure. The observed slab moment distribution was used to determine the point of contraflexure.

(Kim & Lee, 2005) This study provided an improved analytical method that uses super elements to account for the stiffness degradation effect in slabs as a function of lateral drifts for the efficient and accurate analysis of flat slab structures. The correctness and efficiency of the suggested method, as well as the super elements and fake beams employed for efficient analysis, were investigated through the analysis of three example structures. The following are some of the most important observations and findings. The equivalent frame system for flat slab buildings with a regular plan may account for stiffness deterioration in the flat slab system. The equivalent frame approach is difficult to utilize in the case of constructions with irregular plans or slabs with openings due to the difficulties in determining the effective width for the corresponding beams. In the finite element technique, the stiffness decline in the flat slab system might be represented by the lower modulus of elasticity of floor slabs. As a result, more experimental studies are required to obtain more relevant stiffness degradation factors. Any other study findings on slab stiffness deterioration can be simply used to the suggested approach in the same way. If the stiffness degradation in the slab is appropriately handled, structural analysis of flat slab construction with irregular plan or slabs with openings may be conducted, and stress distribution of floor slabs can be simply modeled using the finite element method.

(Hueste & Bai, 2007) An assessment of seismic performance was carried out on a reinforced concrete (RC) frame structure typical of Central American construction in the 1980s. The case study structure is a five-story RC flat-slab office building intended to meet the local code requirements. The structural response was anticipated using synthetic ground motion data and nonlinear static and dynamic analysis. The case study structure's seismic performance was assessed using the FEMA 356 (*Building Science Resource Library | FEMA.Gov*, n.d.) criteria.

Because the case study building does not fulfill the FEMA 356 basic safety objectives for the Memphis movements, three seismic retrofit approaches were used to improve seismic performance: shear walls, RC column jackets, and externally bonded steel plates to limit the column plastic hinge regions. Finally, the seismic performance expected for the three retrofitted structures was evaluated by comparing them to the retrofitted structure. The implementation of the recommended seismic retrofits resulted in varying degrees of improvement in seismic performance. The inclusion of shear walls offered the largest improvement in the seismic behavior of the case study building, according to the FEMA 356 (*Building Science Resource Library | FEMA.Gov*, n.d.) criteria

(O. A. Mohamed & Khattab, 2017) in this paper, they found that Due to desirable technical qualities, there is growing interest in reinforcing concrete slabs with FRP bars rather than conventional steel bars, especially in hostile situations where reinforcing bars may be affected. Because concrete slabs employ the most reinforcing bars in a normal building structure, substituting traditional steel with FRP bars reduces the environmental footprint significantly. Punching shear is a major failure mode in flat slab floor systems, hence it's crucial to understand how flat slabs reinforced with FRP bars handle punching shear

(Shahbaz & Ahmad, 2018) After they compare flat slab and conventional slab graphs from FEA software they found that Storey displacement is proportional to the building's height and increases as the building's height rise. Flat slabs have higher storey displacement values than conventional RC slabs. The Flat slab's Storey Displacement values are 0.33 percent higher than the Conventional slab. also, they concluded that the height of a building has an inverse relationship with storey shear so Its value reduces as the building's height rises, and it is highest at the base, if not the top floor. The storey shear of the flat slab is almost 25.3 percent higher than that of the conventional slab, and finally, they found that the overturning moment is proportional to the square of the slab's height and is greatest near the slab's base. The Conventional slab has a higher overturning moment than the Flat slab. The conventional slab has a 0.26 percent higher overturning moment than the flat slab.

(Vijayan et al., 2019) ETABS software (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) was used to analyze multi-story flat slab tall buildings with and without shear walls. Analytical findings Shear walls have been found to be more effective than those without. So, they found that Storey's behavior varies depending on the period. For the sake of generalization, Storey is successful with mass ratios ranging from 0.1 to 0. and also they get With and without the shear wall, an average reduction in shear of 10%, 18%, and 21% is observed. With and without the shear wall, an average reduction of 10% in the overturning moment is observed. Also, When the strata are of type one, such as rock or hard soil, all slabs deflect within the limit.

(Kayastha & Debbarma, 2019) The linear dynamic technique was used to compare the performance of flat slab buildings and traditional RC frame buildings during an earthquake in this work (RSM). Due to the lack of beams, the stiffness of flat slab building models is dramatically reduced, and it is severely impacted under earthquake loading, as its reactions are significantly greater than those of RC frame buildings. As a result, shear walls in the building's outer periphery modify the flat slab building models, and these models perform well under earthquake loads, even better than typical RC frame buildings. For flat slab buildings with shear walls, the storey displacement and drift are the smallest, and the fundamental natural period of vibration under earthquake is less than in other models. As a result, this article suggests that in multi-story buildings, flat slab systems incorporating a section of shear wall be used instead of regular RC slab systems

(Pradhana et al., 2019) they get that the weight of a building constructed using a flat slab system is less than that of a building constructed with a standard slab system. The seismic base shear value of a structure is affected by its weight. The seismic foundation shear value of a building increases as it becomes heavier. The structural vibration time (Tc) in flat slab structures is larger than in traditional slabs, according to the fundamental period analysis. The structural vibration time (Tc) will be shorter as the building's weight increases. The structural rigidity of a building constructed with a flat slab system is lower than that of a building constructed with traditional slabs. Both flat slab buildings and traditional slab buildings meet the requirements for service and ultimate performance. The story drifts in a structure constructed using a flat slab system are bigger than in a building constructed with traditional slabs. This is related to the fact that traditional slab structures are more rigid than flat slab structures.

(O. Mohamed et al., 2019) The purpose of this research was to discuss solutions for preventing increasing collapse in flat-slab buildings. In flat-slab structures, punching shear has been found as a primary source of progressive collapse failure. Additional moments and shear stresses are transferred to nearby slab/column joints when support loses its load-carrying capacity, leading to probable punching shear failures, according to a case study. As a result, the loss of a column increases the flat slab system's unsupported span while also potentially triggering a cascade of punching shear failures. Bottom reinforcement, in general, and integrity reinforcement within columns, in particular, must be uninterrupted, appropriately lap-spliced, and adequately anchored at the slab or spandrel beam's margins to prevent progressive collapse. Consider using edge beams to reinforce the perimeter of flat plate flooring and aid in the development of two-way membrane action, if possible. Membrane motion is critical for the structure's response after a punching shear failure. Corner columns, whether with or without spandrel beams, do not provide considerable in-plane horizontal restraint to adjunct slab panels.

(Malviya, 2020) According to the needs of the researchers, different slabs were employed in the structures. For multistory buildings, flat slabs are the most common, while waffle and ribbed slabs can be utilized for wide-span structures. The analysis is done using a rigid frame structure and seismic reaction is generally done with a single slab or compared to a conventional slab. Flat slab buildings are used in commercial buildings, while waffle and ribbed buildings can be used for effective architect purposes. Scaffolding is simple in flat, but more difficult and difficult in waffle and ribbed slabs, with a more aesthetic view of the building. We will only give flat slab drop with head and ductile details for all structures in earthquake zones. By adjusting the effective depth and percentage of reinforcement, the ribbed slab is more effective in moment-resisting. It is utilized for slabs and floors with a longer span and fewer columns the waffle slab structure has a higher load carrying capability than other slab types, as well as weight and material savings & Able to control vibrations. It also has an effect on the quick and efficient building. When a great span is necessary with the main beam, the secondary beam is used.

(Siddharth Pastariya & Sameer Bunkar, 2020) This study represents the study of the Flat slab with several floors G + 19 commercial building and a separate area for shear wall, based on analyzing the following conclusions designed for the structure of a flat slab structure, Due to low lateral stiffness, flat slab buildings without shear walls perform poorly during earthquake excitation as compared to flat slab buildings with shear walls. To improve the performance of a flat-slab structure under horizontal loads, particularly in seismically prone areas, structural components such as RC shear walls can be added. Because of the significant difference in story displacement, period, base shear, storey drift, and storey stiffness when compared to other models, it is advised that the flat slab construction with a shear wall at the side center be preferred within the boundaries of this study.

(Abdulrahman & Aziz, 2021). The strengthening does not have any controlling equations. Furthermore, there is no comparative analysis of the codes of standards to assist designers in selecting appropriate design standards. The following can be deduced from the analytical and numerical results, they get the initial step in the analysis is to select the proper failure mode. According to the calculations, the failure mode for all slabs must be a tensile failure of FRP after steel yielding. Changing the failure mode will result in inaccurate results. In estimating the applied service load, this method is a reliable prediction factor for slab column connections. The method of calculating the slab effective length and the concrete compressive strength reduction factor has a significant impact on the final applicable service load calculation in flexure. The punching shear perimeter calculation and the slab reinforcement ratio have a significant impact on the calculation of the ultimate applied service load in punching.

(Sawwalakhe & Pachpor, 2021) The weight of flat slab constructions is higher than that of normal slab structures. When compared to grid slabs and two-way slabs, flat slabs have more bending moment and shear force. Flat slab designs, on the other hand, improve the aesthetic perspective while providing the architect with huge formwork flexibility, ease of placing flexural reinforcement, ease of casting concrete, and open space for water, air, and other pipes. between the slab and a possibly furred ceiling, the saving of one-story height in multi-story structures, and so forth. As a result, the Flat slab is more cost-effective than the traditional and Grid slabs. In comparison to conventional slab structures and Grid Slab, flat slab structures are the best solution for high-rise projects. The conventional slab is more suited to residential and small span constructions, whilst the grid slab is better suited to larger span structures.

(Borkar et al., 2021) After further investigation, they discovered that in all seismic zones, story displacement is greatest in flat systems and least in typical slab systems for both regular and irregular structures. In all seismic zones, story shear is greatest in flat slab systems and least in flat slabs with drop systems for both regular and irregular structures.

(Neamah & Al-Ramahee, 2021) Under concentric and bi-axial pressure, this work presented an experimental investigation of strengthening using column capitals of two different sizes for six flat slabs. Punching shear capacity, crack patterns, and deflection are all characteristics of the flat slabs studied. so, they discovered that Punching shear failure occurred in all of the flat slabs that were tested. The moment caused by bi-axial loading reduced ultimate loads by around 16 percent for the reference slab and 19 percent and 11 percent, respectively, for slabs strengthened with 600 x 600 mm and 800 x 800 mm column capitals. All slabs benefitted from the addition of column capitals, which increased their punching shear capacity. The punched shear capabilities of SE0C6 and SE0C8 increased by around 89 percent and 112 percent, respectively, for concentric loads. The punching capabilities of SE1C6 and SE1C8 increased by 81 percent and 125 percent, respectively, for bi-axial loads. The rise in column capital size from 600 x 600 mm to 800 x 800 mm improves the punching shear capacity of slabs under concentric loads by about 13% and by about 25% for slabs under bi-axial loading. The increase in the critical section of the column, which raises the region resisting stress transfers through the column, caused this rise.

