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INSTITUTE OF ENGINEERING  
PULCHOWK CAMPUS**

**THESIS NO:S015/075**

**Comparative Study of Flat Slab Structures with Steel Bracings**

by

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A THESIS

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## **ABSTRACT**

Many past researches show that the flat slab building system is weak in lateral load resistance induced due to seismic actions. To enhance the seismic performance of flat slab building, it needs an effective lateral load resisting system. In this present work, G+5, G+7 and G+9 storied flat slab building system as well as conventional building system were modelled. For lateral load resistance, various types of steel braces were modelled on flat slab structure and seismic analysis was done. Equivalent static analysis method and Response spectrum analysis method were performed using IS 1893 2016. The comparative study of seismic parameters i.e. maximum storey displacement, maximum inter storey drift, base shear and fundamental natural time period among the various braced as well as unbraced models were performed. The study shows that use of steel bracings as a lateral load resisting system on flat slab building enhances the seismic performance of flat slab system.

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## **LIST OF ABBREVIATIONS AND SYMBOLS**

Ah	Horizontal Base Shear Coefficient
cm	Centimeter
DL	Dead Load
E	Modulus of Elasticity
EL	Earthquake Load
ESA	Equivalent Static Analysis
g	Acceleration due to gravity
I	Importance Factor
IL	Imposed Load
IS	Indian Standard
%	Percentage
KN	Kilo Newton
LL	Live Load
m	meter
mm	millimeter
N	Newton
NBC	Nepal Building Code
R	Response Reduction Factor
RC	Reinforced Concrete
RCC	Reinforced Cement Concrete
RSA	Response Spectrum Analysis
Sa/g	Design/Response acceleration coefficient based on appropriate natural period and type of soil or rock at site
T	Fundamental Natural Time Period
Z	Seismic Zone Factor

## **CHAPTER 1: INTRODUCTION**

### **1.1 General Overview**

#### **1.1.1 Flat Slab**

The term “Flat Slab” means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads [23]. In general, Flat slab is a reinforced concrete slab supported directly by columns with or without drop panels as well as with or without column heads. Reinforced Concrete flat slab system are one of the most popular construction systems widely used in different countries like Spain, Italy, Portugal as well as in metro cities of India. The flat slab system is used in various types of buildings, car parks, garage and many more places. They are favored by both architects and clients because of their aesthetic appeal and economic advantage. However, the higher flexibility of flat slab structure has resulted in their inability to sustain earthquake loads.

Generally, in Nepal, the construction is done with beam, column and slab which is termed as Conventional construction technique. Flat slab building construction system is not highly implemented on our country, because Nepal is situated on high seismic zones and is known as one of the most seismically vulnerable countries. It is situated in high seismic region having the geographical position along the tectonic boundary of the Indian and Eurasian Plates. As flat slab building structures are significantly more flexible than conventional concrete structures, thus becoming more vulnerable to seismic loading. Therefore, the flat slab system needs proper and effective lateral load resistance technique to implement it on high seismic zone.

Initially CAP Turner in USA started the construction of mushroom type flat slab system early from 1906. This is also known as the beginning point of this type of construction. Initially flat slabs were developed without drops and column heads. But in 1960s in Central America, flat slabs displayed critical problems in punching [1]. There are various ways to decrease the punching failure on flat slab i.e. Providing shear reinforcement, increasing the thickness of slab, providing the drop panels on slab, providing the column head together with drop panels, increasing the thickness of drop panels etc. In this study, punching effect on bare model is minimized by providing the drop panels having adequate size and thickness.

There are following types of flat slabs generally used during construction,

1. Simple flat slab
2. Flat slab with drop panels
3. Flat slab with column heads
4. Flat slab with both drop panels and column heads

### **1.1.2 Lateral Load Resisting System**

Lateral load resisting system is the part of structural system and consist of all structural members that resist lateral inertia forces induced in the building during earthquake shaking [22]. In high-rise structures, to increase the lateral strength, a lateral load resisting system is mandatory. A number of researchers have investigated various techniques such as infilling walls, adding walls to existing columns, encasing columns, and adding steel bracing to improve the strength and/or ductility of existing buildings. Some of the examples of lateral load resisting systems are Moment resisting frames, Shear walls, braced frames, Dual structure system, Coupled shear wall, Out-trigger structures, Diagrid etc. This study is concerned only with the comparison of seismic parameters of flat slab building, having four different types of steel braces.

### **1.1.2 Bracing system**

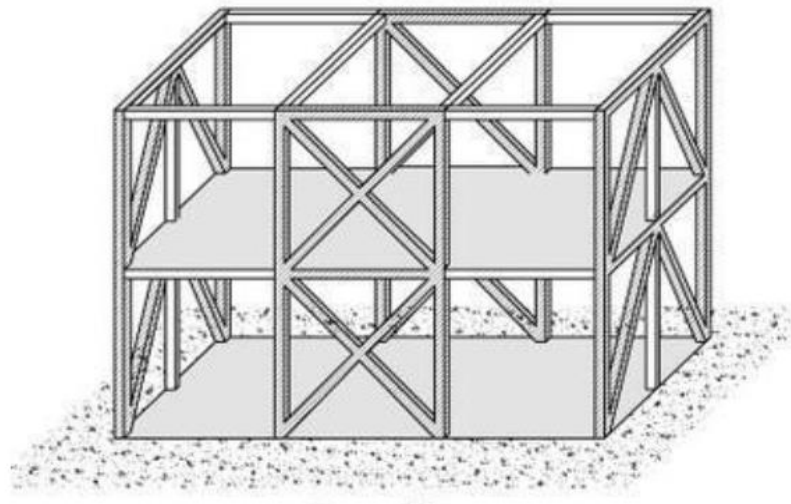


Figure 1: 1 Bracing System

Bracing systems can be defined as members that can resist lateral loads through axial forces in the structural components. Bracing members usually carry the axial loads generated due to seismic activities, which could be either compression force or tension force. Bracings can be used on both steel as well as concrete structures and material of

bracings members also be steel as well as concrete. In the structure, a braced frames performs like vertical trusses. Horizontal floor bracings can also be done in structure but in this study we discussing only about vertical bracings. There are three types of bracing system,

- Buckling-Restrained Braced Frame (BRB) system,
- Concentric Braced Frame (CBF) system and
- Eccentric Braced Frame (EBF) system.

Providing a bracing system on a laterally weak structure will improves the seismic performance of the whole system by increasing its lateral stiffness and capacity. Steel braced frames are efficient structural systems for buildings subjected to seismic or wind lateral loadings. In this study we are considering only concentric bracing system.

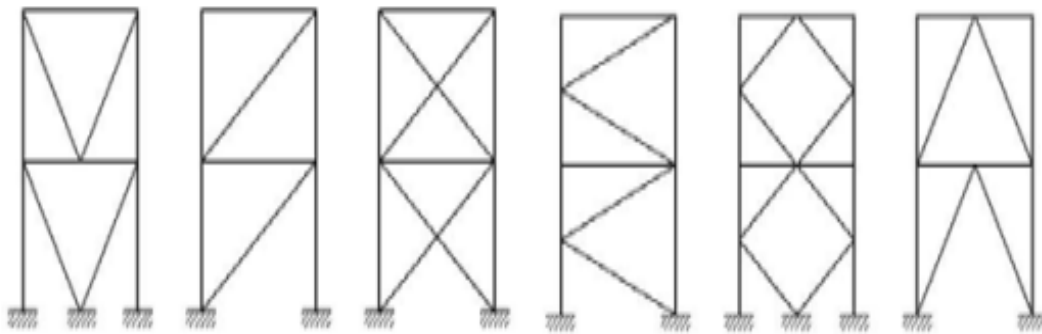


Figure 1: 2 Different types of Concentric Braces

### 1.1.3 Steel Brace in RCC Structure

In general, use of shear walls in reinforced concrete structure and use of steel bracing in steel framed structure is done. However, in recent years there has been lots of studies and application of steel braces on new built RCC structure as well as strengthening of old structure. One of the earliest buildings to incorporate structural bracing is the Dewitt-Chestnut Building in 1965 in Chicago [17]. Later in 1970, Fazlur R. Khan developed the braced tube system to the John Hancock Centre, in Chicago [17]. In 1981 Higashi and Endo et al. also carried out studies on the use of concentric and eccentric bracing in concrete frames [17]. In 1991, Bush et al. used a complex steel frame bracing system in a concrete frame and obtained a substantial increase in the in plane shear resistance of the frame [17]. Now days, Steel braces are used to make existing building stiffen as well as in new building to increase its lateral strength [25]. Steel diagonal

braces can be added to the existing concrete frames. Braces should be arranged so that their center line passes through the centers of the beam column joints. The brace connection should be adequate against out of plane failure and brittle fracture [24]. As we know, the flat slab building system is laterally weak than a conventional beam column structure. This study focuses on the effectiveness of use of different types of steel braces on flat slab structure.

## **1.2 Statement of Problem**

Many past researches show that flat slab system is weak on lateral forces induced by seismic actions, so there needs a proper and effective lateral load resisting system to make it strengthened against earthquake effect. In general, the lateral load resistance system means the use of shear walls on RCC structure and use of steel braces on steel structure. Now days, use of steel braces on RCC structure could be an effective alternative for strengthening the old structure as well as for new structure too.

In this study steel bracings are used as a lateral load resistance system and comparative study is made for different steel bracings configurations. Several previous studies show that the use of bracing in a building is highly efficient and economical method to resist lateral forces. The effect of bracings due to its location and arrangement on a structure is also studied. This study shows the seismic behavior of flat slab structure having steel bracings as a lateral load resisting systems. Diagonal, X, V and Chevron type of bracings are used at different locations such that at corner bays, middle bays, alternate bays and all peripheral bays. For connection of V and Chevron type brace on slab, the concept of concealed beam was applied. For comparative study, the concealed beam was modelled on peripherally on all models. The combined behavior of two different bracings on peripheral bays were also studied. The analysis is performed on ETABS software version 18.1.0. After the completion of this study we will find and able to compare the seismic parameter of flat slab building with different types of steel bracings at different locations and configurations.

### **1.3 Objectives**

The main objective of this research work is to study the effectiveness of steel bracings as a lateral load resistance system on flat slab structures.

The specific objectives of this study are:

- To determine the seismic response parameters (Maximum story displacement, Maximum storey drift, Base Shear and Time period) of the flat slab buildings with steel bracing system.
- To determine the behavior of different bracing systems (i.e. Diagonal, X, V, and Chevron bracings) together with its location effects.
- To determine the most effective bracing which resist the lateral loads among all the bracings considered.

### **1.4 Scope and Limitation of the work**

This thesis work focuses only on the study of seismic parameters of flat slab building having steel braces in vertical arrangement. Four different types of bracings on different bays of buildings are applied and comparative study was done. The modelling is done on ETABS software version 18.1.0. taking three different stories level i.e. G+5, G+7, and G+9 stories, square shaped buildings. The equivalent static analysis and response spectrum analysis is performed and the results are compared.

The limitations of the study are:

- Irregular plan shapes, topology, openings for staircase, lift core walls etc. are not considered.
- Number of Bays and length of Bays are kept same.
- Study is carried out only taking Dead Load as a self-weight of members.
- Selection of optimum size and shape of steel bracings is not done. A standard size and shape of steel brace is taken to make comparable models.
- Cost analysis of braces as well as the feasibility of work was not considered.
- Only four different seismic parameters among the models are compared.

## **1.5 Methodology**

The research methodology involves,

- Extensive review of literatures including, guidelines for flat slab modelling, design, analysis, guidelines for lateral load resisting systems, types, design, analysis, their effect on building etc. and research articles, papers related to flat slab structure, steel bracings on RCC structure, seismic behavior of flat slabs etc.
- Selection of suitable building plan and configurations.
- Modelling of flat slab building on ETABS V18.1.0 software with suitable size and material definition following Indian Standard Codes.
- Modelling of four types of steel braces on bare model at corner bays, middle bays, alternate bays and peripheral bays.
- Performing Equivalent Static Analysis and Response Spectrum Analysis based on IS 1893 2016.
- Comparative study of seismic parameters among different configuration of structure.
- Result interpretation, Conclusion and Recommendations.

## **1.6 Organization of Thesis**

This thesis report presents the “Comparative Study of Flat Slab Structures with Steel Bracings”. The report is organized in the following manner.

**Chapter 1** It gives a general introduction about flat slab building system and bracing systems. It also highlights the need of this research work, scope and limitation of the research work as well as it outlines the overview of the report.

**Chapter 2** Presents literature review on flat slab, lateral load resisting systems, steel brace and application of steel brace on frame as well as on flat slab structures.

**Chapter 3** Presents about research methodology as well as formulation of work and modelling of structural components on software ETABS (Extended Three-Dimensional Analysis of Building System).

**Chapter 4** Presents about the concept of analysis carried out in this research work. It contains the procedure of the Equivalent static analysis and Response Spectrum analysis.

**Chapter 5** Presents about the results and discussions obtained from the analysis. Also it contains comparative study of seismic parameters of different models and configurations.

**Chapter 6** Presents conclusions of research work as well as recommendation for the future work.

## **CHAPTER 2: LITERATURE REVIEW**

A flat slab consists of a reinforced concrete slab that is directly supported by concrete columns without the use of intermediate beams. C.A.P. Turner constructed flat slabs in U.S.A. in 1906 mainly using intuitive and conceptual ideas, which was the earliest point of this type of construction. Many slabs were load-tested between 1910- 20 in U.S.A. It was only in 1914 that Nicholas proposed a method of analysis of flat slabs based on simple statics. This method is used even today for the design of flat slabs and flat plates and is known as the direct design method. Structural engineers commonly use the equivalent frame method with equivalent beams such as the one proposed by Jacob S. Grossman in practical engineering for the analysis of flat plate structures. Floor systems consisting of flat slabs are very popular in countries where cast-in place construction is predominant form of construction because of many advantages in terms of architectural flexibility, use of space, easier formwork, and shorter construction time. Flat slabs are being used mainly in office buildings due to reduced formwork cost, fast excavation, and easy installation.

### **2.1 IS Provision for Flat Slab**

#### **2.1.1 IS 456 2000**

As per IS 456 2000, Clause 31.1 The term flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads. A flat slab may be solid slab or may have recesses formed on the soffit so that soffit comprises a series of ribs in two directions. The recesses may be removable or permanent filler blocks.

31.2.1 Thickness of flat slab: The thickness of flat slab shall be generally controlled by considerations of span to effective depth ratios given in Clause 23.2. For slabs with drops conforming to 31.2.2, span to effective depth ratios given in 23.2 shall be applied directly; otherwise the span to effective depth ratios obtained in accordance with provisions in 23.2 shall be multiplied by 0.9. For this purpose, the longer span shall be considered. The minimum thickness of slab shall be 125mm.