(Al-Zahra et al., 2021) The impact of high concrete compressive strength on reducing long-term deflection was discovered to be significant, particularly for small spans. The average long-term deflection is reduced by (56 percent, 53 percent, 50 percent, 44 percent, 39 percent, 33 percent, and 31 percent) for spans (4, 5, 6, 7, 8, 9, and 10 m) when concrete compressive strength is increased from 21MPa to 49MPa. Also, in terms of the live load impact, it was discovered that raising the live load results in greater long-term deflection, but this effect diminishes as span lengths grow.

2.4 Summary

What has already been done in the past is highlighted in this chapter. We reviewed the analysis of multistory buildings with various flat slab thicknesses using ETABs, as well as the benefits and drawbacks of employing flat slabs. In addition, various practical applications of flat slabs have been demonstrated. We reviewed some of the topics that will aid us in making decisions and determining why the flat slab thickness effect is so significant.

CHAPTER 3

MODELING AND ANALYSIS

3.1 Introduction

Today's computers and software are advanced design tools, but they require precise input to achieve dependable results. So The primary goal of this project is to analyze an industrial structure with different flat slab thicknesses in ETABS (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) in order to address the thickness effect on the structure and to determine the minimum thickness of flat slab that can safely handle the applied load. And BNBC 2020 (BNBC, 2020) code was used to perform the computations.

3.2 T-Shaped Building with flat slab

As Figure 3.1 and 3-2 shows the 2D view 3D view of 8 stories T-shaped building having flat slab that measures area of 4133.34 square feet (384m^2) with columns spaced 4m from center to center and with and Floor to Floor height of 3m was used in this project

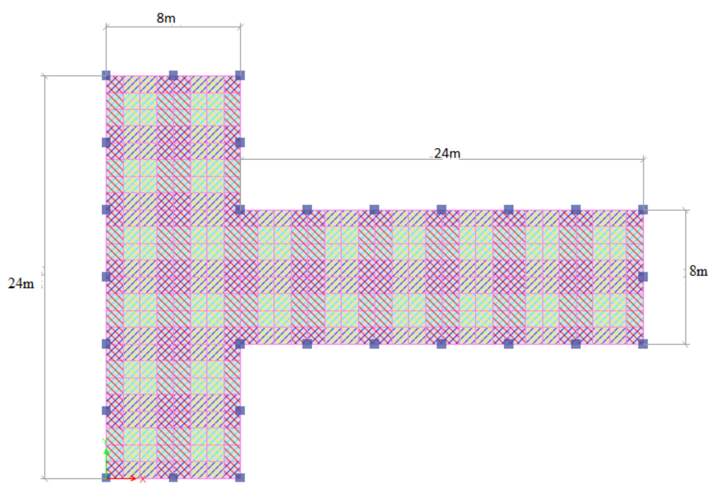

Figure 3.1:2D plan view of T-shaped building

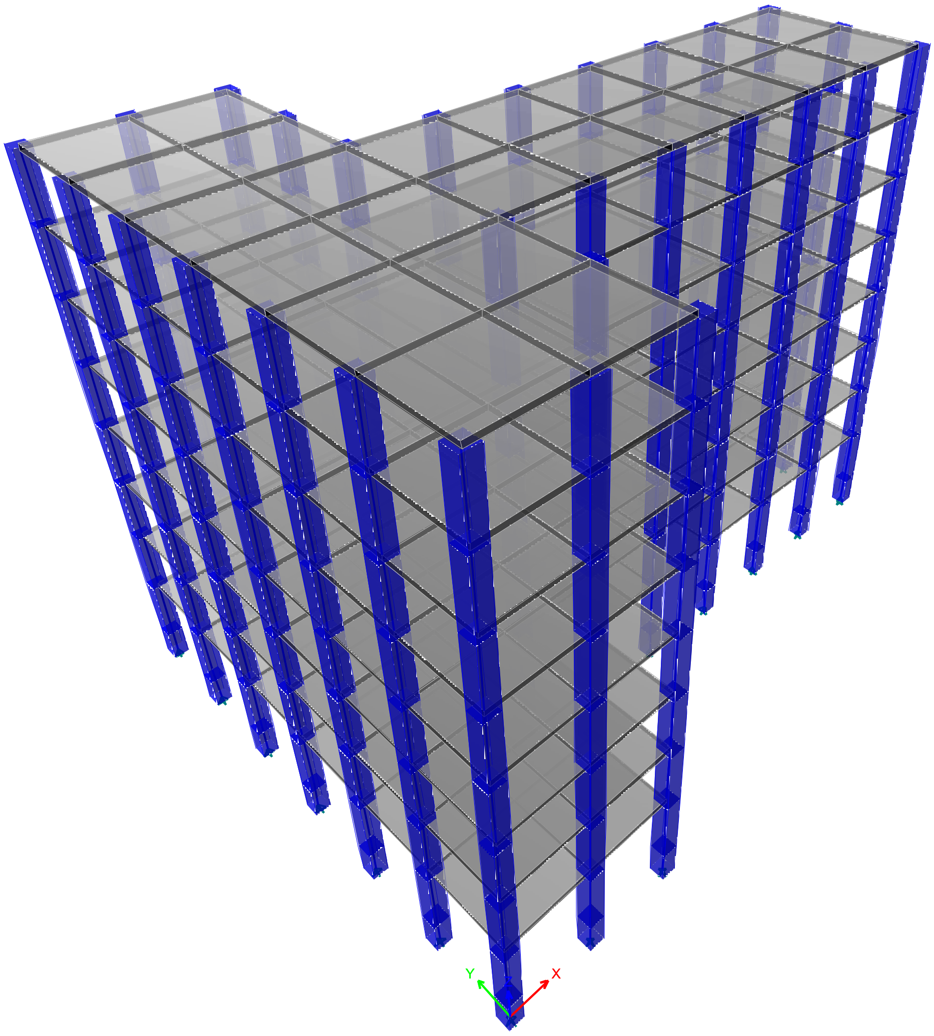

Figure 3.2: 3D view of 8 stories T-shaped building

3.3 Computer software /FEA package used

ETABS Version v2016 (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) was used for all of the structural modeling and analysis. Modeling was carried out in three dimensions using linear elastic analysis examples. Also, Microsoft Excel (*Excel 2021 - Microsoft Lifecycle | Microsoft Docs*, n.d.)was used to create a graph from the data analysis.

3.4 Detailing analysis and input Data

To analyze this T-shaped model several input data were made in to the such as wind load, earthquake (seismic load), live load and wind load by using BNBC 2020 (BNBC, 2020) code

3.4.1 Structural dimensions of the building

Table3.1 description of the building model, show the specific dimensions and type of building structure that is used for this T-Shaped structure, and since the plan is T-Shape having dimension shown the above figure 3.1

Table 3.1 structural dimensions of the building

Parameters	Dimensions
Plan dimension	24m X 24m X 8m
A number of stories:	8m
Bottom story height:	3m
Story height:	3m
Building frame system: intermediate moment-resisting frame (IMRF) building use:	Industrial

3.4.2 Materials specification

The material's description, which contains requirements, tolerances, life span, specifications, suppliers, and safety information, is referred to as Material Specifications, so the material specification that was used to analyze this T-shaped multi-stories building model was described in the table below 3.2

Table 3.2 material specification

Material specification	
Grade of Concrete	f'_c =27.6 N/mm^2
Grade of Steel	fy =415 N/mm^2
Density of Brick walls Considered	γ =20 kN/m^3
Density of Concrete	$\gamma = 20kN/m^3$

3.4.3 Gravity loads

Gravity loads are the vertical forces exerted on a structure. The weight of the structure, the presence of people, and snow are all instances of loads that necessitate a complete load path to the ground. A floor slab supports the resultant gravity load.

Table 3.3 shows and values and types of loads that were used to analyze this T-Shaped building model as per BNBC 2020(BNBC, 2020)

Table 3.3 Gravity load on the building

Parameter	Value
Live load	100.25 Psf (4.800 kN/m^2) excluding rooftop
Live load at the rooftop	60.56 Psf (2.900 kN/$m^{2)}$
floor finish	25.06 Psf (1.200 kN/m^2) excluding rooftop
Partition load	33.10 Psf (1.584 kN/m^2) excluding rooftop

3.4.4 Wind load

The word 'Wind Load' refers to any stresses or forces exerted by the wind on a structure or building. This load is dispersed across the structure's surface area. The magnitude of this load increases with the height of the structure, i.e. taller structures have a greater wind effect than shorter buildings. For computing of wind load, ASCE 7-10 (Asce & Sei, n.d.) was used.

Table 3.4 shows wind input load data as per BNBC 2020 (BNBC, 2020) code, structure location is in Dhaka, so wind speed and exposure type is guided by using BNBC 2020 (BNBC, 2020) code

Table 3.4 wind load data

Parameter	value
Wind speed	147 Km/h
importance factor	1
Exposure type	B
Story range	From the ground floor to the roof story
Topographical factor (K_{zt})	1
Gust factor	0.85
Directional factor (K_d)	0.85

3.4.5 Seismic load /Earthquake load

Earthquake load occurs as a result of the inertia force produced in the building as a result of seismic excitations. The inertia force varies with mass. The greater the mass of the structure, the greater the earthquake loading, to identify the force and intensity of an earthquake, each building or structure is assigned a seismic design group. It will be used to design buildings in such a way that the earthquake damage is minimized. Some structures in the same neighborhood may be affected differently by earthquake loading. During an earthquake, one of the most important factors is the flexibility of the building, the flexibility is defined by the height-to-width ratio. The greater the ratio, the greater the building's flexibility. The stiffness of the building is another physical behavior. The stiffness of the taller building will be less.