31.2.2 Drop: The drops when provided shall be rectangular in plan, and have a length in each direction not less than one third of the panel length in that direction. For exterior

panels, the width of drops at right angles to the non-continuous edge and measured from center-line of the columns shall be equal to one half the width of drop for interior panels.

23.2 The thickness of the flat slab up to spans of 10m shall be generally controlled by considerations of span to effective depth ratios given as:

Cantilever 7; Simply supported 20; Continuous 26

All other required design parameters and method of analysis of flat slab system are defined on respective sections and clauses of IS 456 2000.

## **2.2 Literature Related to Flat Slab**

Karki & Suwal [1] studied by considering traditional and flat slab building system having G+5, G+8 and G+11 stories. For lateral strengthening, perimeter beam and shear wall system was modelled in flat slab buildings. The effect of positioning of shear walls on seismic performance of flat slab building models were analyzed. Comparative study of seismic parameter (Storey Displacement, Drift, Base shear, Time period) were done. The analysis showed that with the use of shear walls and perimeter beam, flat slabs can be considered as system with an acceptable seismic risk.

Ema Coelho & Paulo Candeias [2] carried out an experimental program for flat slab building in full scale at the ELSA Laboratory, with the objective of assessing the seismic behavior of the flat slab structures. It is found that flat slab structures show relatively higher flexibility as compared to the traditional structure.

Sanjay P. N. [3] studied about the behavior of flat slab RCC structure under earthquake loading, which contains the comparative study of the seismic behavior of multi-story flat slab building with drop panels and without drop panels for different seismic zones. This study concludes that building having drop panels have more lateral load carrying capacity than without drop panels.

R. P. Apostolska [4] studies about the seismic performance of flat slab buildings, with some sort of structural modification. Addition of perimeter beam and reinforced concrete wall on flat slab can achieve safety against seismic activity.

Lan N Robertson [5] study about the analysis of flat slab structure using three dimensional model having both gravity and lateral loads. For lateral loads shear wall

was modelled. The study compares the results with analytical as well as practical results.

P. Desain & Cholekar [6] study about the dynamic behavior of conventional and flat slab structure. The flat slab structure was taken with drop and without drop. Also with masonry infill and without infill case was considered. Dynamic analysis is carried out considering IS standard and seismic Zone III. The comparative study of seismic parameters such as time period, base shear, displacement and axial forces are done.

Navyashree K, Sahana T.S [7] study about the performance of flat slab and conventional RC frame building taking three different stories level. The building was modelled and analyzed on seismic zone V and the vulnerability of the structure was evaluated. The study concludes the poor performance of flat slab towards the earthquake loads so that we need special design conception and guidelines for flat slab structure on seismic prone areas.

Bhavesh Rajesh Sahni [8] study about the behavior of pure flat slab, flat slab with the application of shear wall and comparison with conventional slab system. The analysis was carried out by using ETABS and results are compared in different seismic zones. The different seismic parameters such as drift, displacement, overturning moment and base reactions were studied and concluded that use of shear wall on flat slab gets even better seismic performance than the conventional system.

M.Techi Tata [9] carried out the study of seismic behavior of buildings having flat slabs with and without drop. The study was carried out on different seismic zones and modelled on ETABS software. The study concludes with the remarks that, flat slab with drop panels structure shows better seismic performance than the structure without drop panels.

Kalyan Chowdary [10] examines about the high rise thirty storey building with beam slab, flat slab and alternate flat beam slab system. The study was carried out in zone V. The comparative study among flat slab structure and conventional RC structure was made.

K. S. Sable [11] study about the seismic behavior of multistory building having flat slab system and conventional frame system. Analysis was carried out in STAAD Pro software. Traditional RCC structure and flat slab structure were analyzed with different heights. After completion of study comparative results are concluded.

Abhishek Lakshman [12] compares the seismic vulnerability of conventional structure and flat slab structure and concludes that flat slab system responds more to earthquake load than the conventional structure.

G. S. Neenska-Cvetanovska [13] compares the seismic parameters of multistory building for different seismic zones. Flat slab with proper design and considerations can be used as a durable and resistive system.

R. Mundhada, Khan [14] compares about the seismic parameters of flat slab with grid slabs having multiple stories. It was found that base shear at terrace level of flat slab is more than grid slab system. The study shows that storey drift and time period of flat slab is more than grid slab.

### **2.3 Literature Related to Steel Brace on RCC Structure**

Woo-Seung Shin & Kim [15] study about the seismic retrofit of flat plate structures. Column Jacketing, Steel bracings and Reinforcement of column-slab connection techniques are studied with nonlinear static and dynamic analysis. Among the retrofit schemes steel braces were most effective in increasing stiffness as well as strength of the structure.

A. K Jain [16] study about the effect of steel bracings on RCC frame structure subjected to scaled up El Centro earthquake 1940. Inelastic seismic behavior of the RC frames with X and K bracing were analyzed and it is found that lateral displacement of building was reduced and stiffness of the structure was increased significantly.

Maheri & Shahebi [17] study about the use of steel bracings on RCC framed structure. The study is carried out through a series of tests and the objective of the tests was to determine the degree of effectiveness of various diagonal steel bracing arrangements to increase the in-plane shear strength of the concrete frame and also the relative behavior of tension and compression braces. This investigation concludes, with the proper connection between brace and frame, the steel bracing could be an alternative or supplement to shear walls in RCC frame buildings in seismically active zones.

Razak & Kong [18] reviews about the influence of various types of steel bracings to the structural and seismic performance of RCC buildings. Proper and efficient structural bracings in high rise building will lead towards the safe, sustainable and more economic construction.

Dr. Chadan Kumar et al. [19] work with the study of effect of steel bracings on RC framed structure. The comparative study of G+9 storey RCC framed structure was done by using different braces and shear walls. The study was carried out in different seismic zones. It was concluded that the chevron type of steel bracing was found to be more efficient in zones II and III. Similarly, X type bracing was found to be more efficient in Zones IV and V.

Pratik Patel et al. [20] works on comparative study of different bracing systems in RCC building using STAAD Pro software. This study includes the comparison between unbraced building and braced building. Finally, results are presented by comparing seismic parameters. This study concludes that X- braced frames are more efficient and safe at time of earthquake when compared with moment resisting frames and V-braced frames.

Harshita M K et al [21] workout on analysis of RC framed structure with different bracings systems and configurations. The model was prepared with ETABS and situated on zone IV. The effectiveness of braces was studied using 16 models out of which one is the bare frame model. The performance of the building was studied in terms of lateral displacement, base shear and time period. After providing the steel braces on RCC structure, the seismic performance of braced building was improved significantly than the unbraced frame. It was also found that the various arrangements of bracing systems have great influence on seismic performance of the building.

After reviewing the literatures, it was a well-known factor that flat slab building is laterally weak and it needs the proper lateral load resisting system. So that, in this study steel braces are chosen as lateral load resisting system and the comparative study was conducted for four different types of braces. For connection of V and Chevron braces, the concealed beam concept was applied. Concealed beam is defined as the beams whose depth is equal to the thickness of the slab and its width may vary up to 1.5 to 2 times as per requirements. It is also called hidden beam and generally it is used to disperse loads on supporting slab. The suitability of bracings and their effectiveness on controlling the seismic parameters are only the concern of this research work.

## **CHAPTER 3: MODELLING**

### **3.1 General**

For the analysis and the comparative study of seismic parameters of the buildings, the mathematical modelling of the structures is required. Proper model development of the structures helps to achieve the accurate output results of the structural analysis which is obviously the primary target of this study.

In this study, three dimensional modelling of the structure is done by ETABS software. Both linear static and linear dynamic analysis of various models are done. A simple symmetric geometrical plan of flat slab building with drop panels are taken for study purpose. Three different stories level are taken i.e. G+5, G+7, G+9 Storey. A similar type conventional building having beam column system also modelled. Application of four different types of steel braces i.e. Diagonal, X, V and Chevron are done at different locations i.e. Corner bays, middle bays, alternate bays and all peripheral bays. Again combination of two different bracings also done and the effect of bracings on flat slab building was analyzed.

### **3.2 Modelling Data**

#### **3.2.1 Plan and Configuration**

A simple square shaped plan is taken for study. Number of bays are four and the bay size is 5m. Typical storey height is taken 3m and three different storey levels i.e. G+5, G+7, G+9 stories are modelled for study purpose. Cantilever projection of 0.5m is taken on each floors in each direction measuring from center of outer column.

#### **3.2.2 Material Properties**

The Concrete grade of M25 is used with an elastic modulus of 25000MPa according to IS 456:2000. The concrete weight per unit volume is taken as 25 KN/m<sup>3</sup> with Poisson's ratio 0.2. Reinforcement bar HYSD 500 TMT with elastic modulus of 200000MPa is used for structural design. Unit weight of bar is taken 76,900 KN/m<sup>2</sup> with Poisson's ratio 0.3. For bracings Fe 345 steel grade is used and a standard heavy weight I beam ISHB 350-1 is used for all models.

### 3.2.3 Section Properties

Preliminary selection of size is done by following minimum requirements of Indian standards IS 456-2000 [23]. Final sizes are obtained after design check of structure. A square column of size 400mm x 400 mm is taken for G+5 storied building. And square column of size 450mm x 450mm is taken for G+7 storey building and 500mm x 500mm for G+9 storied building. For flat slab with drop models, slab thickness is taken 200mm thick with 100mm thick drop panels. The shape of drop panel is rectangular and size is 2.5m x 2.5m. For the connection of steel braces on slab, the concealed beam of depth 200mm and width 400mm was modelled. For conventional beam column system, same size of column is used. The beam of size 300mm x 400mm for G+5 and G+7 storey building is taken for conventional building. For G+9 storey building beam of size 300mm x 500mm is used with slab thickness 150mm in all models.

### 3.2.4 Loads and Load Combinations

In this study Dead Load is considered as only self-weight of structural members. Live load is taken 3KN/m<sup>2</sup> as per IS 875 Part 2. Seismic load is taken by following IS 1893-2016. For the seismic analysis, the seismic zone is taken Zone V with response reduction factor 3, Importance factor 1.2 and soil type II. The Bare Models are designed as per Load Combination from IS 1893 2016. Punching failure is checked by ETABS default method. Final sizes of bare models are obtained after design check. Load combinations applied on bare models are as follows;

Frame Design Load Combinations for Flat Slab with Drop-Bare Model and Conventional Building Bare- Model are,

- a) 1.5DL
- b) 1.5DL+1.5LL
- c) 1.2DL+1.2LL+1.2EL
- d) 1.2DL+1.2LL -1.2EL
- e) 1.5DL+1.5EL
- f) 1.5DL-1.5EL
- g) 0.9DL+1.5EL
- h) 0.9DL-1.5EL

Slab Design Load Combinations for Flat Slab with Drop-Bare Model are,

- a) 1.5DL
- b) 1.5DL+1.5LL
- c) 1.5DL+1.5LL+EL
- d) 1.5DL+1.5LL -EL
- e) 1.2DL+1.2LL+1.2EL

- f) 1.2DL+1.2LL-1.2EL
- g) 1.5DL+1.5EL
- h) 1.5DL-1.5EL
- i) 0.9DL+1.5EL
- j) 0.9DL-1.5EL

### 3.2.5 Mass Source

Seismic weight is the total dead weight of the structure plus part of the imposed loads that may reasonably be expected to the structure at the time of earthquake shaking. Mass source is defined so that a program can calculate the mass of the structure. As per IS 1893 2016 up to and including 3 KN/m<sup>2</sup> imposed UDL, the percentage of Imposed load take is 25.

### 3.3 Model Lists and Nomenclature

The modeling is done in ETABS V.18.1.0 with concrete grade of M25 and rebar grade of Fe-500 for all the models. The four different types of steel braces in vertical arrangement are modelled. The braces are provided on different bays of the building. In the short form, all the models are nomenclature as provided in Table 3:1. The detail list of models are as follows:

Table 3: 1 Model Description and Nomenclature

S.N.	Description of Models	Nomenclature
1	Flat Slab with Drop- Bare	FSWD-B
2	Conventional Building- Bare	CB-B
3	Diagonal Bracings at Corner Bays	DG-CB
4	X Bracings at Corner Bays	X-CB
5	V Bracings at Corner Bays	V-CB
6	Chevron Bracings at Corner Bays	CH-CB
7	Diagonal Bracings at Middle Bays	DG-MB
8	X Bracings at Middle Bays	X-MB
9	V Bracings at Middle Bays	V-MB
10	Chevron Bracings at Middle Bays	CH-MB
11	Diagonal Bracings at Alternate Bays	DG-AB
12	X Bracings at Alternate Bays	X-AB
13	V Bracings at Alternate Bays	V-AB
14	Chevron Bracings at Alternate Bays	CH-AB
15	Diagonal Bracings at Peripheral Bays	DG-PB
16	X Bracings at Peripheral Bays	X-PB
17	V Bracings at Peripheral Bays	V-PB
18	Chevron Bracings at Peripheral Bays	CH-PB
19	Configuration 1A (X at Corners & V at Middle Bays)	C-1A
20	Configuration 1B (X at Corners & Chevron at Middle Bays)	C-1B
21	Configuration 1C (X at Corners & Diagonal at Middle Bays)	C-1C
22	Configuration 2A (V at Corners & X at Middle Bays)	C-2A
23	Configuration 2B (V at Corners & Chevron at Middle Bays)	C-2B
24	Configuration 2C (V at Corners & Diagonal at Middle Bays)	C-2C

25	Configuration 3A (Chevron at Corners & X at Middle Bays)	C-3A
26	Configuration 3B (Chevron at Corners & V at Middle Bays)	C-3B
27	Configuration 3C (Chevron at Corners & Diagonal at Middle Bays)	C-3C
28	Configuration 4A (Diagonal at Corners & X at Middle Bays)	C-4A
29	Configuration 4B (Diagonal at Corners & V at Middle Bays)	C-4B
30	Configuration 4C (Diagonal at Corners & Chevron at Middle Bays)	C-4C

All total 90 models of flat slab building having steel braces together with three conventional bare models are modelled and analysis were performed. Comparative study of different bracings is made and results are prepared in graphical representation. Conventional building's results are also plotted together with braced and unbraced flat slab models.