Table 3.5 shows seismic and earthquake input data that is used to analyze this T-shaped building model in ETABS (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) And all data was collected from BNBC 2020 (BNBC, 2020)

Table 3.5 Earth Quake data

Parameter	value
Seismic zone	Zone 2
Soil type	SD
Importance factor	1
Response modification R	8
Ct	0.9
Spectral Accel (Ss)	0.5
Spectral Accel (S1)	0.2
Site coefficient F_a	1.35
Site coefficient F_v	2.7
Story range	Bottom to Roof story
Zone factor	0.15

3.4.6 load combinations

As per BNBC 2020 (BNBC, 2020) “clause 2.7.3 assumptions” When the strength design approach is implemented, structural components and foundations must have strength equal to or more than that required to resist the most negative effect of the combinations of calculated loads listed in the below

Basic load combination

a) 1.4T1
b) 1.2T1+1.6T2
c) 1.2T1+T2
d) 1.2T1+0.8TW1
e) 1.2T1-0.8TW1
f) 1.2T1+0.8TW2
g) 1.2T1-0.8TW2
h) 1.2T1+1.6TW1+T2
i) 1.2T1-1.6TW1+T2
j) 1.2T1+1.6TW2+T2
k) 1.2T1-1.6TW2+T2
l) 1.2T1+TE1+T2
m) 1.2T1-TE1+T2
n) 1.2T1+TE2+T2
o) 1.2T1-TE2+T2
p) 0.9T1+1.6TW1
q) 0.9T1-1.6TW1
r) 0.9T1+1.TW2
s) 0.9T1-1.6TW2
t) 0.9T1+TE1
u) 0.9T1-TE1
v) 0.9T1+TE2
w) 0.9T1-TE2

T1= dead load
Tw1=wind load in x-direction
TE1 =seismic load x-direction

T2= dead load
Tw2=wind load in the y-direction
TE2 =seismic load y-direction

3.4.7 work flow chart

The figure below figure3.3 shows the steps that were taken to analyze this building model, first T-shape plan was selected, then sections were defined and loads were applied with the help of the BNBC2020 (BNBC, 2020) code, and then finally model was analyzed and the result was discussed in chapter 4

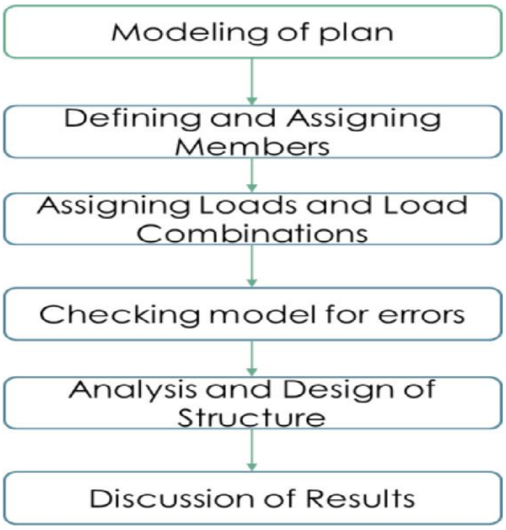

Figure 3.3 work flow chart

3.5 Summary:

In this chapter, we looked at the basics of modeling and analysis for buildings with flat slabs, as well as the software used for design and analysis. The code was followed, Modeling of the building, various types of loads that were applied to the building, and a Flowchart of work

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Introduction

In this chapter, I will present my findings after analyzing this T-shape building model with deferent flat slab thicknesses as well as different column sizes, during this project 36 different cases were analyzed with help of ETABS software (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) and then maximum story displacement due to the earthquake in both directions and maximum deflection of each case data results was recorded with help of WPS office spreadsheet (*WPS Office Spreadsheet | Free Download and Create Professional Excel*, n.d.). and then result from this data is presented section 4.3 in this chapter

4.2 Result analysis and evaluation

I made A lot of trials with different flat slab thicknesses and column sizes by using ETABS (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) to check whether deflection is under the limit, According to the ACI 308-14 (ACI Committee 318, 2014) deflection imitation Equation 4.1.

$$\textbf{Deflection limitation} \leq \textbf{L/180} \qquad \textbf{(4.1)}$$

L= slab span length in mm, so for this T-shape model L=4000mm

I got 22.22 mm after calculating the deflection value by using Equation 4.1. then after analyzing the T-shaped model in ETABS software (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) I determine the minimum and maximum deflections in each case, as well as the maximum story displacement caused by the earthquake, in both directions

4.3 Maximum Story Displacement due to the earthquake and flat Slab Deflection

The greatest displacement of a node on a building's top floor or roof from its original location is referred to as maximum story displacement. So, in this project, after a model was analyzed within ETAB software (*ETABS - Documentation - Computers and Structures, Inc. - Technical Knowledge Base*, n.d.) maximum story displacement due to earthquake in both directions and slab deflections in different 32 cases with various slab thicknesses and column sizes were addressed and presented here in graphs.

Table 4.1 various slab thicknesses and column sizes with specimen ID

Slab ID	Slab Thickness	Column ID	Square Column Size
S1	125 mm	T1	300mm x 300mm
S2	150 mm	T2	400mm x 400mm
S3	175 mm	T3	500mm x 500mm
S4	200 mm	T4	600mm x 600mm
S5	225 mm	T5	700mm x 700mm
S6	250mm	T6	750mm x 750mm

S1T1 stands for 125 mm flat slab thickness and 300mm by 300mm column cross-section. After implementing this in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.1 also, the maximum deflection was found to be 134.801mm after analysis, which did not meet the requirements of equation 4.1.

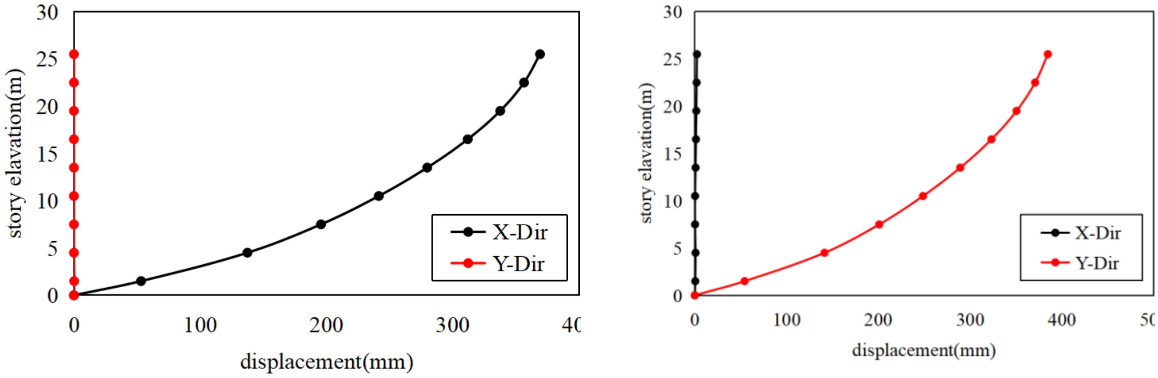

Figure 4.1: S1T1 displacement due to earthquake effect

S1T2 stands for 125mm flat slab thickness and 400mm x 400mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.2 also, the maximum deflection was found to be 122.101mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

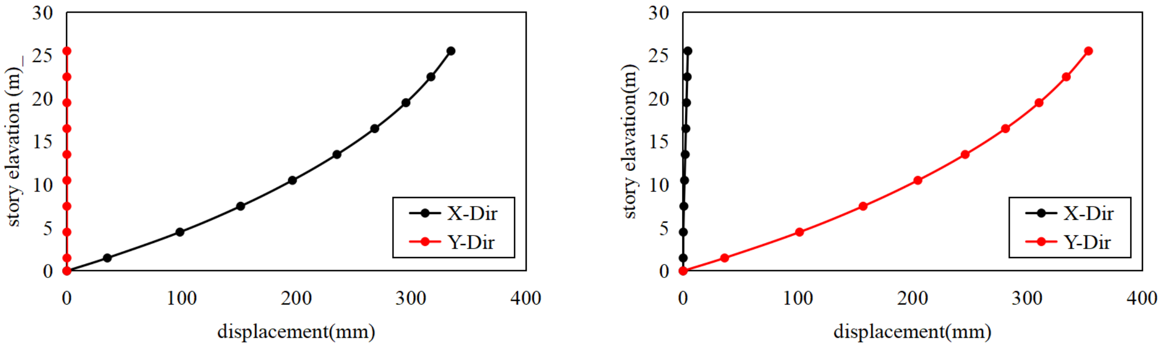

Figure 4.2: S1T2 displacement due to earthquake effect

S1T3 stands for 125 mm flat slab thickness and 500mm x 500mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.3 also, the maximum deflection was found to be 116.712 mm after analysis, which did not meet the requirements of equation 4.1. then another trial was made

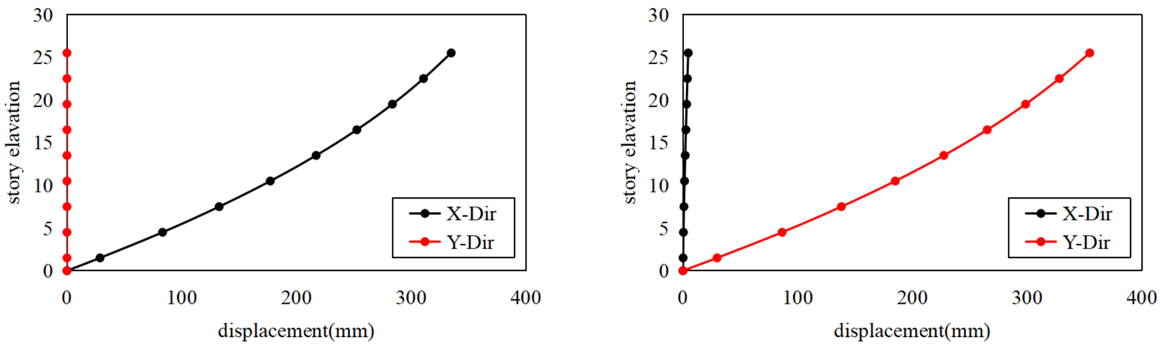

Figure 4.3: S1T3 displacement due to earthquake effect

S1T4 stands for 125 mm flat slab thickness and 600mm x 600mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.4 also, the maximum deflection was found to be 113.91 mm after analysis, which did not meet the requirements of equation 4.1., then another trial was made