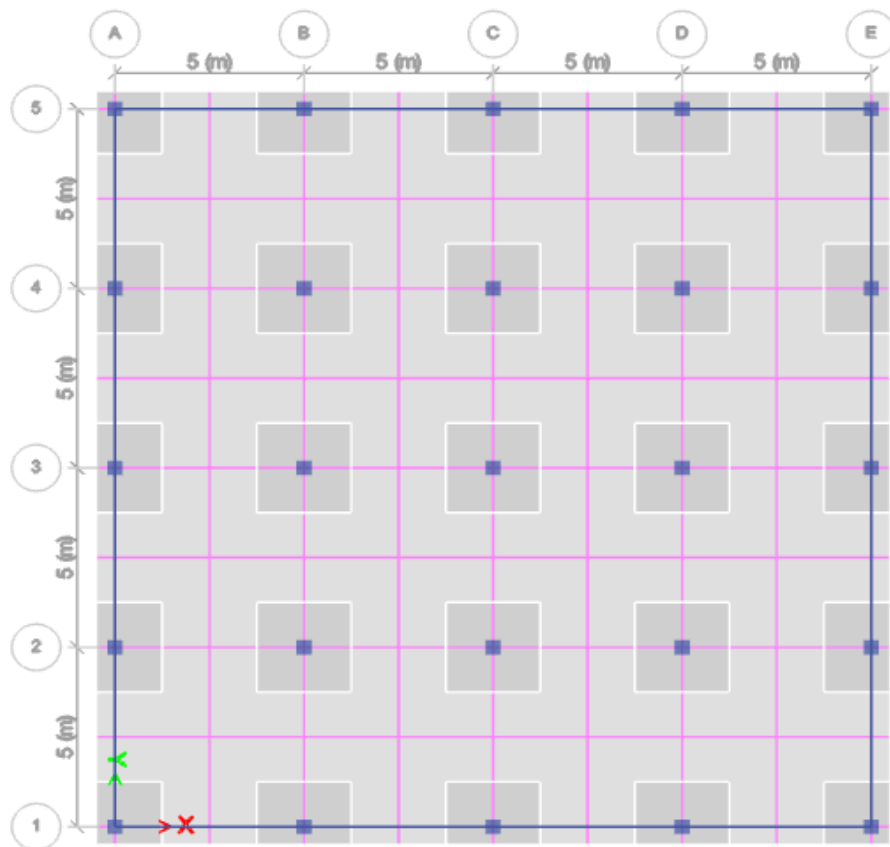


Figure 3: 1 Geometric Plan of Flat Slab building with Concealed Beam and Drop Panels

The schematic pattern of application of steel braces on different bays are shown in figures below.

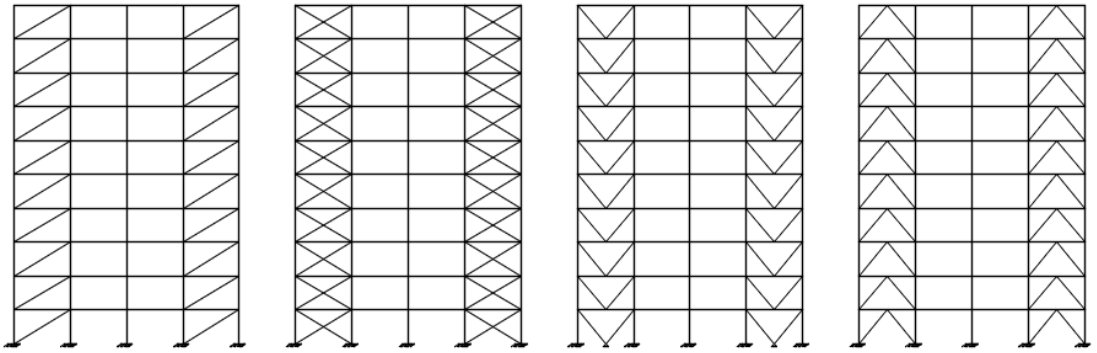


Figure 3: 2 Diagonal, X, V & Chevron Type Bracings at Corner Bays Respectively

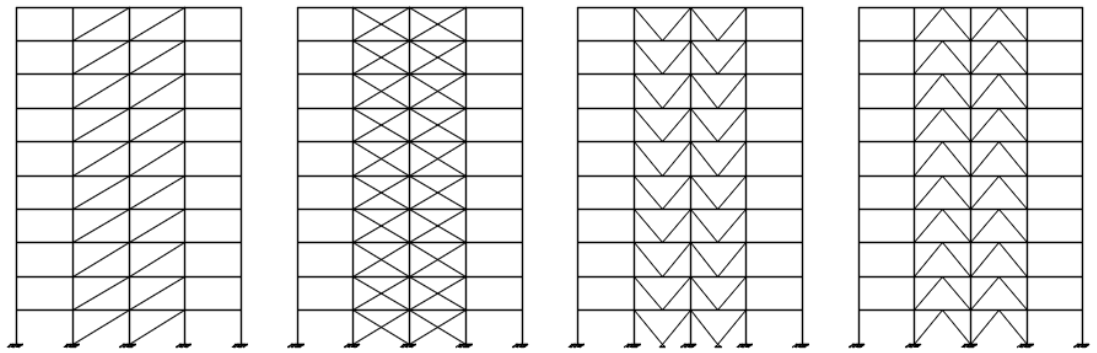


Figure 3: 3 Diagonal, X, V & Chevron Type Bracings at Middle Bays Respectively.

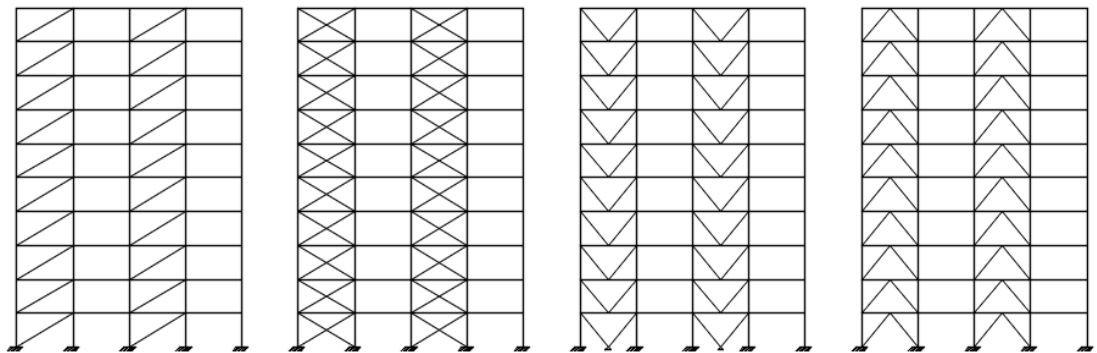


Figure 3: 4 Diagonal, X, V & Chevron Type Bracings at Alternate Bays Respectively

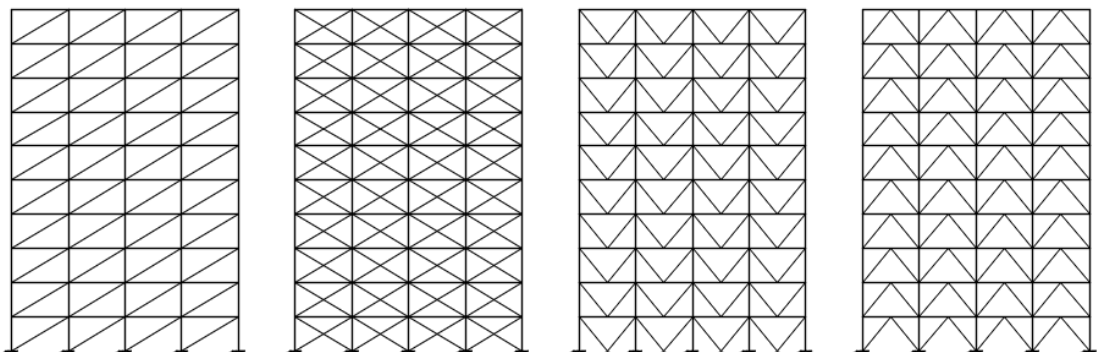


Figure 3: 5 Diagonal, X, V & Chevron Type Bracings at Peripheral Bays Respectively.

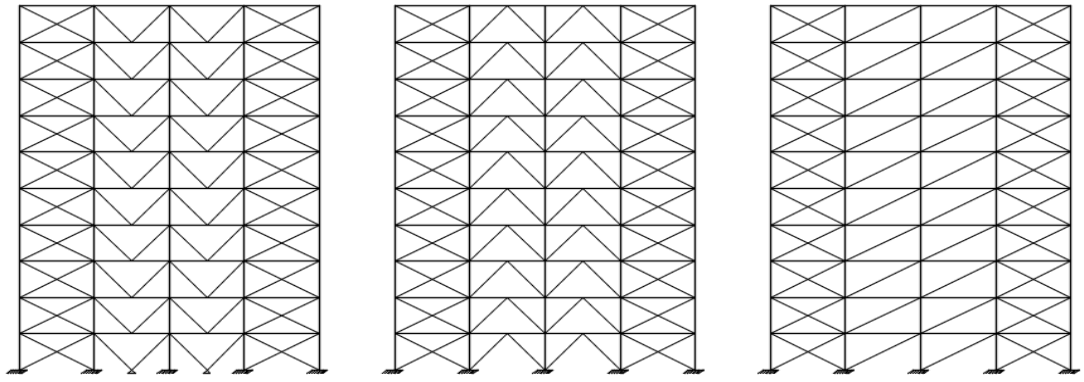


Figure 3: 6 Configurations 1A,1B and 1C respectively

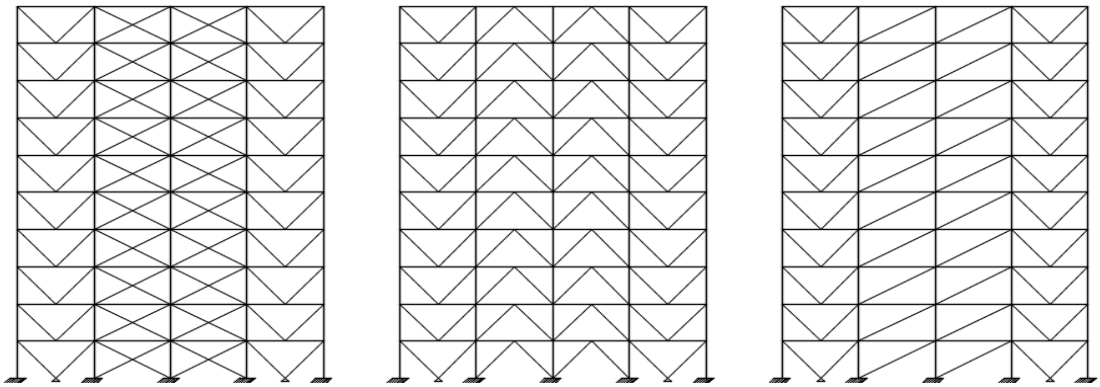


Figure 3: 7 Configurations 2A,2B and 2C respectively

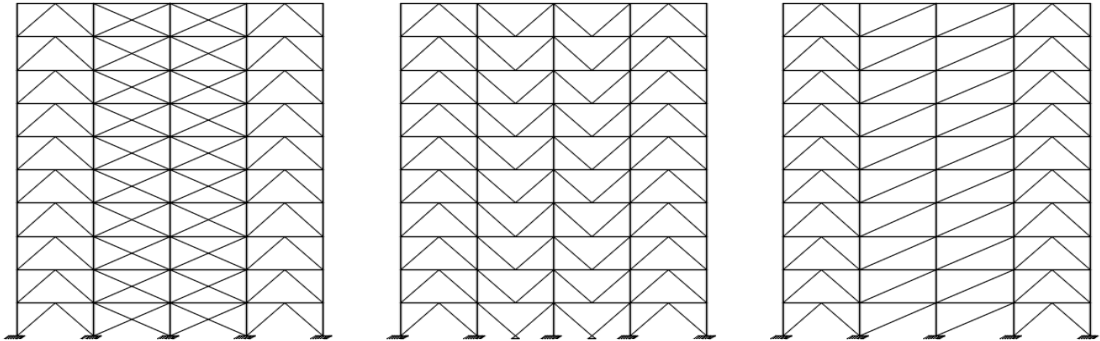


Figure 3: 8 Configurations 3A, 3B and 3C respectively

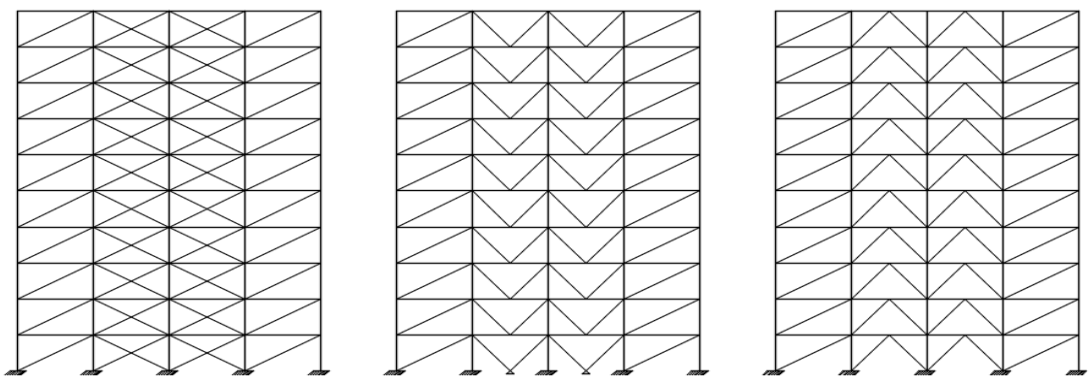


Figure 3: 9 Configurations 4A, 4B and 4C respectively

Some of the images of building models after completion of modelling steps on ETABS are presented as,