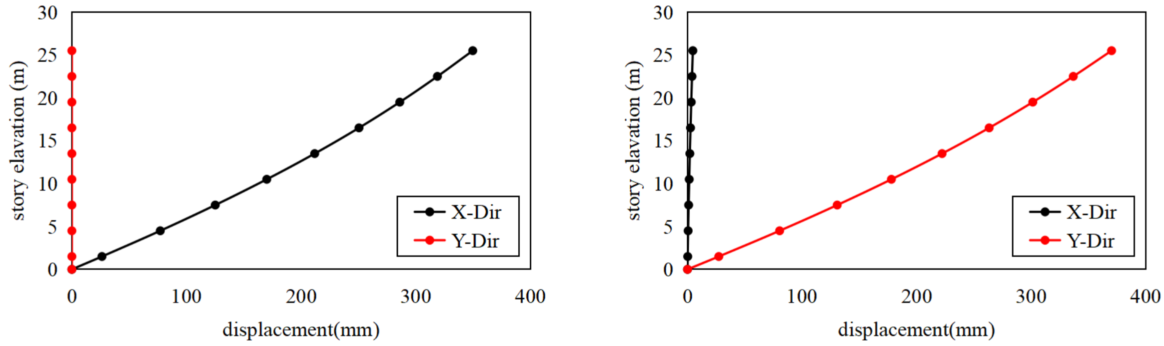

Figure 4.4: S1T4 displacement due to earthquake effect

S1T5 stands for 125 mm flat slab thickness and 700mm x 700mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.5 also, the maximum deflection was found to be 112.262mm after analysis, which did not meet the requirements of equation 4.1. then another trial was made

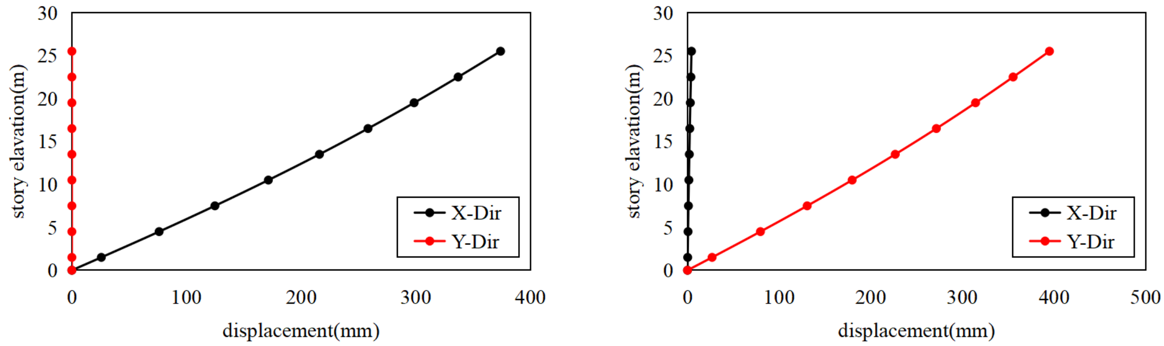

Figure 4.5: S1T5 displacement due to earthquake effect

S1T6 stands for 125 mm flat slab thickness and 750mm x 750mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.6 also, the maximum deflection was found to be 111.861 mm after analysis, which did not meet the requirements of equation 4.1. then another trial was made

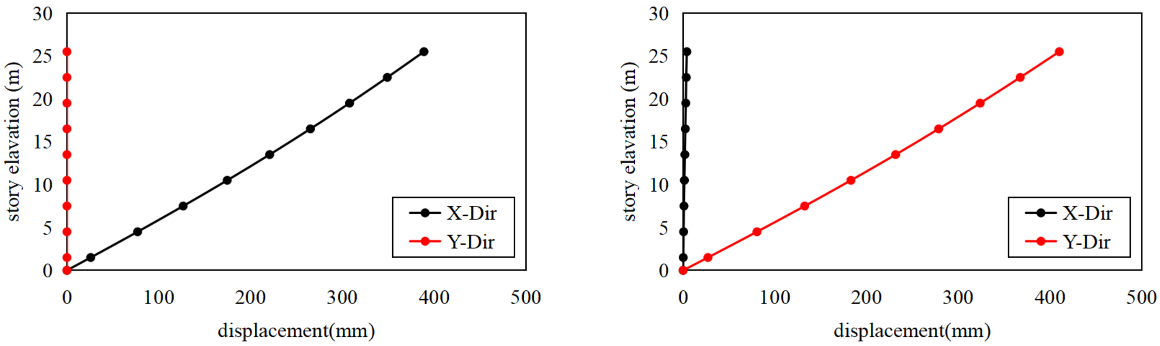

Figure 4.6: S1T6 displacement due to earthquake effect

S2T1 stands for 150 mm flat slab thickness and 300mm x 300mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.7 also, the maximum deflection was found to be 93.211 mm after analysis, which did not meet the requirements of equation 4.1., then another trial was made

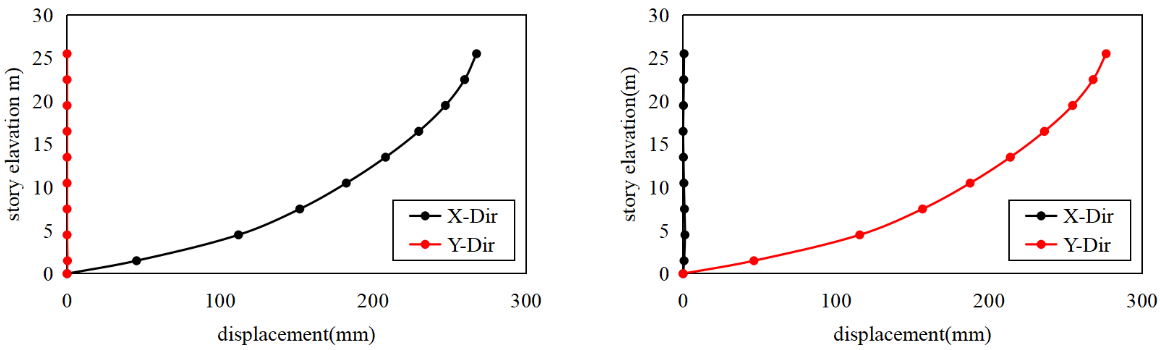

Figure 4.7: S2T1 displacement due to earthquake effect

S2T2 stands for 150 mm flat slab thickness and 400mm x 400mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.8 also, the maximum deflection was found to be 80 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

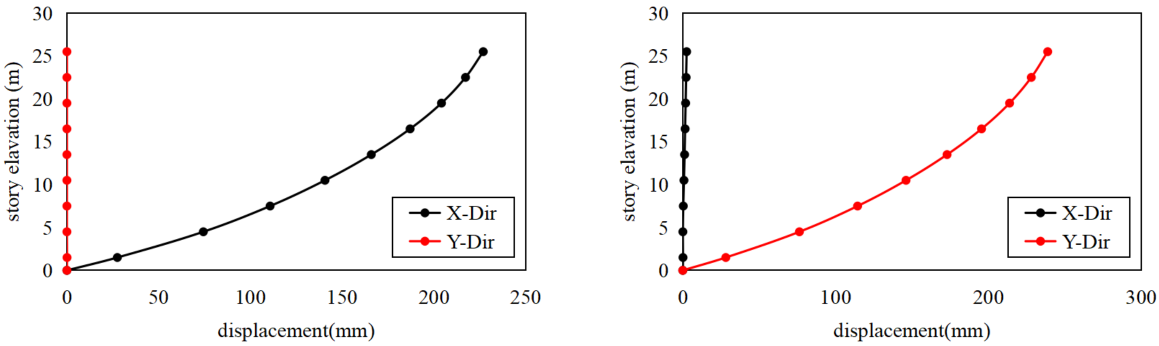

Figure 4.8: S2T2 displacement due to earthquake effect

S2T3 stands for 150 mm flat slab thickness and 500mm x 500mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.9 also, the maximum deflection was found to be 74.788 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

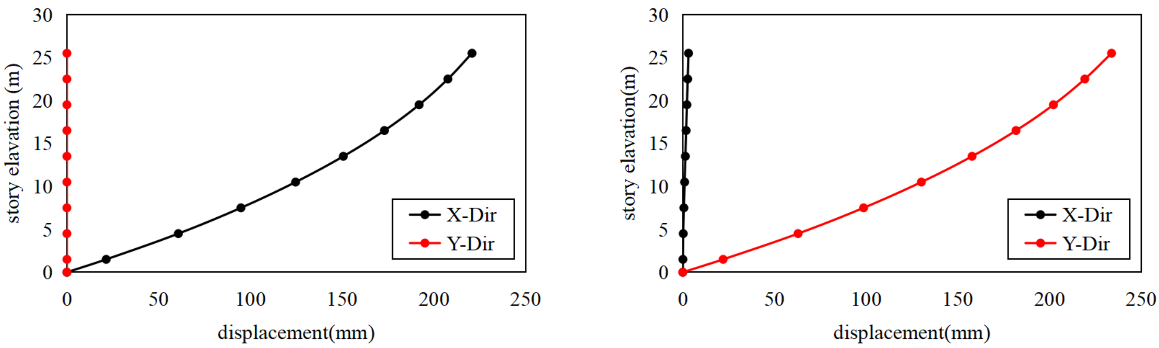

Figure 4.9: S2T3 displacement due to earthquake effect

S2T4 stands for 150 mm flat slab thickness and 600mm x 600mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.10 also, the maximum deflection was found to be 71.901 mm after analysis, which did not meet the requirements of equation 4.1. then another trial was made

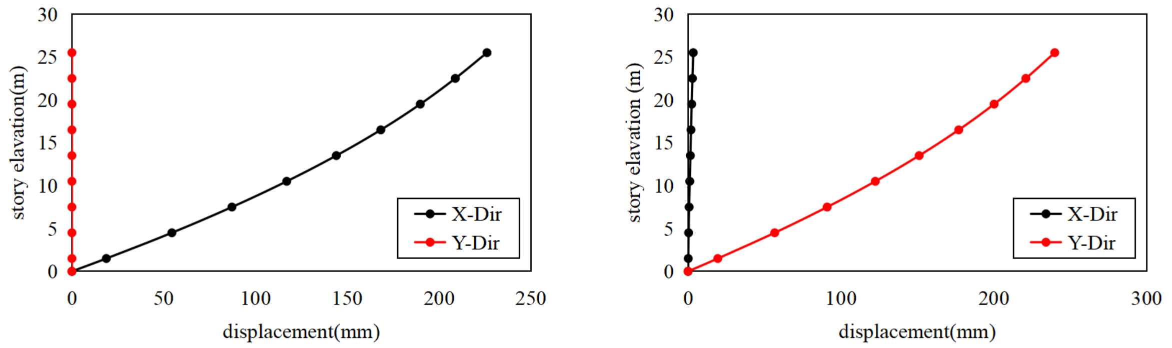

Figure 4.10:S2T4 displacement due to earthquake effect

S2T5 stands for 150 mm flat slab thickness and 700mm x 700mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.11 also, the maximum deflection was found to be 70.196 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