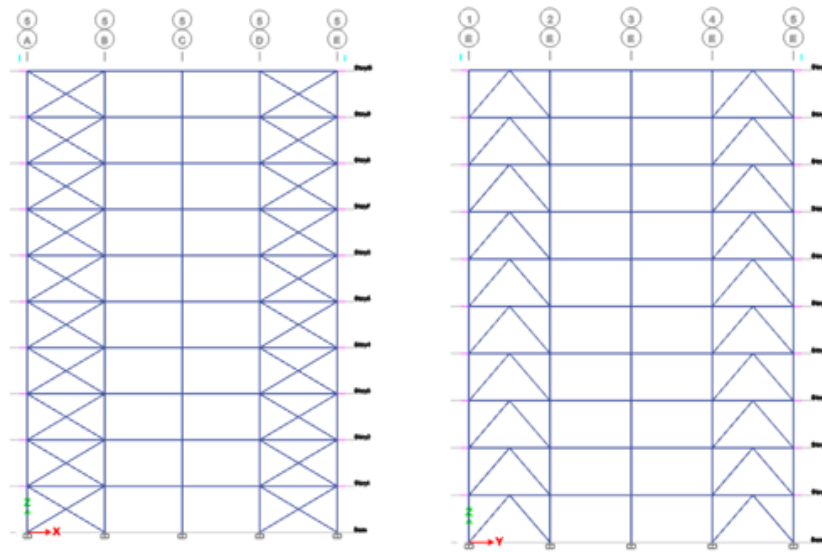


Figure 3: 10 X and Chevron Brace at Corner Bays after modelling on ETABS

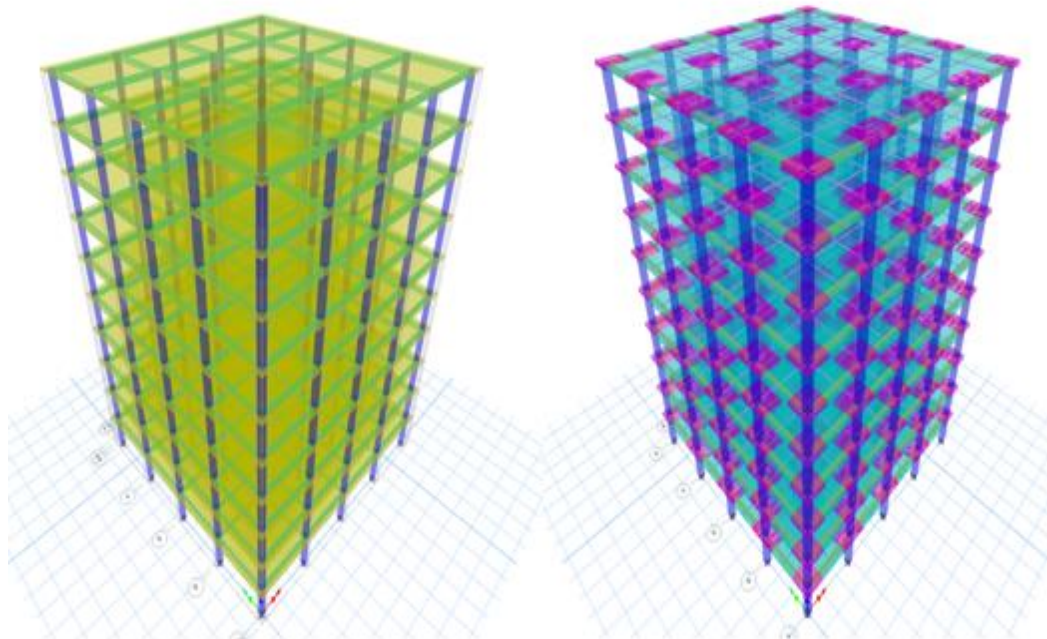


Figure 3: 11 Conventional and Flat Slab Building Model (3D), G+9 Storey

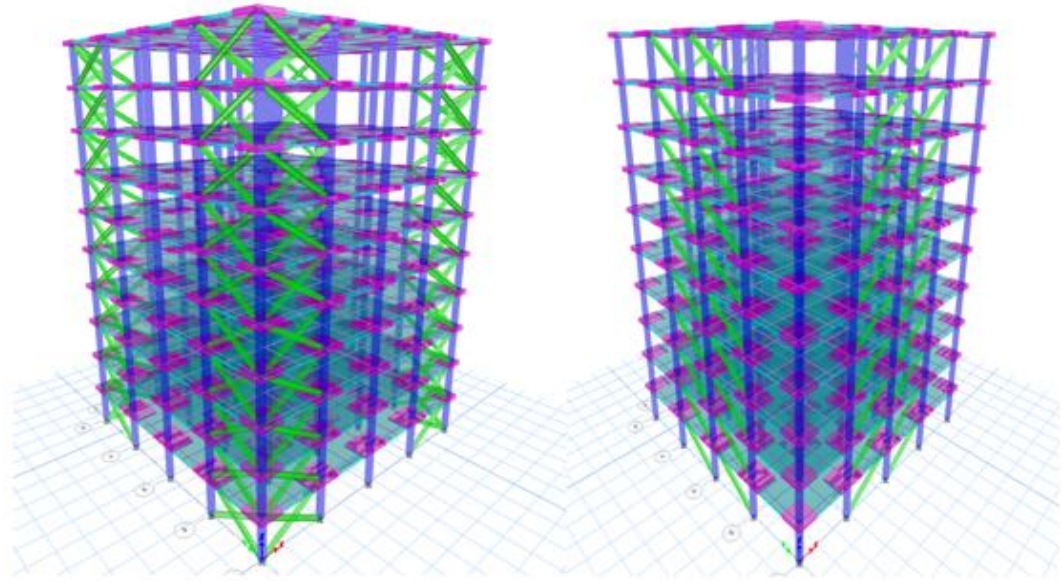


Figure 3: 12 X at Corner Bays and Diagonal at middle bays braced model (3D), G+9 Storey

Figure 3:10 show the two dimensional image of application of X and chevron braces on the corner bays of flat slab building. Figure 3:11 is the three dimensional modeled image of conventional building and flat slab building model having drop panel as well as concealed beam on peripheral bays. Figure 3:12 show the three dimensional image of building in which X and Diagonal braces are applied on corner and middle bays respectively. In the same way, by following the schematic pattern of braces shown on Figure 3.2 to Figure 3.9 the remaining models are prepared and the seismic analysis was carried out.

## CHAPTER 4: SEISMIC ANALYSIS

### 4.1 Equivalent Static Analysis

This method is also known as Seismic Coefficient Method. The equivalent static lateral force method is a simplified technique to substitute the effect of dynamic loading of an expected earthquake by a static force distributed laterally on a structure for design purposes. This force is called as the Seismic Design Base Shear  $V_B$  and remains the primary quantity involved in force-based earthquake-resistant design of buildings.

As per the Indian Seismic Code IS:1893 2016, first the design base shear  $V_B$  shall be computed for the building as a whole. Then, this shall be distributed to the various floor levels at corresponding center of mass. And, finally this design seismic force at each floor level shall be distributed to individual lateral load resisting elements through structural analysis considering the floor diaphragm action.

Design Base Shear  $V_B$  is given by:

$$V_B = A_h W = \frac{ZI}{2R} \left(\frac{S_a}{g}\right) W \quad (4.1)$$

Where,

$W$  is the seismic weight of the building.

$A_h$  = design horizontal acceleration coefficient using approximate fundamental natural period  $T_a$  along the considered direction of shaking.

$Z$  = seismic zone factor

$I$  = importance factor given in IS 1893 (Parts 1 to 5) for the corresponding structures; when not specified, the minimum values of  $I$  shall be

- a) 1.5 for critical and lifeline structures;
- b) 1.2 for business continuity structures; and
- c) 1.0 for the rest.

$R$  = response reduction factor

$\frac{S_a}{g}$  = design acceleration coefficient for different soil types, normalized with peak ground acceleration.

## **4.2 Response Spectrum Analysis**

Response spectrum analysis is a method to estimate the structural response to short, nondeterministic, transient dynamic events. Examples of such events are specially earthquakes and shocks. Since the exact time history of the load is not known, it is difficult to perform a time-dependent analysis. Due to the short length of the event, it cannot be considered as an ergodic ("stationary") process, so a random response approach is not applicable either. The response spectrum method is based on a special type of mode superposition. The idea is to provide an input that gives a limit to how much an Eigen mode having a certain natural frequency and damping can be excited by an event of this type. Linear dynamic analysis shall be performed to obtain the design lateral force (design seismic base shear, and its distribution to different levels along the height of the building, and to various lateral load resisting elements) for all buildings, where equivalent static analysis can't be performed.

A response spectrum is a function of frequency or period, showing the peak response of a simple harmonic oscillator that is subjected to a transient event. The response spectrum is a function of the natural frequency of the oscillator and of its damping. It is not a direct representation of the frequency content of the excitation (as in a Fourier transform), but rather of the effect that the signal has on a postulated system with a single degree of freedom (SDOF).

The response spectrum of a single time signal is seldom of interest for an analysis, since it would be better to perform a direct time domain analysis of the structure with the original signal as input. In order to be able to use a response spectrum for analysis of an event that has not yet happened, a design response spectrum is created. The design response spectrum can be seen as an envelope over all known and anticipated earthquakes in a certain geographical region. Design response spectra are often provided in terms of the period, rather than the frequency. Since one is the inverse of the other, the two graphs are just mirrored when plotting on a logarithmic scale.

### **4.2.1 Number of Modes**

The number of modes  $N_m$  to be used in the analysis for earthquake shaking along a considered direction should be such that the sum total of modal masses of these modes considered is at least 90% of total seismic mass.

### 4.2.2 Combination of Modes

In practice, several modes will have natural frequencies in the frequency range covered by the design response spectrum. This means that some combination of their responses is needed. There are several rules for how this combination can be arranged. These summation rules are nonlinear. For all combination types, all result quantities are strictly positive. The responses of different modes considered shall be combined by one of the two methods given below:

a) The most popular method for superposition of the periodic modes is the complete quadratic combination (CQC) method.

$$\lambda = \sqrt{\sum_{i=1}^{N_m} \sum_{j=1}^{N_m} \lambda_i \rho_{ij} \lambda_j} \quad (4.2)$$

Where,

$\lambda$  = estimate of peak response quantity

$\lambda_i$  = response quantity in mode i

$\lambda_j$  = response quantity in mode j

$\rho_{ij}$  = cross – modal correlation co-efficient

$$= \frac{8 \xi^2 (1 + \beta) \beta^{1.5}}{(1 - \beta^2)^2 + 4 \xi^2 \beta (1 + \beta)^2} \quad (4.3)$$

$N_m$  = number of modes considered

$\xi$  = modal damping coefficient ratio = 0.05

$\beta$  = natural frequency ratio =  $\omega_j / \omega_i$

$\omega_j$  = circular natural frequency in mode j

$\omega_i$  = circular natural frequency in mode i

b) Alternatively, the peak response quantities may be combined as follows:

i) If building does not have closely – spaced modes, then net peak response quantity  $\lambda$  due to all modes considered shall be estimated as:

$$\lambda = \sqrt{\sum_{i=1}^{N_m} \sum_{i=1}^{N_m} (\lambda_k)^2} \quad (4.4)$$

Where,

$\lambda_k$  = peak response quantity in mode k, and

$N_m$  = number of modes considered.

ii) If building has a few closely – spaced modes, then net peak response quantity  $\lambda^*$  due to these closely space modes alone shall be obtained as:

$$\lambda^* = \sum[\lambda_c] \quad (4.5)$$

Where,

$\lambda_c$  = peak response quantity in closely spaced mode c. The summation is for closely spaced modes only. Then, this peak response quantity  $\lambda^*$  due to closely spaced modes is combined with those of remaining well-separated modes by method described above.

### 4.2.3 Simplified Method of Dynamic Analysis of Buildings

Regular buildings may be analyzed as a system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. In such case, the following expressions shall hold in the computation of the various quantities:

1. Modal mass – Modal mass  $M_k$  of mode k is given by:

$$M_k = \frac{[\sum_{i=1}^n W_i \phi_{ik}]^2}{g \sum_{i=1}^n W_i (\phi_{ik})^2} \quad (4.6)$$

Where,

$g$  = acceleration due to gravity

$\phi_{ik}$  = mode shape coefficient at floor i on mode k

$W_i$  = seismic weight of floor i of the structure

$n$  = number of floors of the structure

2. Mode Participation Factor ( $P_k$ ):

$$P_k = \frac{\sum_{i=1}^n W_i \phi_{ik}}{\sum_{i=1}^n W_i (\phi_{ik})^2} \quad (4.7)$$

3. Design lateral force at each floor in each mode – Peak lateral force  $Q_{ik}$  at floor i in mode k is given by:

$$Q_{ik} = A_k \phi_{ik} P_k W_i \quad (4.8)$$

Where,

$A_k$  = design horizontal acceleration spectrum using natural period of oscillation  $T_k$  of mode k obtained from dynamic analysis.

4. Storey shear forces in each mode - Peak shear force  $V_{ik}$  acting in storey  $i$  in mode  $k$  is given by:

$$V_{ik} = \sum_{j=j+1}^n Q_{ik} \quad (4.9)$$

5. Storey shear force due to all modes considered – Peak storey shear force  $V_i$  in storey  $i$  due to all modes considered, shall be obtained by combining those due to each mode

6. Lateral forces at each storey due to all modes considered – Design lateral forces  $F_{roof}$  level and  $F_i$  at level of floor  $i$  shall be obtained as:

$$F_{roof} = V_{roof} \quad (4.10)$$

$$F_i = V_i - V_{i+1} \quad (4.11)$$

#### 4.2.4 Scale Factor

The design base shear  $V_B$  estimated shall not be less than the design base shear  $\bar{V}_B$  calculated using a fundamental period  $T_a$ .

When  $V_B$  is less than  $\bar{V}_B$ , the force response quantities ( for example member stress resultants, storey shear forces, and base reactions) shall be multiplied by  $\bar{V}_B / V_B$ . For earthquake shaking considered along,

7. The two mutually perpendicular plan directions X and Y, separate multiplying factors shall be calculated, namely  $\bar{V}_{BX} / V_{BX}$  and  $\bar{V}_{BY} / V_{BY}$ , respectively.

8. The vertical Z direction, the multiplying factor shall be taken as

$$\text{Max} [ \bar{V}_{BX} / V_{BX} ; \bar{V}_{BY} / V_{BY} ]$$

#### 4.2.5 According to CSI Literature

The spectrum ordinates defined within various code options, including IS:1893, are normalized values in which spectral accelerations are divided by gravity acceleration. The spectrum must be converted to the specific set of units used throughout the model by applying a scale factor given as the value of gravity acceleration in the current units of your model.

Note that the design spectrum of IS:1893 is actually the MCE-level spectrum which must be reduced by dividing this value by a factor of  $2R$ , in which  $R$  is the response reduction factor. In the first run, the value of the scale factor should be  $SF = I^*g / (2R)$ ,

in which  $I$  is the importance factor. After the first run, check the base shear which develops in the model, and if this value is less than the code-prescribed minimum, then increase the scale factor of the first run such that the resultant base shear matches the code specification.

## CHAPTER 5: RESULT AND DISCUSSION

The comparative study of different seismic parameters of various models were done. As the models are taken as perfectly symmetric, the seismic parameters are same for both axes.

### 5.1 Comparative Study of Bare Models and Braced Models

#### 5.1.1 Maximum Storey displacement

##### 5.1.1.1 Bare vs Corner Bays Braced models

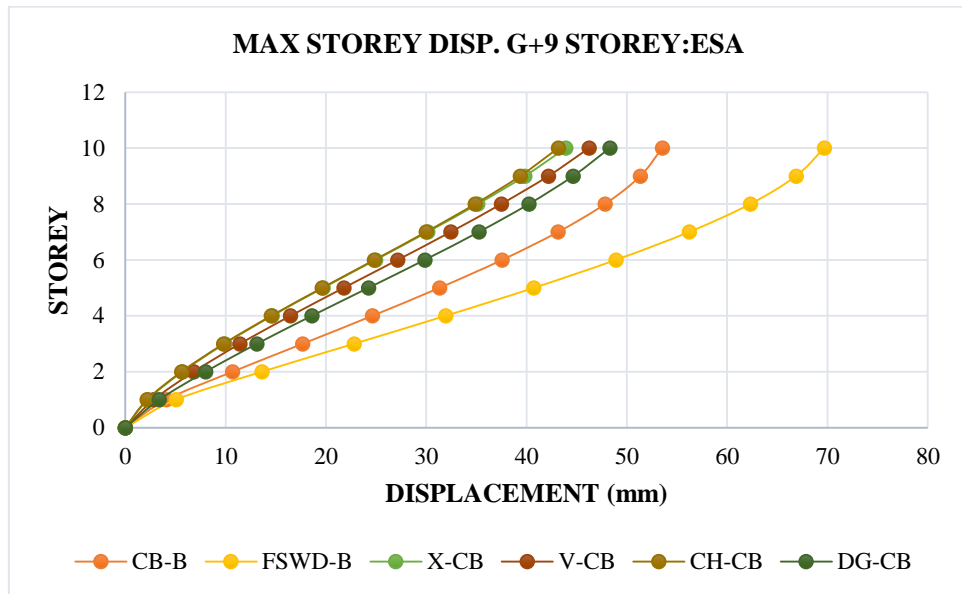


Figure 5: 1 Max. Storey Displacement, Corner Bays Bracings, G+9 Storey due to ESA

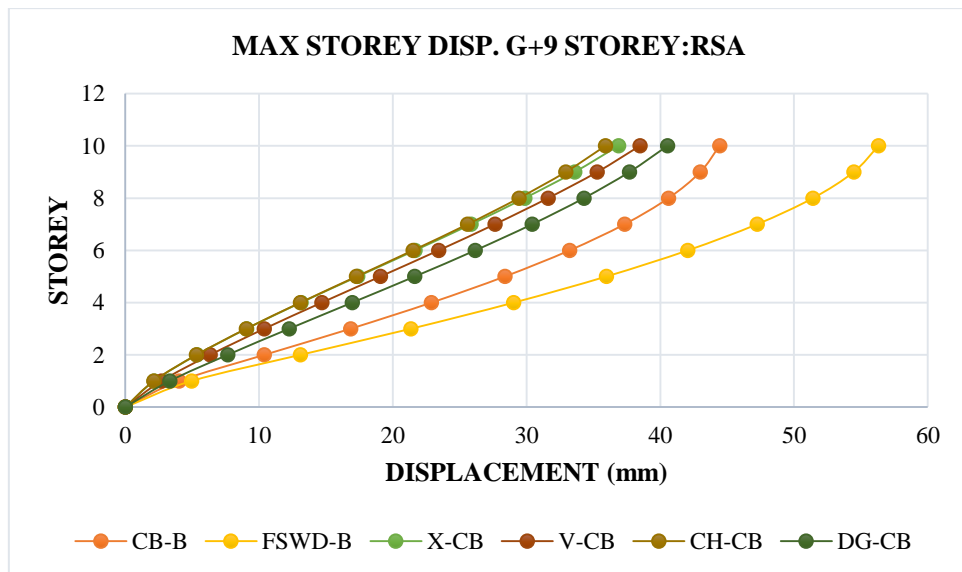


Figure 5: 2 Max. Storey Displacement, Corner Bays Bracings, G+9 Storey due to RSA

The Figures 5:1 and 5:2 are the plot of maximum storey displacement of G+9 stories building for equivalent static analysis and response spectrum analysis together with bare and corner bays braced models. The plot shows that, the flat slab building bare model has higher values of storey displacement than on conventional type building. The storey displacement values are more in Equivalent Static Analysis than Response Spectrum Analysis. After installation of steel braces on corner bays of flat slab building, the lateral displacement values of each storey were reduced correspondingly. For G+9 stories building, Diagonal, X, V and Chevron type braces reduces the storey displacement in the range of 30% to 43%, 37% to 59%, 33% to 50% and 38% to 59% respectively in equivalent static analysis. Likewise, in response spectrum analysis, the corresponding reduction is in the range of 28% to 43%, 35% to 60%, 31% to 52% and 36% to 60%. At corner location, X and Chevron type bracings shows most effective result than V and Diagonal type braces. Similar graphical results for G+5 and G+7 stories building were shown on APPENDIX A. The corresponding displacement values are provided in tabular form on APPENDIX E.

### 5.1.1.2 Bare vs Middle Bays Braced models

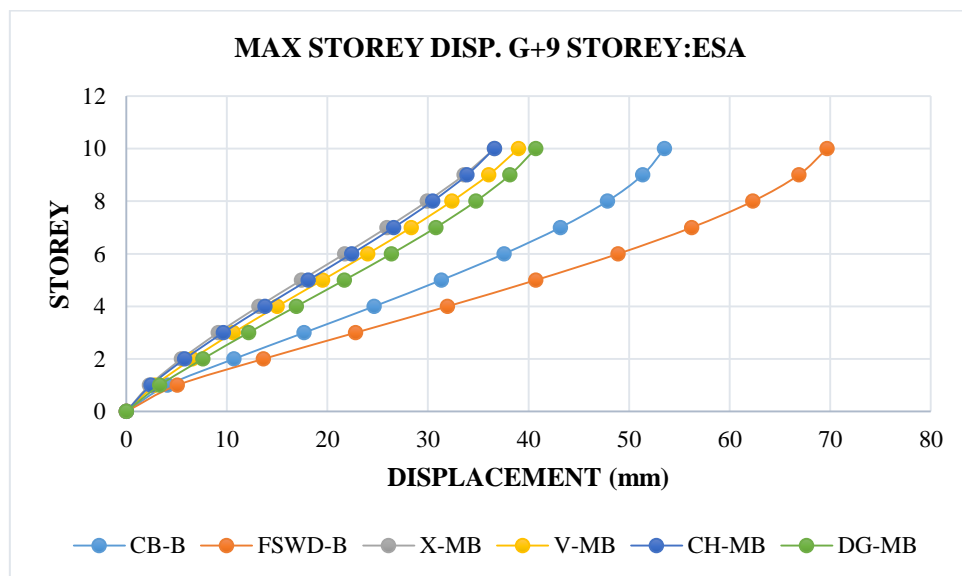


Figure 5: 3 Max. Storey Displacement, Middle Bays Bracings, G+9 Storey due to ESA

The Figure 5:3 and 5:4 are the plot of maximum storey displacement values for G+9 stories building due to Equivalent static analysis and response spectrum analysis for unbraced as well as middle bays braced models. Providing the steel braces on middle bays contributes higher reduction in storey displacements than the corner bays bracings. For G+9 stories building, Diagonal, X, V and Chevron type braces reduces the

displacement values in the range of 41% to 48%, 47% to 60%, 44% to 54% and 47% to 58% respectively for ESA. Similarly, the corresponding maximum reduction values for RSA are about 47%, 60%, 54% and 58% respectively. In middle bays bracings, X and Chevron type brace shows effective reduction than diagonal and V type steel brace. Keeping the number of bays braced are same, the results are more significant on middle bays bracing location. Similarly, graphical results of G+5 and G+7 stories are presented on APPENDIX A. The corresponding displacement values are provided in tabular form on APPENDIX E.

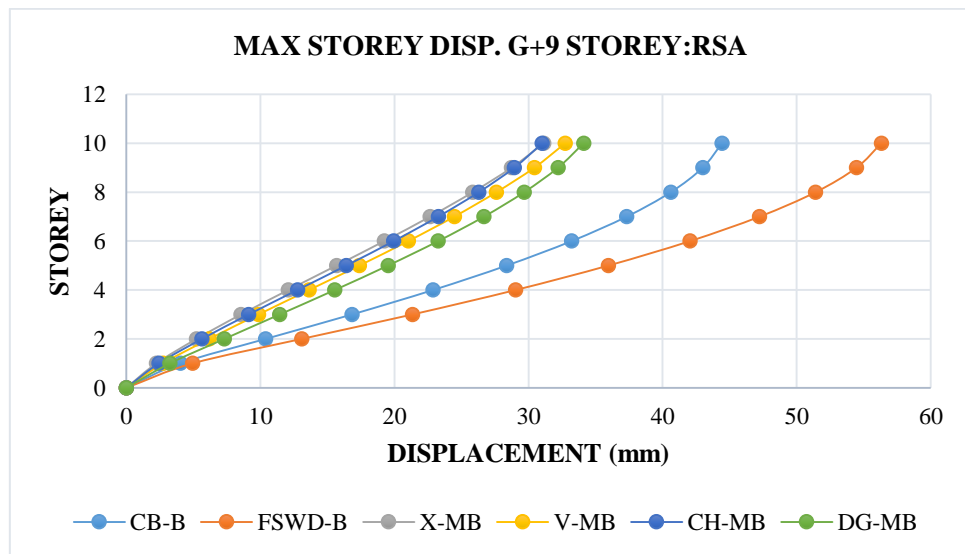


Figure 5: 4 Max. Storey Displacement, Middle Bays Bracings, G+9 Storey due to RSA

### 5.1.1.3 Bare vs Alternate Bays Braced models

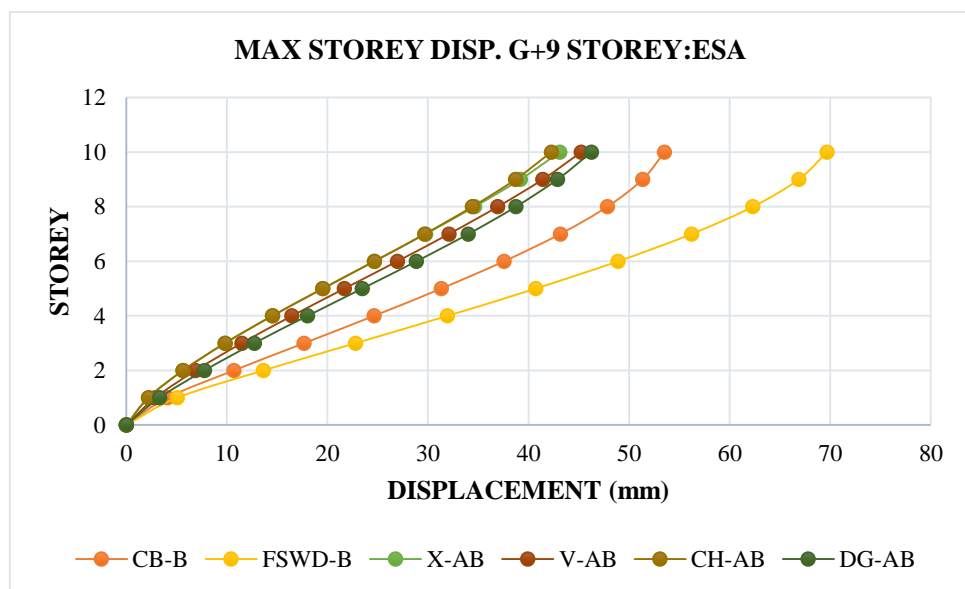


Figure 5: 5 Max. Storey Displacement, Alternate Bays Bracings, G+9 Storey due to ESA

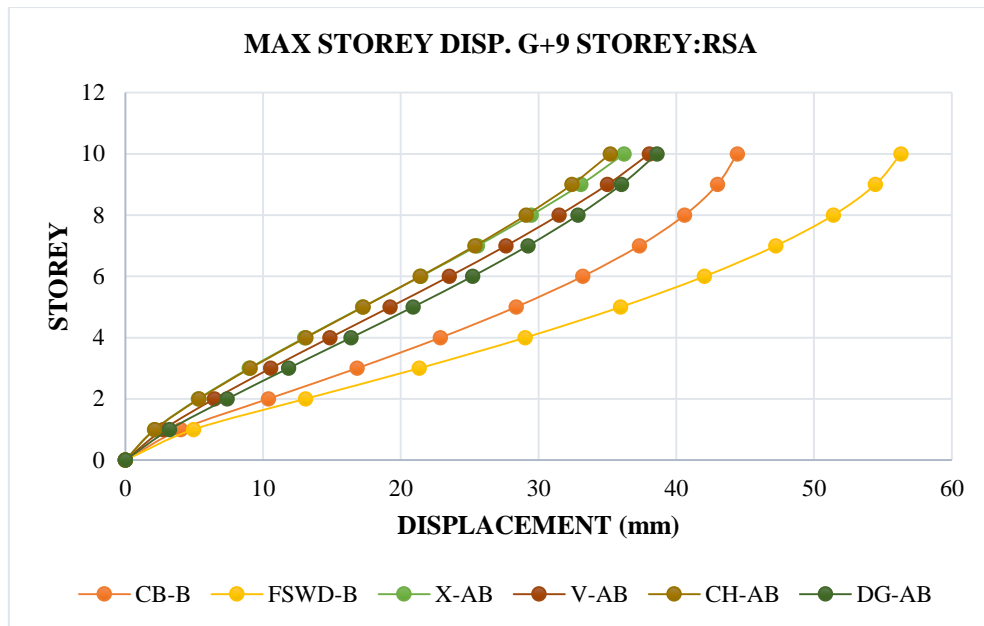


Figure 5: 6 Max. Storey Displacement, Alternate Bays Bracings, G+9 Storey due to RSA  
 Figures 5:5 and 5:6 are the plots of storey displacement for alternate bays braced and unbraced models of G+9 stories building due to ESA and RSA. Alternate bays bracings also reduces the storey displacements and structure becomes stiffer than bare models. Keeping the number of braced bays same the best location among corner, middle and alternate bays is middle bays bracings. For G+9 stories building, alternate bays braces reduce the displacement in the range of 33% to 44%, 38% to 59%, 35% to 50%, 39% to 59% by diagonal, X, V and Chevron types bracings respectively. The results are somehow closer to corner bays bracings. In this case also X and Chevron type bracings shows significant result than other bracings. For G+5 and G+7 stories buildings, the alternate bays bracings, the graphical results are presented in APPENDIX A. The corresponding displacement values are provided in tabular form on APPENDIX E.

#### 5.1.1.4 Bare vs Peripheral Bays Braced models

After the application of different types of steel braces peripherally on a building, the structure becomes highly stiff and the displacement values of each stories reduces significantly. Clearly from graphical representation, it is found that X type bracings shows minimum value of storey displacement among other types. Then after Chevron, V and Diagonal type braces comes order wise. Similarly, significant reduction on the displacement values was obtained for G+5 and G+7 stories building. Figures 5:7 and 5:8 are the plot of storey displacement for G+9 stories building due to ESA and RSA with peripheral bays bracings.