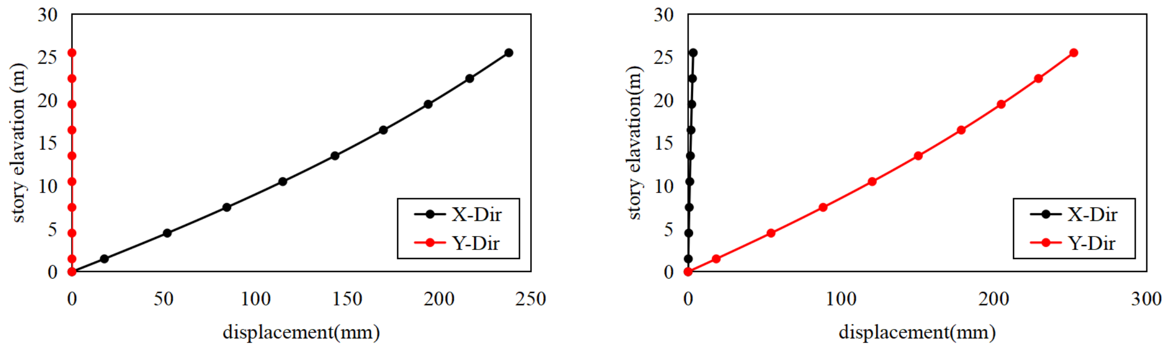

Figure 4.11: S2T5 displacement due to earthquake effect

S2T6stands for 150 mm flat slab thickness and 750mm x 750mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.12 also, the maximum deflection was found to be 69.953 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

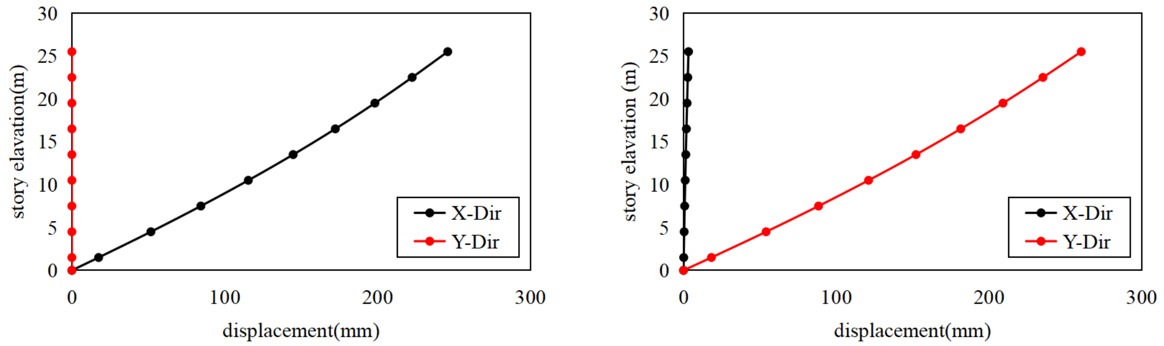

Figure 4.12: S2T6 displacement due to earthquake effect

S3T1 stands for 175 mm flat slab thickness and 300mm x 300mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.13 also, the maximum deflection was found to be 71.467 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

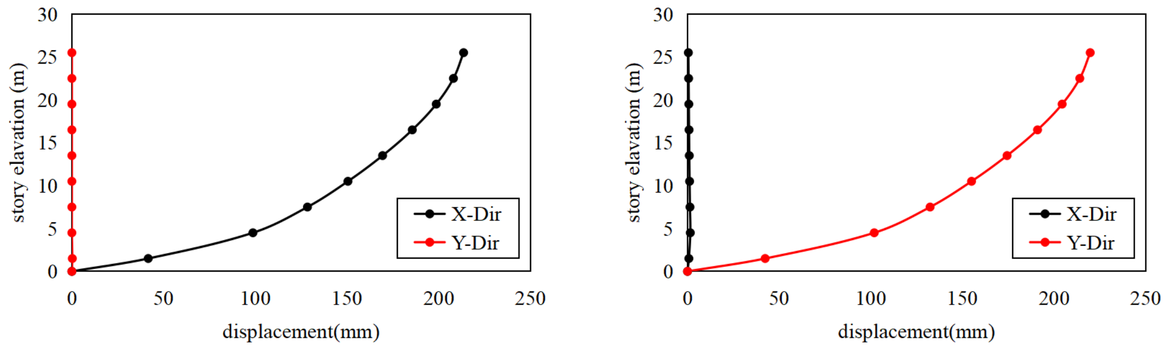

Figure 4.13: S3T1 displacement due to earthquake effect

S3T2 stands for 175 mm flat slab thickness and 400mm x 400mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.14 also, the maximum deflection was found to be 58.461 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

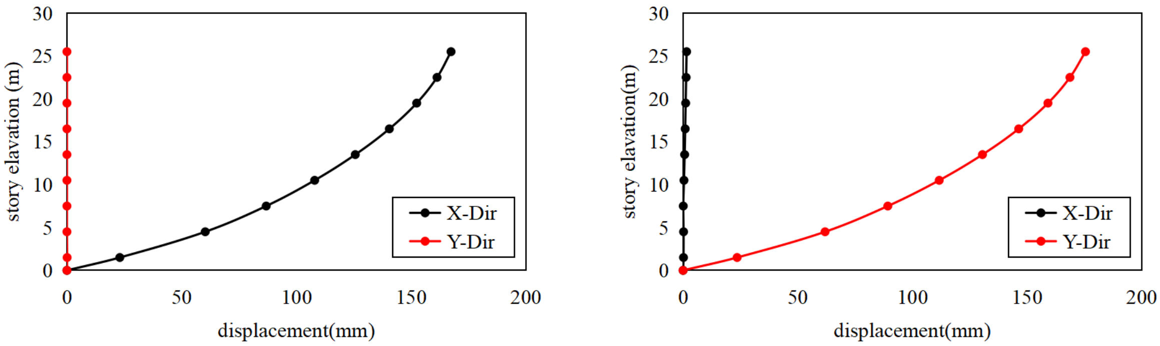

Figure 4.14: S3T2 displacement due to earthquake effect

S3T3 stands for 175 mm flat slab thickness and 500mm x 500mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.15 also, the maximum deflection was found to be 52.837 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

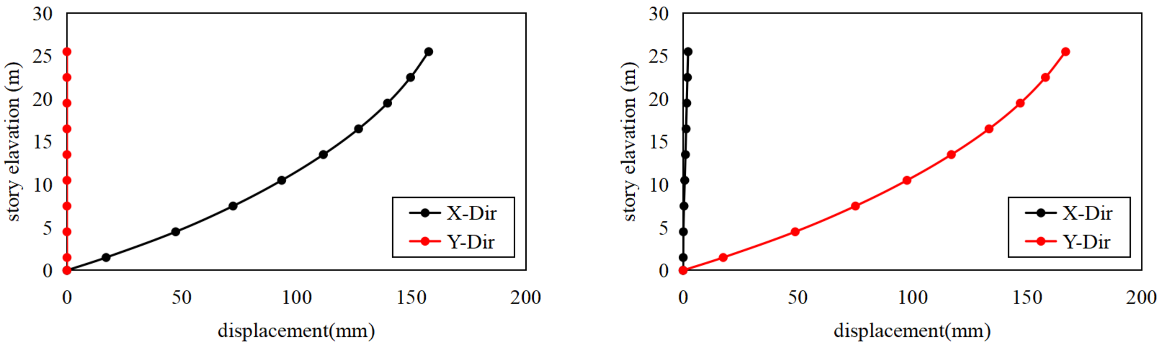

Figure 4.15: S3T3 displacement due to earthquake effect

S3T4stands for 175 mm flat slab thickness and 600mm x 600mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.16 also, the maximum deflection was found to be 49.883 mm after analysis which did not meet the requirements of equation 4.1, then another trial was made

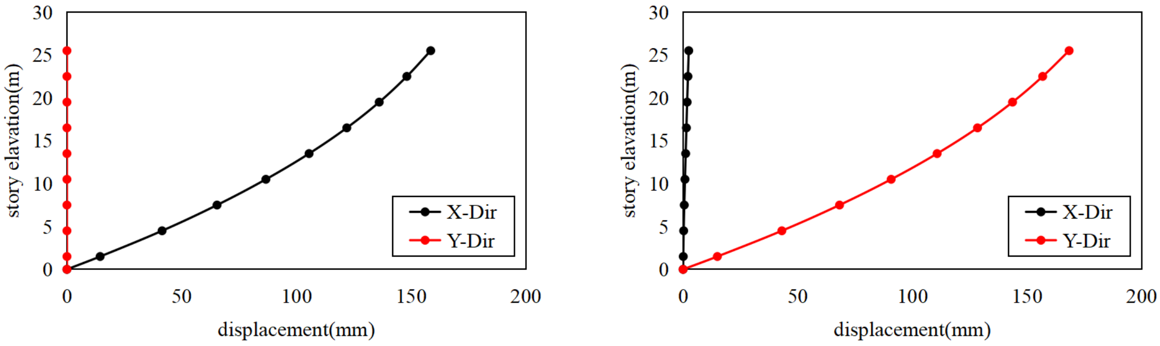

Figure 4.16: S3T4 displacement due to earthquake effect

S3T5 stands for 175 mm flat slab thickness and 700mm x 700mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.17 also, the maximum deflection was found to be 48.129 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

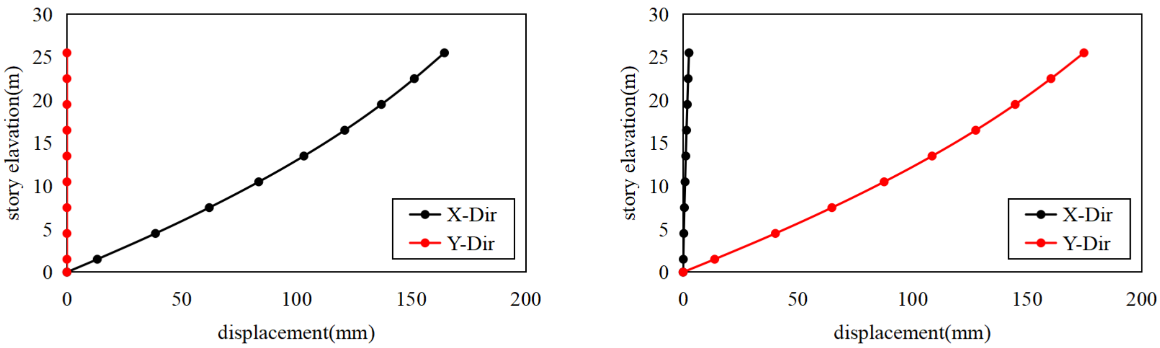

Figure 4.17: S3T5 displacement due to earthquake effect

S3T6stands for 175 mm flat slab thickness and 750mm x 750mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.18 also, the maximum deflection was found to be 47.507 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

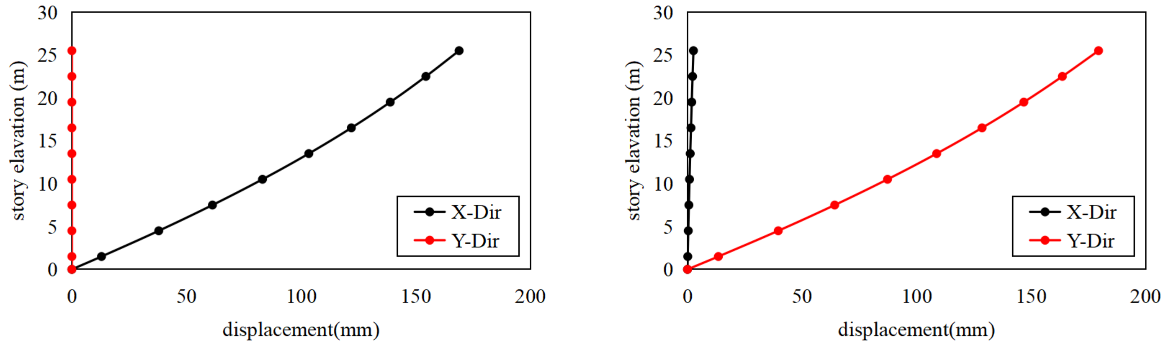

Figure 4.18: S3T6 displacement due to earthquake effect

S4T1stands for 200 mm flat slab thickness and 300mm x 300mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.19 also, the maximum deflection was found to be 58.92 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

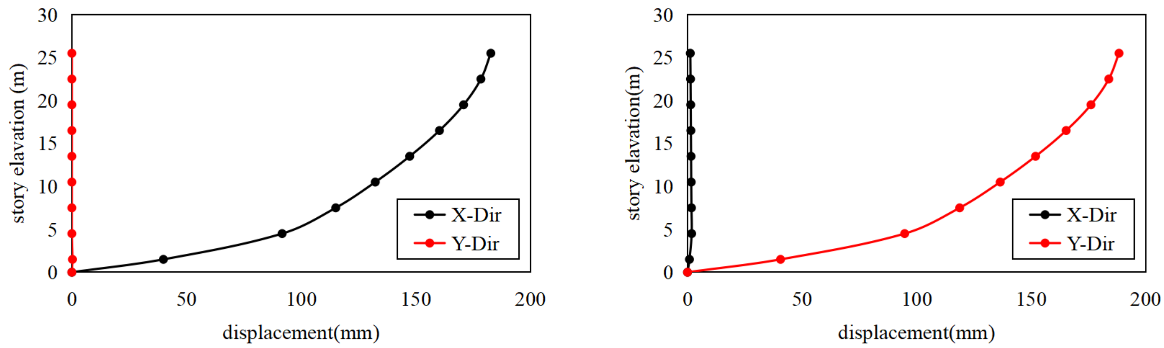

Figure 4.19: S4T1 displacement due to earthquake effect

S4T2stands for 200 mm flat slab thickness and 400mm x 400mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.20 also, the maximum deflection was found to be 45.882 mm after analysis, which did not satisfy above equation 4.1, then another trial was made

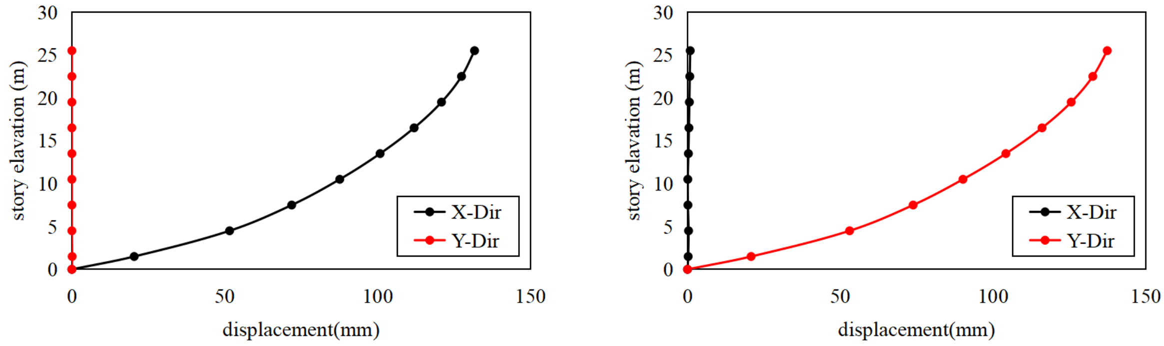

Figure 4.20: S4T2 displacement due to earthquake effect

S4T3stands for 200 mm flat slab thickness and 500mm x 500mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.21 also, the maximum deflection was found to be 40.182 mm after analysis which did not meet the requirements of equation 4.1, then another trial was made

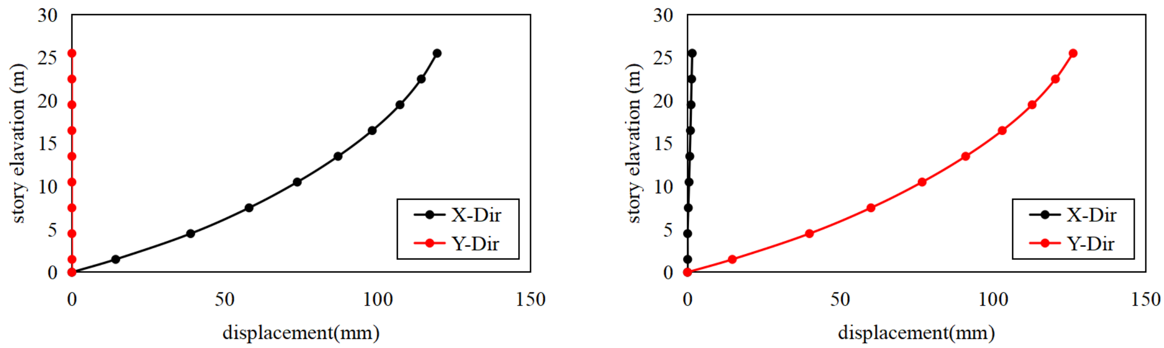

Figure 4.21 S4T3 displacement due to earthquake effect

S4T4stands for 200 mm flat slab thickness and 600mm x 600mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.22 also, the maximum deflection was found to be 37.175 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

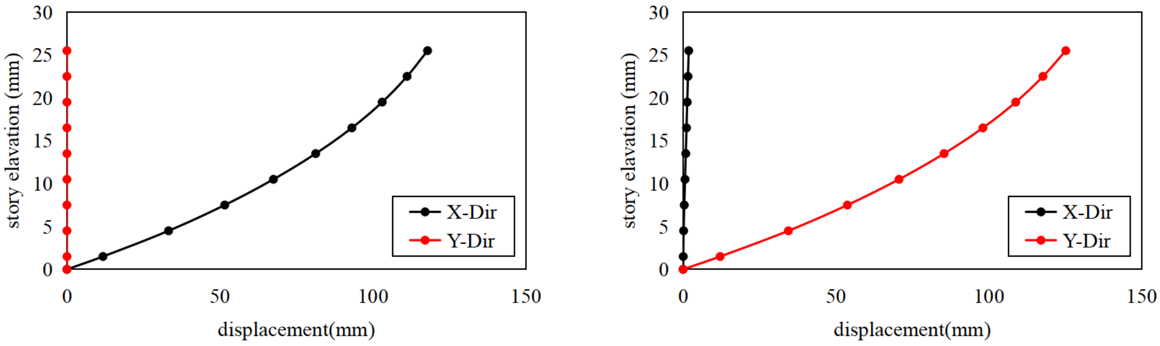

Figure 4.22: S4T4 displacement due to earthquake effect

S4T5 stands for 200 mm flat slab thickness and 700mm x 700mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.23 also, the maximum deflection was found to be 35.382 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

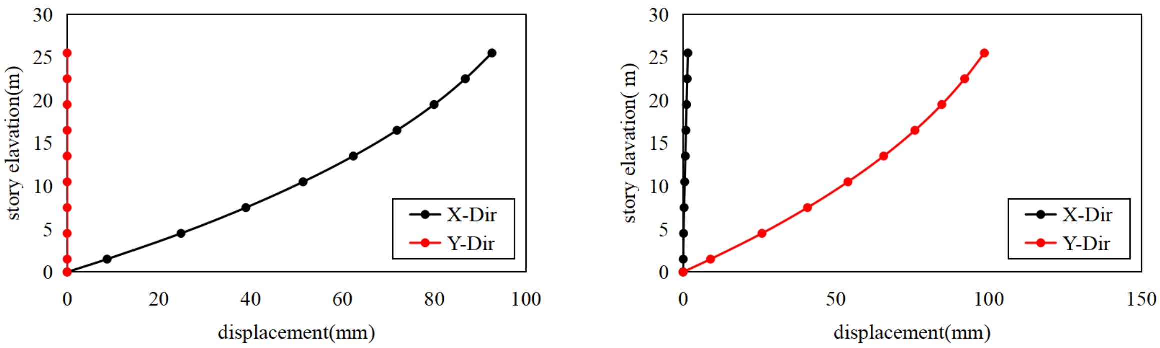

Figure 4.23: S4T5 displacement due to earthquake effect

S4T6 stands for 200 mm flat slab thickness and 750mm x 750mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.24 also, the maximum deflection was found to be 34.745 mm after analysis which did not meet the requirements of equation 4.1, then another trial was made