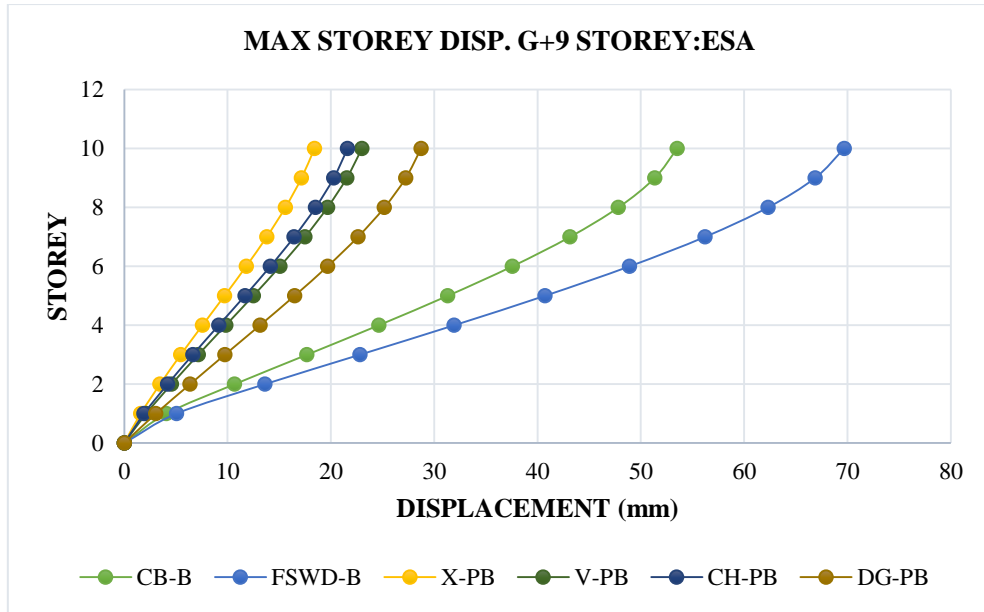


Figure 5: 7 Max. Storey Displacement, Peripheral Bays Bracings, G+9 Storey due to ESA

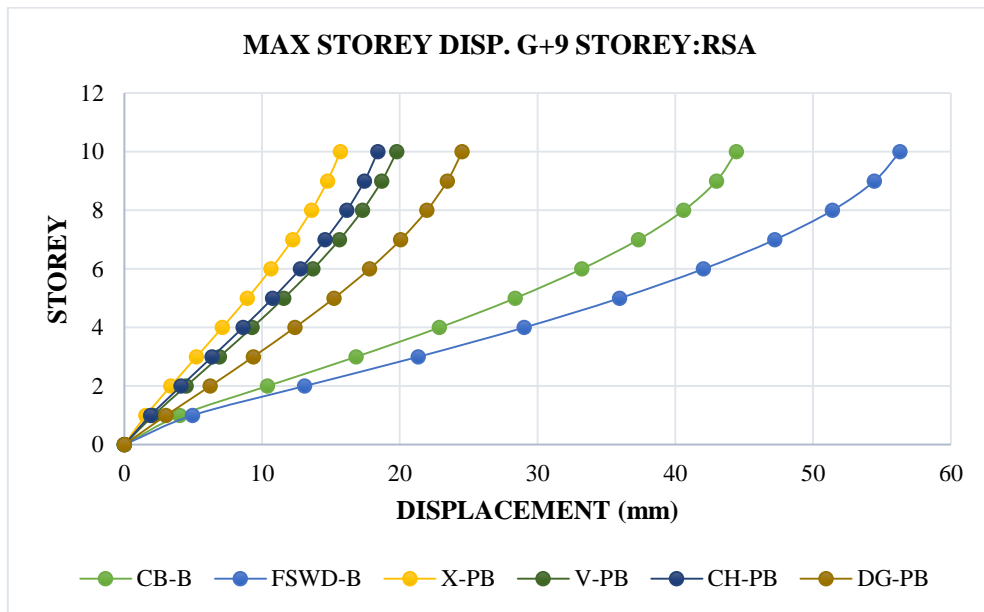


Figure 5: 8 Max. Storey Displacement, Peripheral Bays Bracings, G+9 Storey due to RSA

In case of Peripheral bays bracings, due to ESA, the diagonal, X, V and Chevron type braces reduces the displacement in the range of 58% to 60%, 68% to 77%, 58% to 70% and 62% to 72% respectively. For G+5 and G+7 stories building, the corresponding plot was shown on APPENDIX A.

## 5.1.2 Maximum Storey Drifts

### 5.1.2.1 Bare vs Corner Bays Braced models

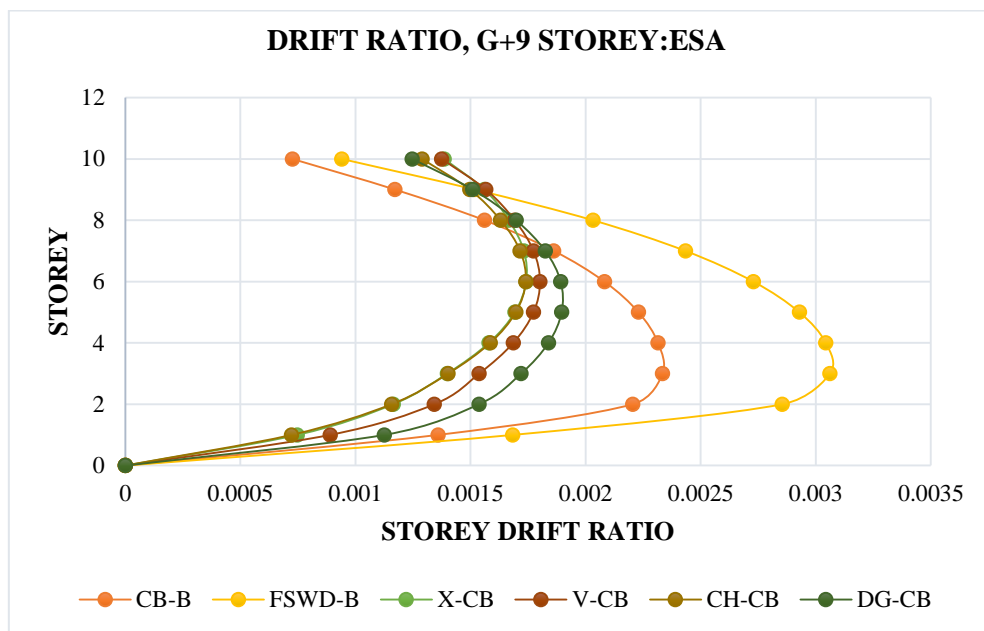


Figure 5: 9 Drift Ratio, Corner Bays Bracings, G+9 Storey due to ESA

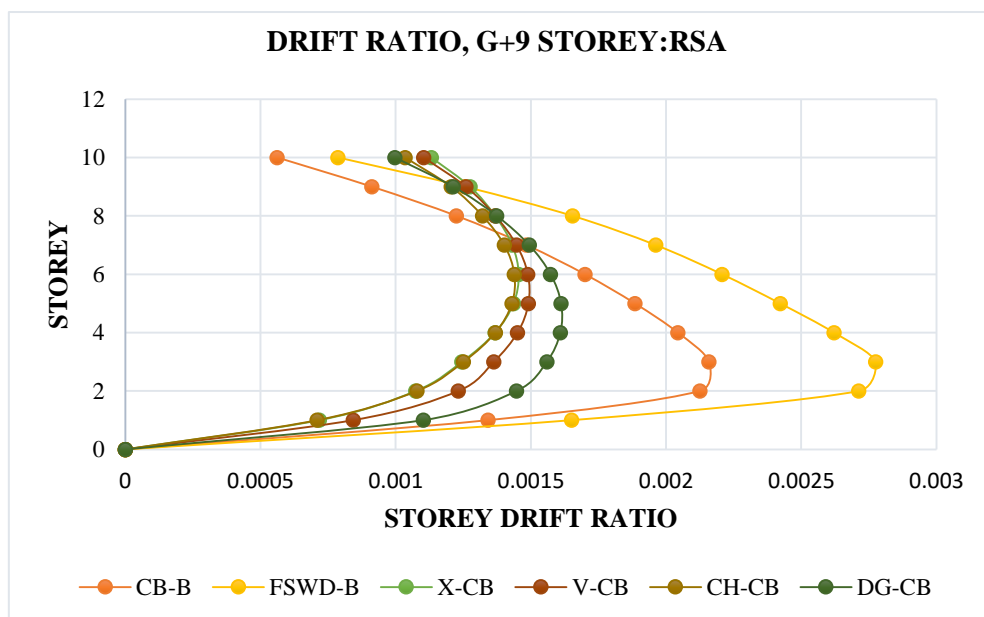


Figure 5: 10 Drift Ratio, Corner Bays Bracings, G+9 Storey due to RSA

Figure 5:9 and Figure 5:10 are the plot of inter storey drift ratio of G+9 stories building after placing the braces on corner bays due to ESA and RSA respectively. On comparison with conventional building, the flat slab buildings have higher values of

inter storey drift ratios. The storey drift values are more in Equivalent Static Analysis than Response Spectrum Analysis. The inter storey drift value for bare models is more than for braced models. In case of corner bays bracings, the X-bracings and Chevron bracings significantly reduce the inter storey drift ratios than the other types of bracings. For G+5 and G+7 stories building, the results are presented in APPENDIX B.

### 5.1.2.2 Bare vs Middle Bays Braced models

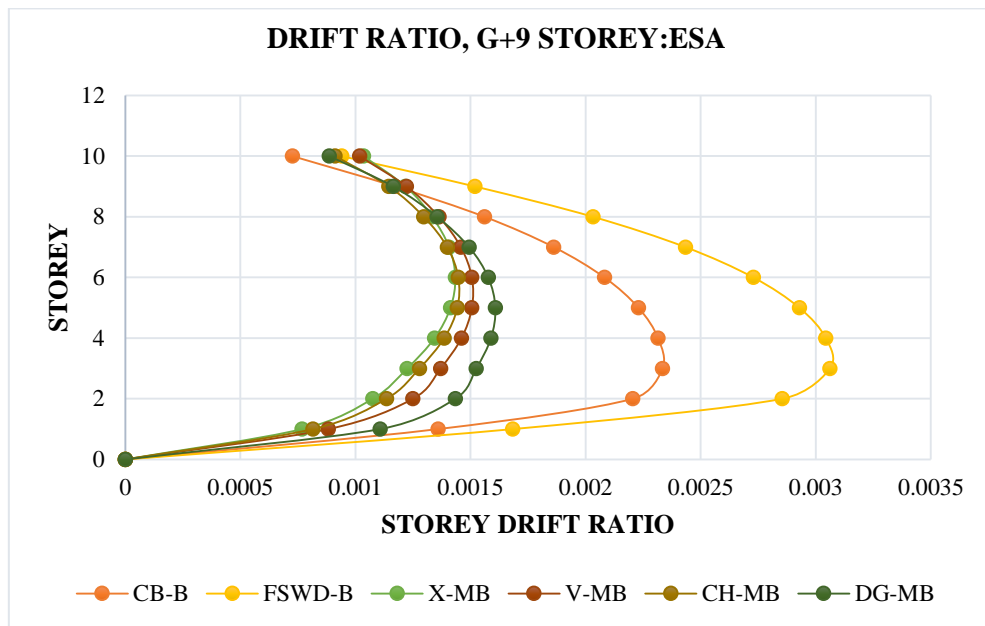


Figure 5: 11 Drift Ratio, Middle Bays Bracings, G+9 Storey due to ESA

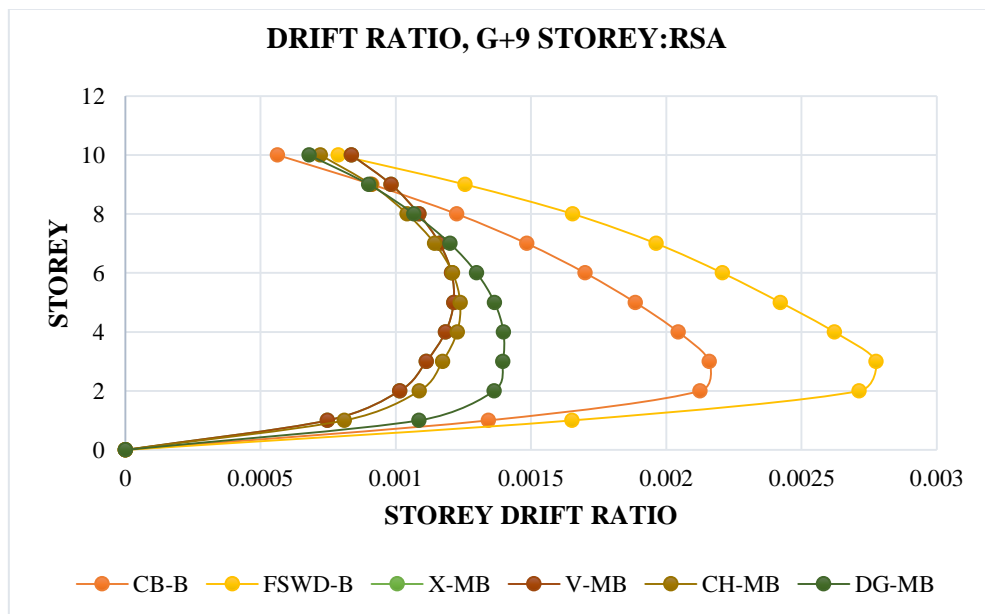


Figure 5: 12 Drift Ratio, Middle Bays Bracings, G+9 Storey due to RSA

Figures 5:11 and 5:12 are the plot of drift ratio of G+9 storied building having four different braces at middle bays due to ESA and RSA respectively. As in corner bays bracings, there is significant reduction in inter storey drift ratio values for the models having braces on middle bays. Among these two, the maximum reduction is for middle bays than corner bays. Figure 5:11 shows that, maximum drift ratio above 0.003 for storey 2,3 and 4 but after providing braces on middle bays, the corresponding value reduces and get nearly about 0.0015. X and chevron type brace reduces high values of drift ratio than diagonal and V types. For G+5 and G+7 stories building, the graphical results are presented in APPENDIX B and tabular results on APPENDIX F.

### 5.1.2.3 Bare vs Alternate Bays Braced models

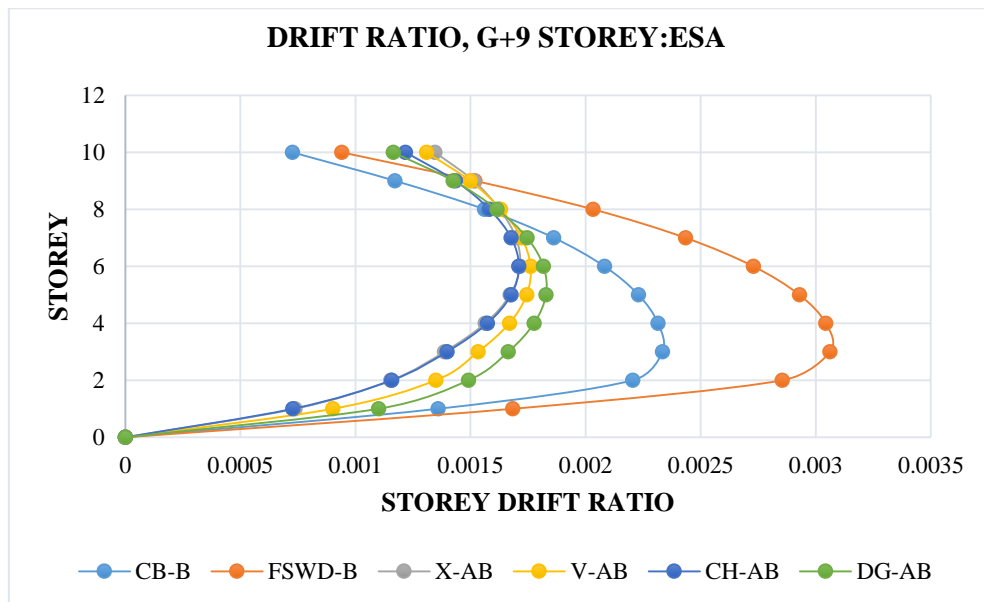


Figure 5: 13 Drift Ratio, Alternate Bays Bracings, G+9 Storey due to ESA

Figure 5:13 and Figure 5:14 are the plot of storey drift ratio of G+9 stories building after the application of steel braces on alternate bays due to ESA and RSA respectively. In this case comparison was made between unbraced models and alternate bays braced models. X type and Chevron type steel braces shows significant reduction in inter storey drift ratio than other braces while placing them in alternate bays. The drift ratios for corner bays bracings and alternate bays bracings are somehow closer. For G+5 and G+7 stories building, the plots are presented on APPENDIX B. Likewise tabular data are presented on APPENDIX F.

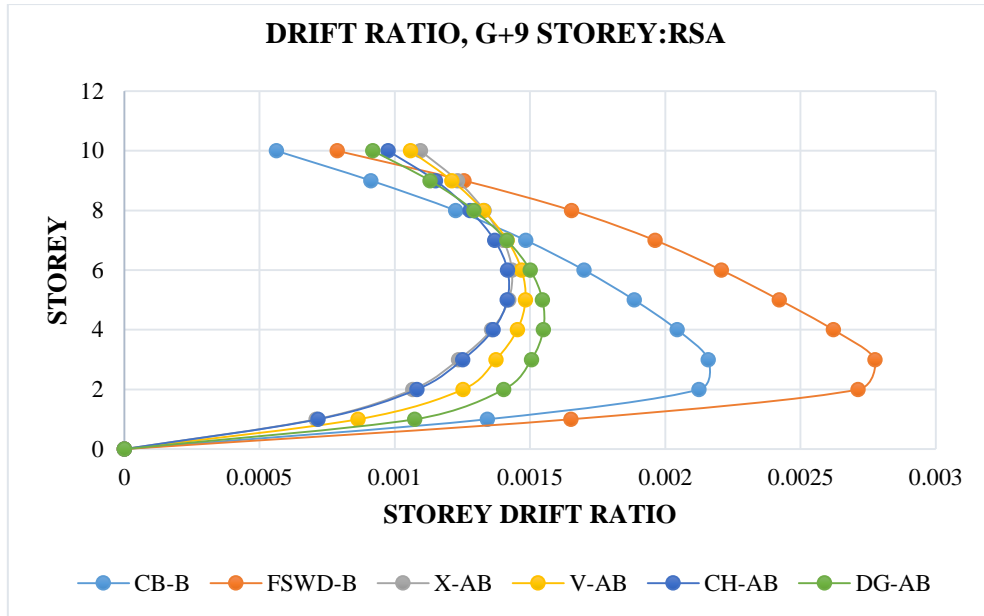


Figure 5: 14 Drift Ratio, Alternate Bays Bracings, G+9 Storey due to RSA

#### 5.1.2.4 Bare vs Peripheral Bays Braced models

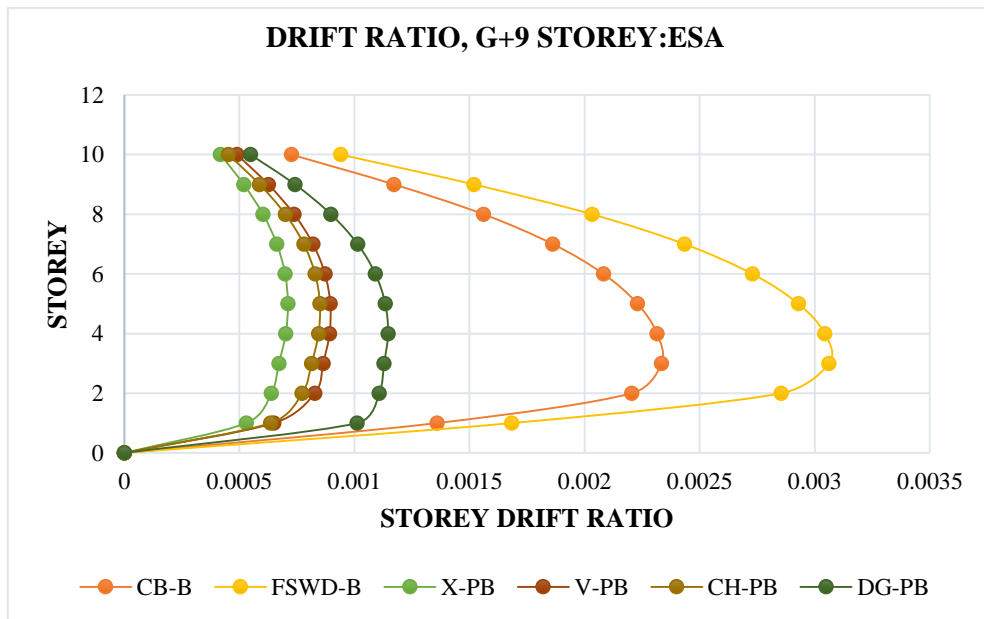


Figure 5: 15 Drift Ratio, Peripheral Bays Bracings, G+9 Storey due to ESA

Figure 5:15 and Figure 5:16 are the plot of storey drift ratio of G+9 storey building after application of steel braces on peripheral bays. In this case various types of steel braces are provided peripherally to study the behaviour of structure. The structure becomes more stiff towards lateral displacement so that its inter storey drift ratios decreases

highly as shown in graph. Clearly graph shows that, X type braces is highly effective in this case then after Chevron, V and Diagonal correspondingly.

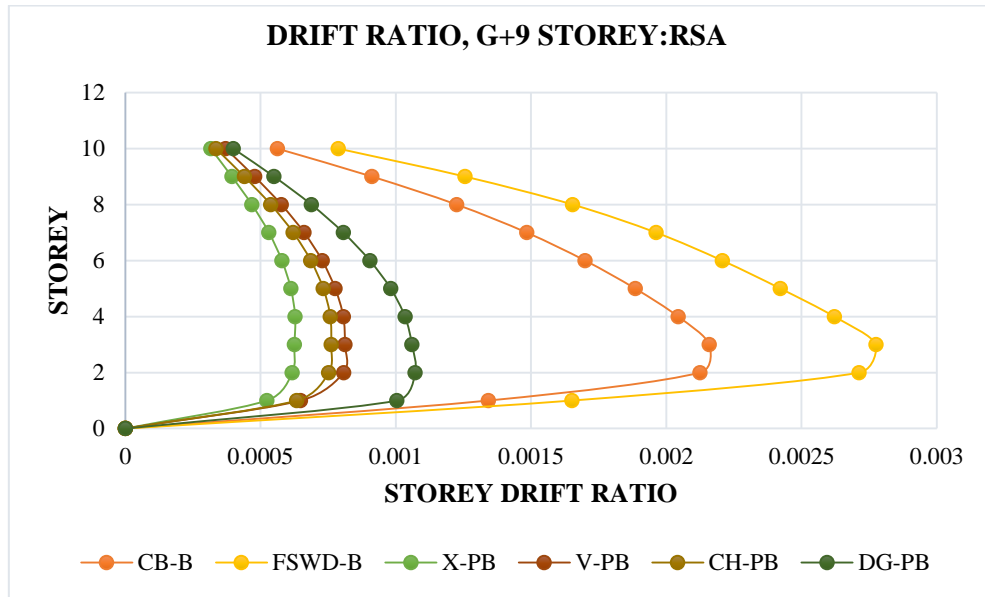


Figure 5: 16 Drift Ratio, Peripheral Bays Bracings, G+9 Storey due to RSA

After providing bracings peripherally, the inter storey drift ratio values goes below 0.001 for X, V and chevron type bracings. The cooresponding plots for G+5 and G+7 stories building are presented on APPENDIX B and F.

### 5.1.3 Top Storey Displacement Reduction

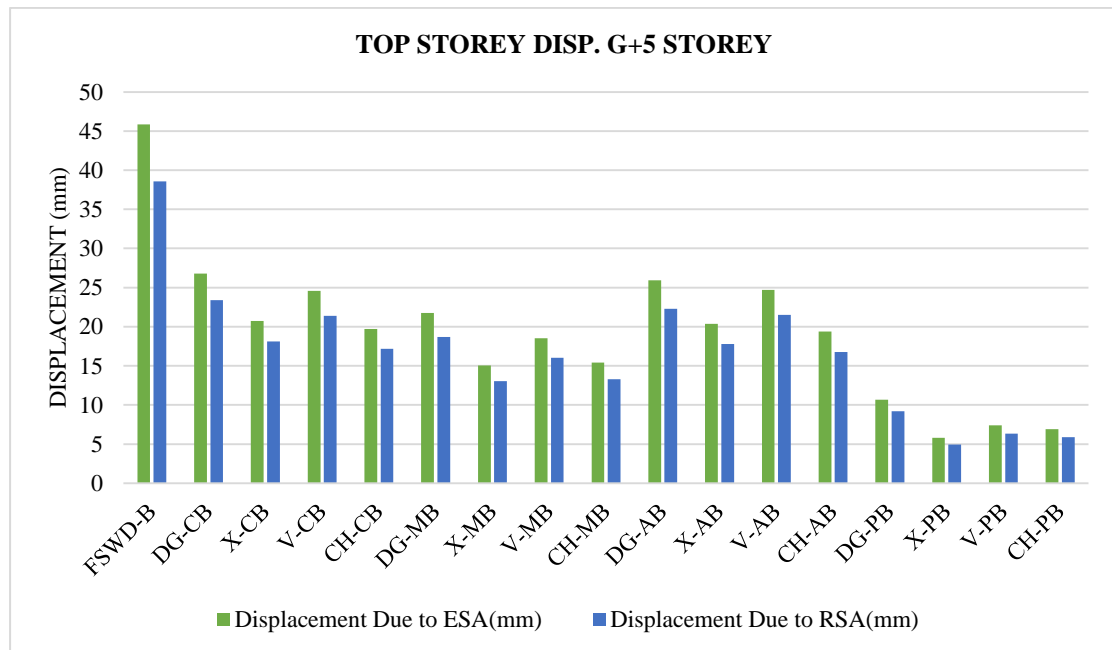


Figure 5: 17 Top Storey Displacement due to ESA & RSA, G+5 Storey

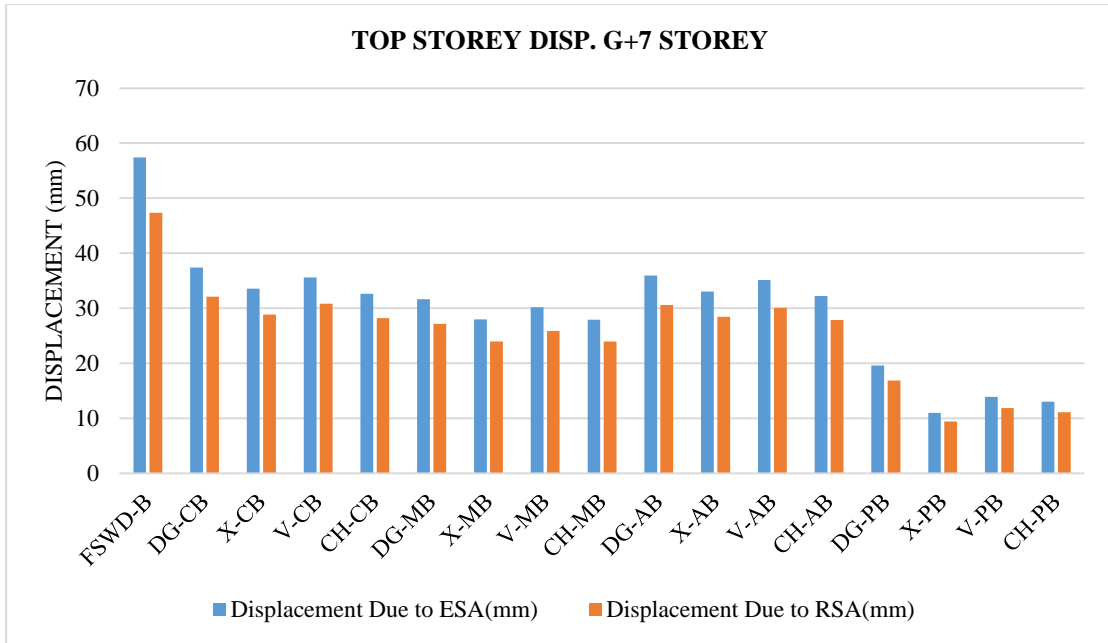


Figure 5: 18 Top Storey Displacement due to ESA & RSA, G+7 Storey

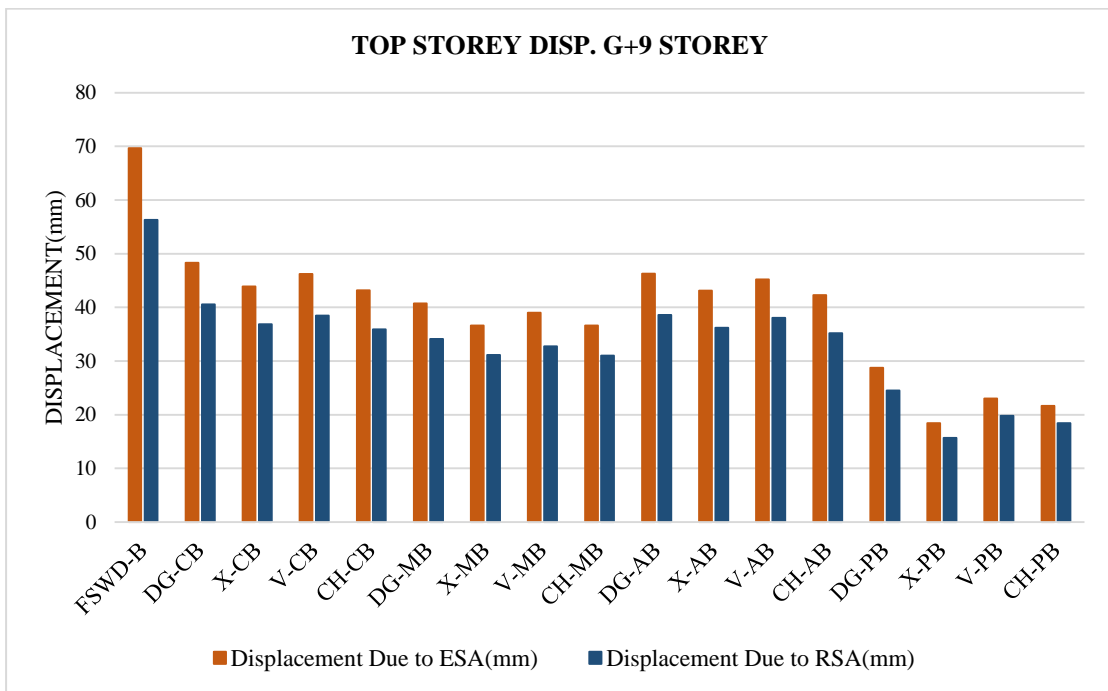


Figure 5: 19 Top Storey Displacement due to ESA & RSA, G+9 Storey

Figures 5:17, 5:18 and 5:19 are the plot of top storey displacement of the building due to equivalent static analysis and response spectrum analysis. The comparative study of top storey displacement values among G+5, G+7 and G+9 stories building together with braced and unbraced models shows that, after providing a steel braces the story displacement values decrease significantly. Among the various types of bracings, X and