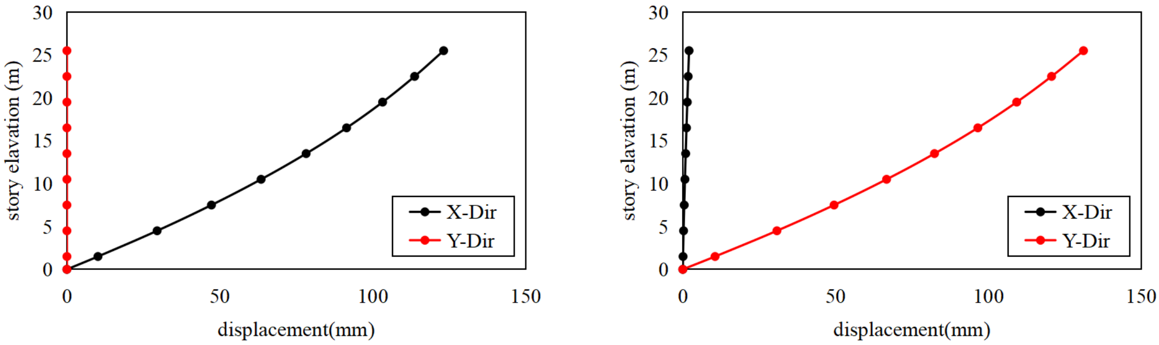

Figure 4.24: S4T6 displacement due to earthquake plot

S5T1 stands for 225 mm flat slab thickness and 300mm x 300mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.25 also, the maximum deflection was found to be 51.119 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

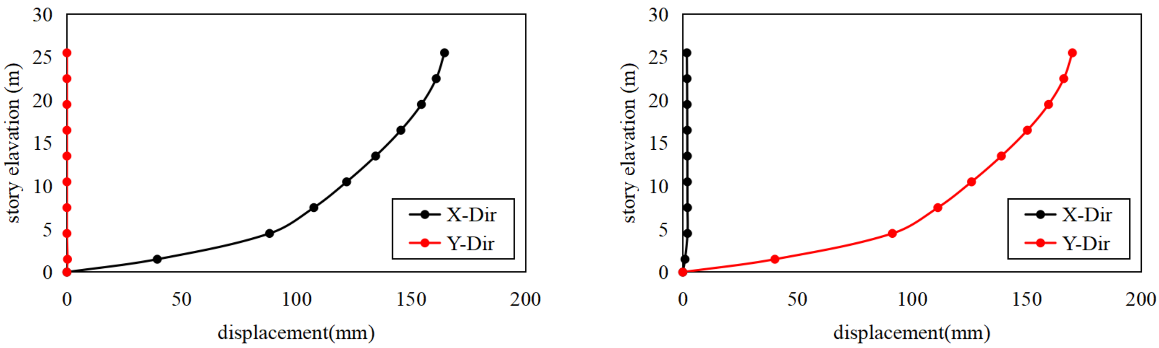

Figure 4.25: S5T1 displacement due to earthquake effect

S5T2stands for 225 mm flat slab thickness and 400mm x 400mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.26 also, the maximum deflection was found to be 38.107 mm after analysis which did not meet the requirements of equation 4.1, then another trial was made

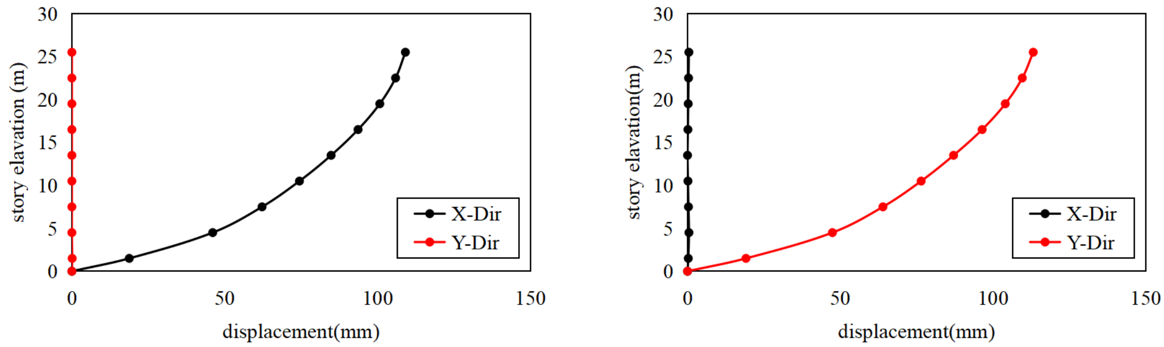

Figure 4.26: S5T2 displacement due to earthquake plot

S5T3stands for 225 mm flat slab thickness and 500mm x 500mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.27 also, the maximum deflection was found to be 32.348 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

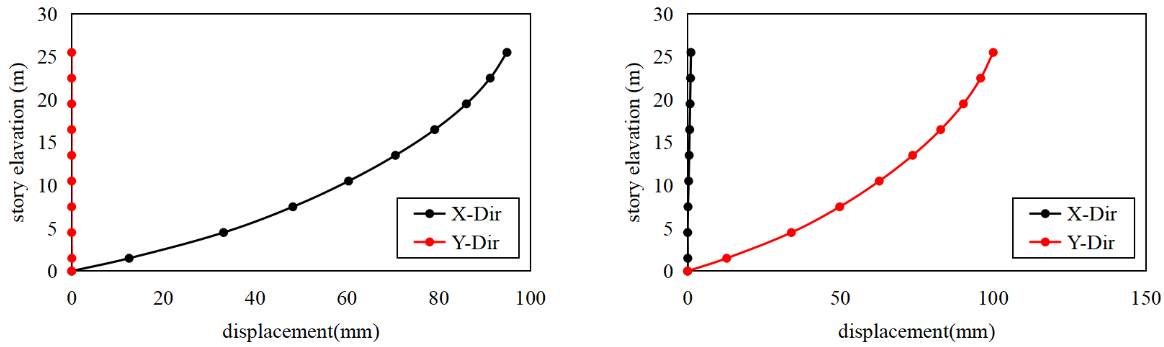

Figure 4.27: S5T3 displacement due to earthquake effect

S5T4stands for 225 mm flat slab thickness and 600mm x 600mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.28 also, the maximum deflection was found to be 29.229 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

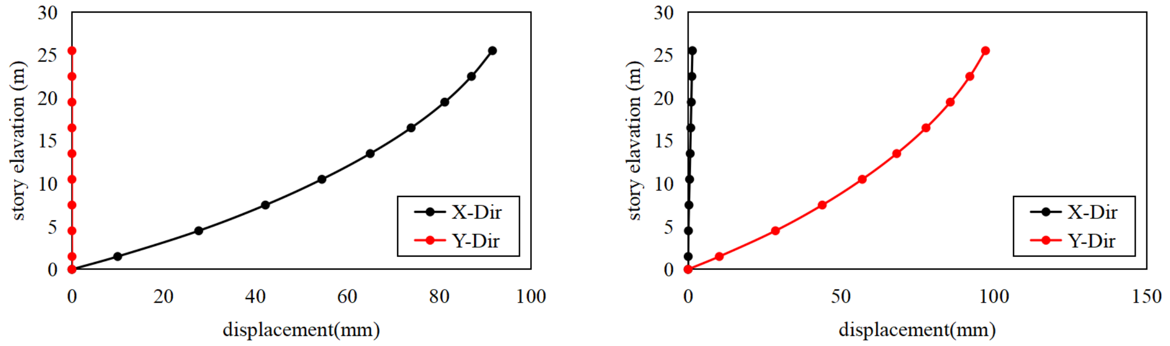

Figure 4.28: S5T4 displacement due to earthquake effect

S5T5stands for 225 mm flat slab thickness and 700mm x 700mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.29 also, the maximum deflection was found to be 27.476 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

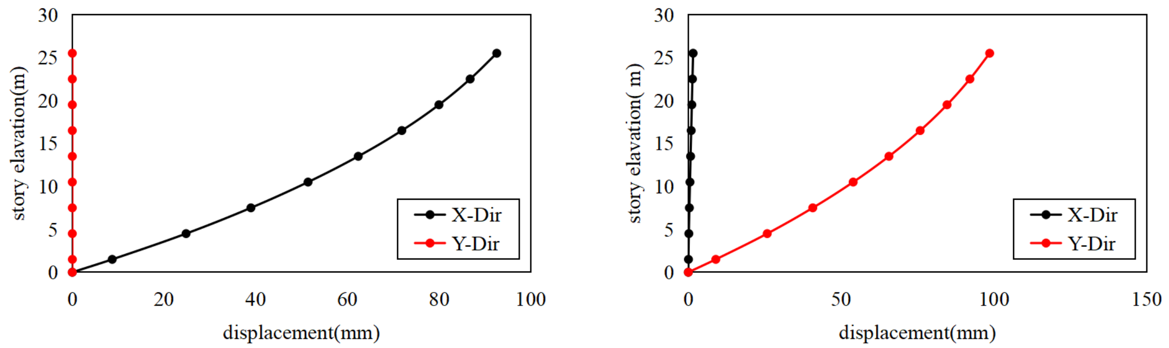

Figure 4.29: S5T5 displacement due to earthquake effect

S5T6stands for 225 mm flat slab thickness and 750mm x 750mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.30 also, the maximum deflection was found to be 26.85 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

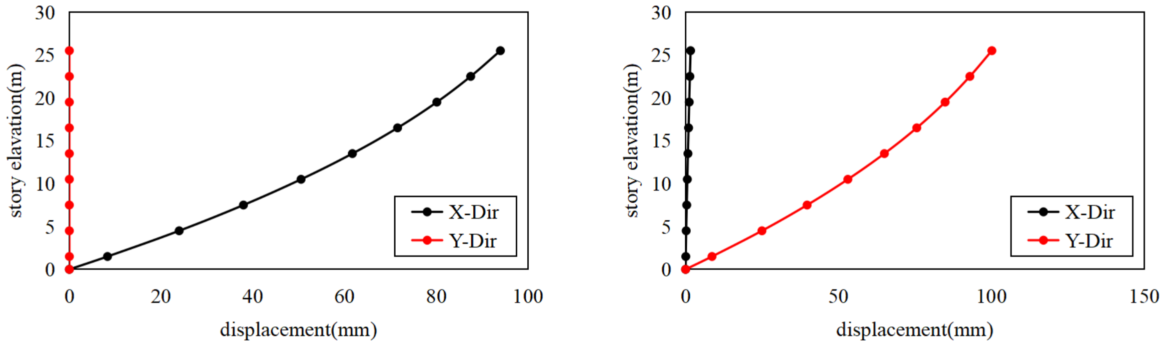

Figure 4.30: S5T6 displacement due to earthquake plot

S6T1stands for 250 mm flat slab thickness and 300mm x 300mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.31 also, the maximum deflection was found to be 46.117 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

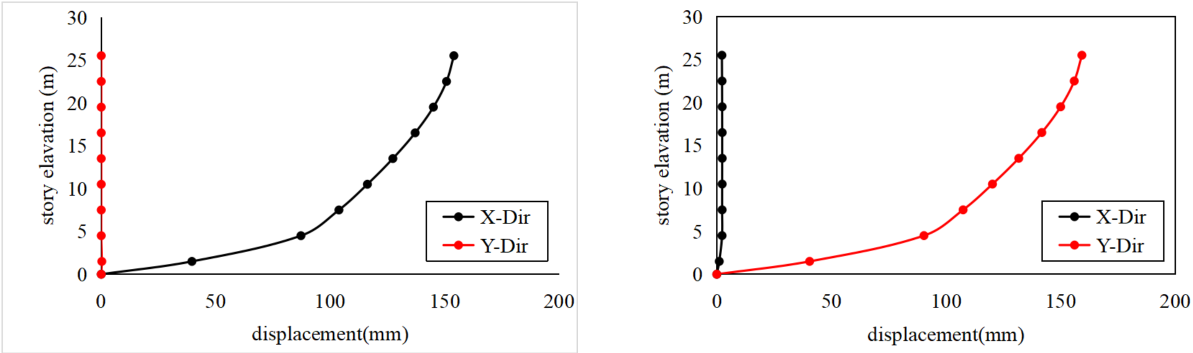

Figure 4.31: S6T1 displacement due to earthquake effect

S6T2stands for 250 mm flat slab thickness and 400mm x 400mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.32 also, the maximum deflection was found to be 33.036 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

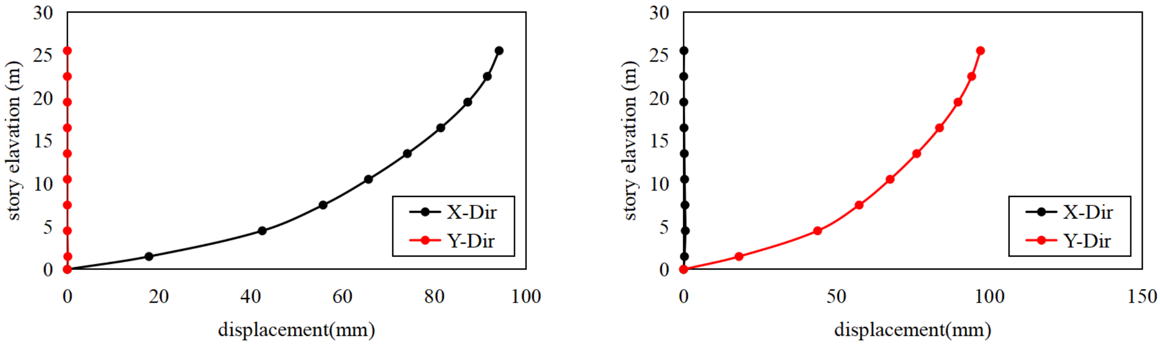

Figure 4.32: S6T2 displacement due to earthquake effect

S6T3stands for 250 mm flat slab thickness and 500mm x 500mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.33 also, the maximum deflection was found to be 27.227 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

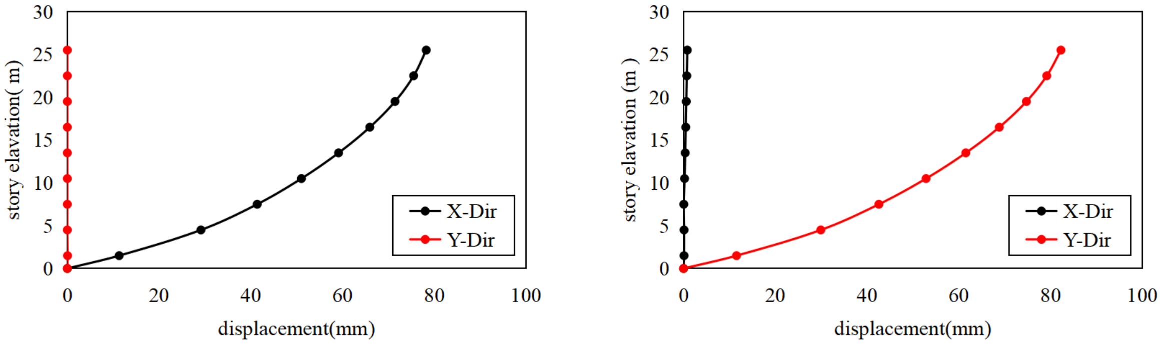

Figure 4.33: S6T3 displacement due to earthquake effect

S6T4stands for 250 mm flat slab thickness and 600mm x 600mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.34 also, the maximum deflection was found to be 24.143 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

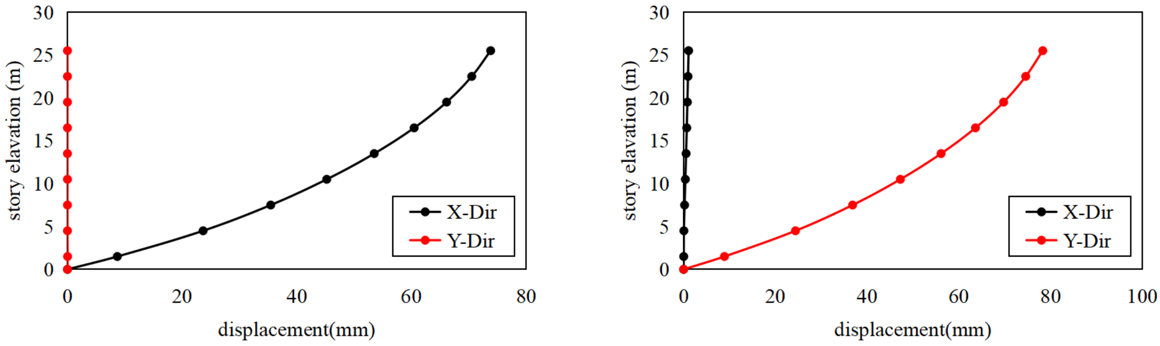

Figure 4.34: S6T4 displacement due to earthquake effect

S6T5stands for 250 mm flat slab thickness and 700mm x 700mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.35 also, the maximum deflection was found to be 22.295 mm after analysis, which did not meet the requirements of equation 4.1, then another trial was made

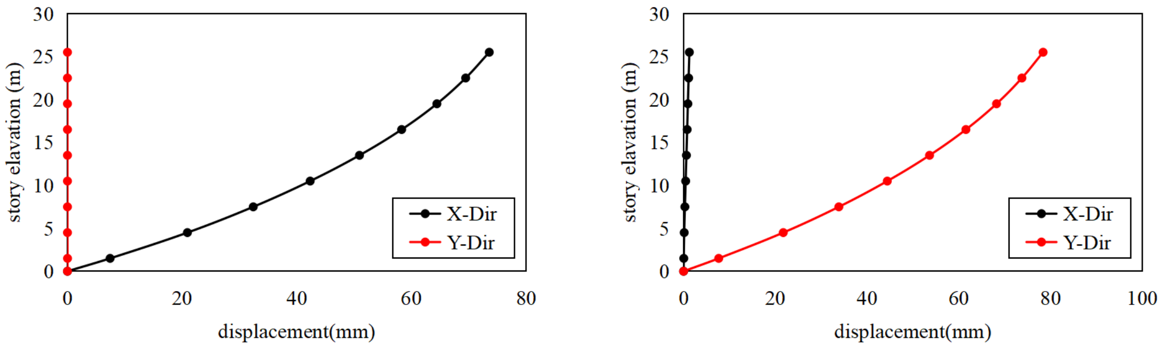

Figure 4.35: S6T5 displacement due to earthquake effect

S6T6stands for 250 mm flat slab thickness and 750mm x 750mm square column cross-section. After implementing this data in the T-shape building model the earthquake response action for both directions was discovered as shown in below Figure 4.36 also, the maximum deflection was found to be 21.634 mm after analysis, which satisfies the above equation 4.1, then Finally, we can conclude that S6T6, with a slab thickness of 250 mm and with column cross-section of 750mm by 750 mm, is suitable for this T-shape building structure having flat slab to avoid deflection failure.

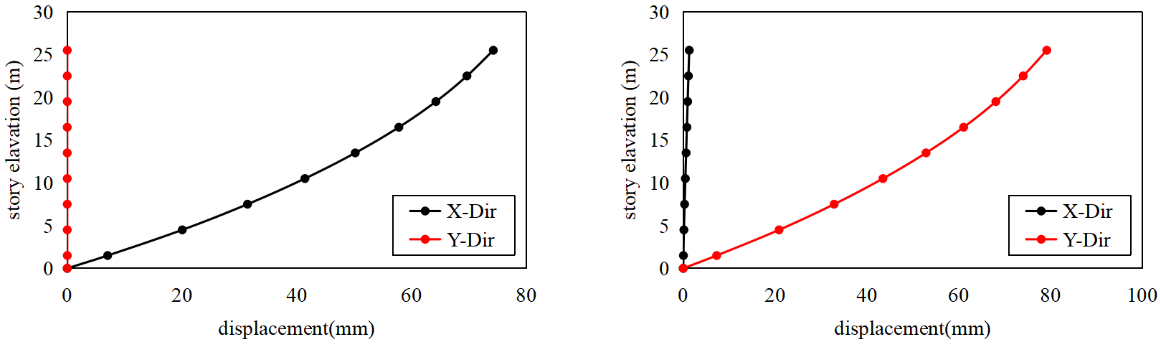

Figure 4.36: S6T6 displacement due to earthquake effect

4.4 Summary

In this chapter, I discussed the results of my modeling analysis though since my main goal for this project was to find an appropriate Flat slab thickness and to address the effect of slab thickness. After running 36 trials with different slab thicknesses and column sizes, I discovered that S6T6, which has a 250 mm slab thickness and a 750 mm by 750 mm cross-section of the column, is a suitable slab thickness for this T-shape building.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The summary of this project After analyzing the T-shaped building model with flat slabs in ETABS software to address slab thickness and find the appropriate flat slab thickness in this building, the following conclusions are drawn from the scope of this work:

- The minimum flat slab thickness that can handle the loads in this project model without undesired slab deflection was determined to be 250 mm.
- Furthermore, this slab thickness can only be satisfied if the column size is 750 mm by 750 mm or greater.
- the deflection value was decreasing as the thickness of the slab increases
- We also discovered that there is a column effect and the deflection value is decreasing when column crosssection increases

5.2 Future Recommendation

Those planning to conduct research on this topic should keep the following points in mind for further investigation:

- Future work on the project can include flat slab analysis and design using a grid mesh model with various flat slab shapes and analysis using Finite Element software.
- The behavior of the structure in different seismic zones, as well as the behavior of a building with flat slabs and a column head.
- Other software, such as SAP2000, can also be used to analyze the structure.

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