Chevron type bracings are more efficient in decreasing displacement values while bracings at corner bays. Braces after providing on alternate bays shows somehow closer towards corner bays bracings. On middle and peripheral bays, X type braces significantly reduces the storey displacement values than other bracings. The minimum reduction is done by diagonal type steel braces. On comparison to bare models, nearly 42% to 58% top storey displacements values are reduced by providing corner bracings in G+5 Stories building. Likewise, for G+7 stories building, nearly 35% to 44% values decreases. Similarly, for G+9 Stories building 30% to 39% displacement values reduced by providing corner bracings. On comparison to bare models, about 41% to 58% in ESA and 39% to 56% in RSA, the top storey displacements values are reduced by providing bracings at corner bays in G+5 Stories building. Likewise, for G+7 stories building, about 35% to 44% (ESA) and 32% to 41% (RSA) values decreases. Similarly, for G+9 Stories building, about 30% to 39% (ESA) and 28% to 37% (RSA) displacement values reduced by providing corner bays bracings. On comparison to bare models, about 52% to 67% (ESA) and 51% to 67% (RSA) top storey displacements values are reduced by providing middle bays bracings in G+5 Stories building. Likewise, for G+7 stories building, about 44% to 52% (ESA) and 42% to 49% (RSA) values decreases. Similarly, for G+9 Stories building, about 41% to 47% (ESA) and 39% to 44% (RSA) displacement values reduced by providing middle bays bracings. On comparison to bare models, about 43% to 57% (ESA) and 42% to 56% (RSA) top storey displacements values are reduced by providing alternate bays bracings in G+5 Stories building. Likewise, for G+7 stories building, about 37% to 44% (ESA) and 35% to 41% (RSA) values decreases. Similarly, for G+9 Stories building, about 33% to 39% (ESA) and 31% to 38% (RSA) displacement values reduced by providing alternate bays bracings. On comparison to bare models, about 76% to 88% top storey displacements values are reduced by providing peripheral bays bracings in G+5 Stories building. Likewise, for G+7 stories building, about 65% to 81% values decreases. Similarly, for G+9 Stories building 58% to 74% displacement values reduced by providing peripheral bays bracings. The tabular data for reduction is presented on APPENDIX G.

### 5.1.4 Base Shear

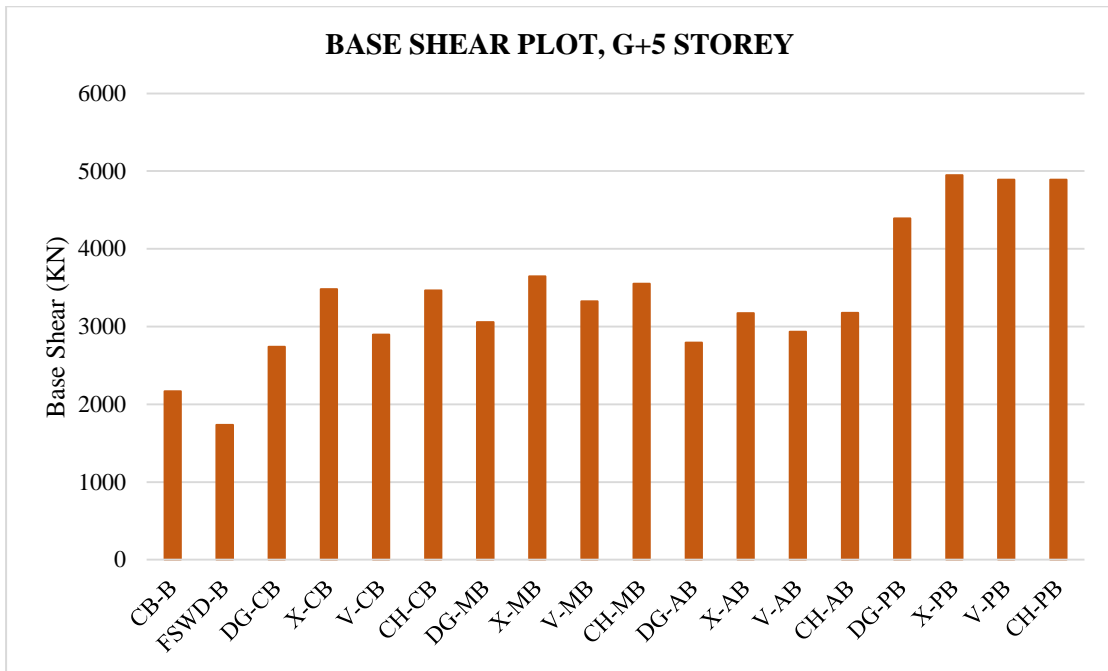


Figure 5: 20 Base Shear Plot, G+5 Storey

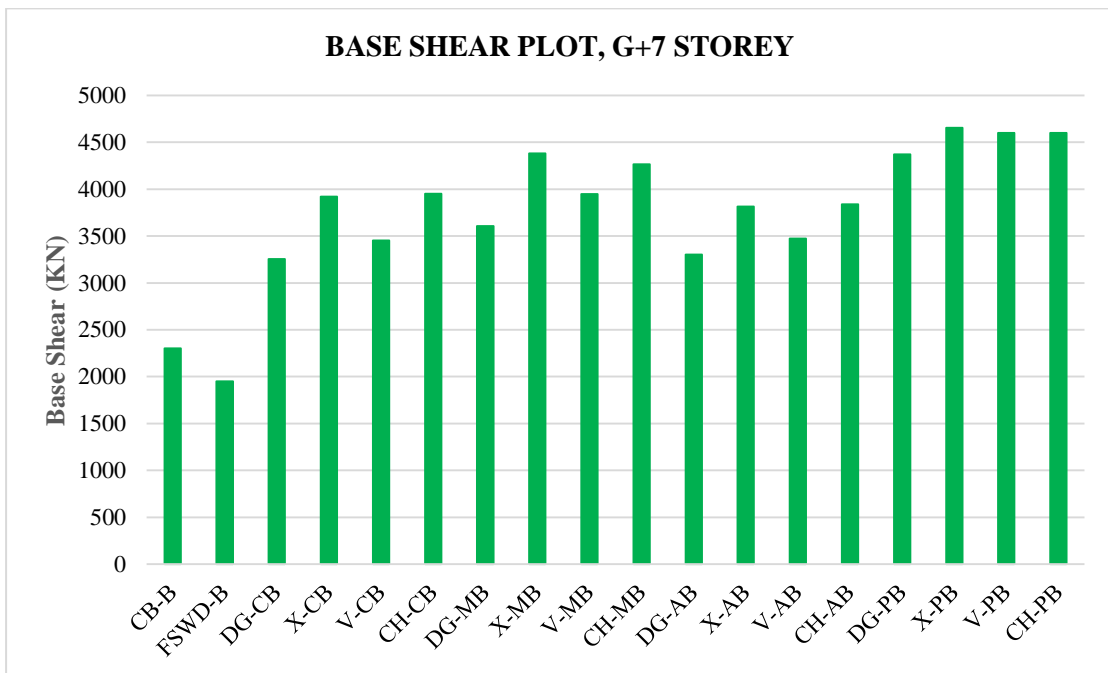


Figure 5: 21 Base Shear Plot, G+7 Storey

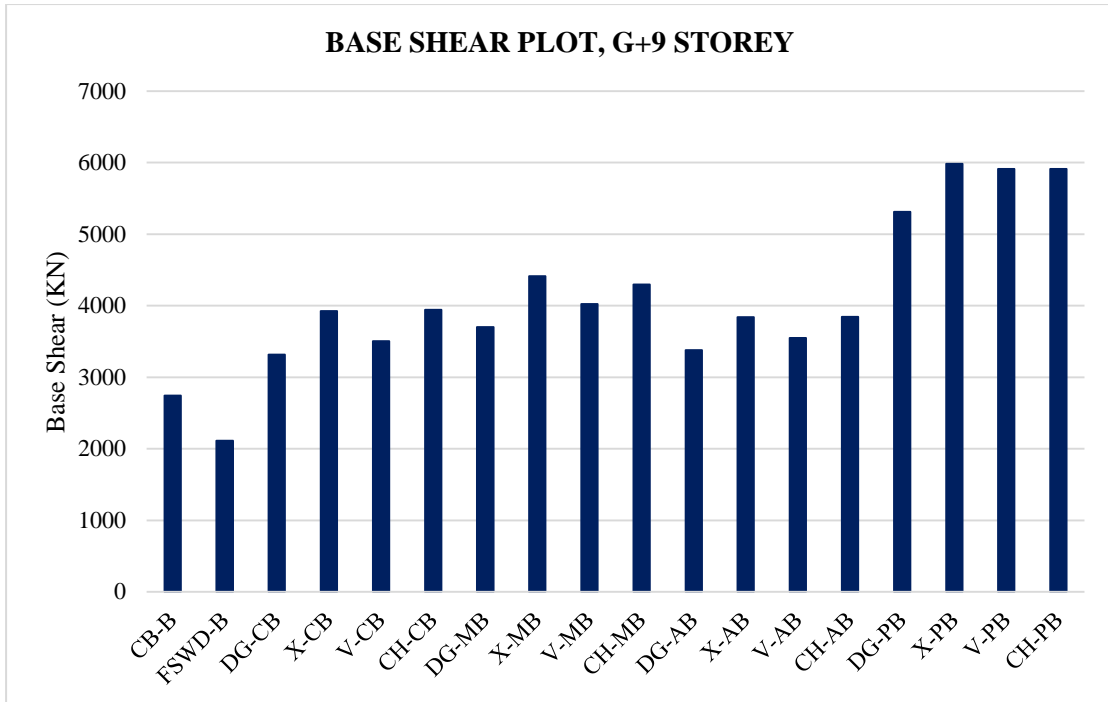


Figure 5: 22 Base Shear Plot, G+9 Storey

The plot of base shear values for G+5, G+7 and G+9 stories braced as well as unbraced building models indicates that Base shear values for pure flat slab building is lower than the conventional building. After providing bracings on flat slab building the base shear values increased significantly, which indicates the increase in stiffness of structure. Maximum base shear is obtained by providing X- type bracings. Minimum base shear is obtained from diagonal type bracings. After providing bracings on flat slab system, base shear increases nearly about 150 to 300% depending upon types and number of bays braced. Among various types of bracings, the X and Chevron type braces plays a remarkable role to increase base shear. And minimum base shear is for diagonal type brace. On comparison to bare model, nearly 174% to 204% base shear increase on G+7 Storied building by providing different bracings on corner bays. Likewise, for G+9 Stories building 164% to 188% base shear values increases by providing corner bracings. On comparison to bare model, nearly 193% to 235% base shear increase on G+7 Storied building by providing different bracings on middle bays. Likewise, for G+9 Stories building 183% to 218% of base shear value increases by providing middle bays bracings. On comparison to bare model, nearly 177% to 204% base shear increase on G+7 Storied building by providing different bracings on alternate bays. Likewise, for G+9 Stories building 167% to 290% of base shear value increases by providing alternate bays bracings. On comparison to bare model, nearly 245% to 250% base shear

increase on G+7 Storied building by providing different bracings on peripheral bays. Likewise, for G+9 Stories building 263% to 296% of base shear values increases by providing peripheral bays bracings. With the increase of height of building, the corresponding increase in base shear was observed clearly. Increasing the number of braced bays will ultimately increase the stiffness of structure and base shear correspondingly. The base shear result in tabular format is provided on APPENDIX H.

### 5.1.5 Time Period

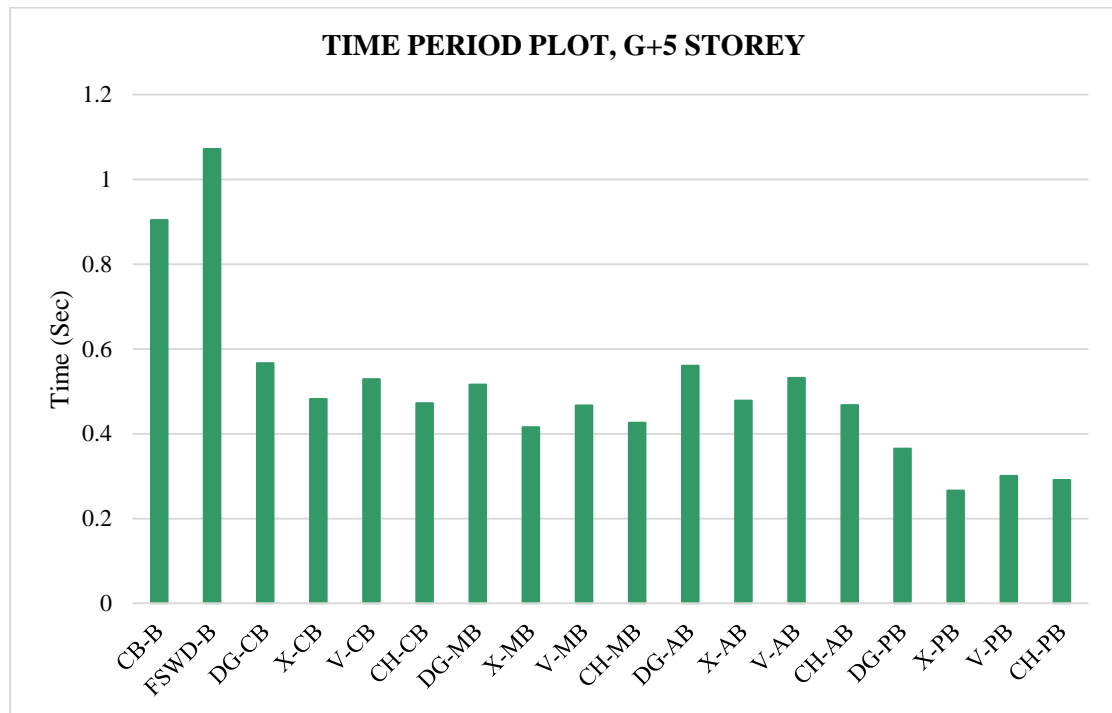


Figure 5: 23 Time Period, G+5 Storey

Figures shows the plot of fundamental time period for bare model and braced models of G+5, G+7 and G+9 Storied building. On comparison to conventional building bare models and flat slab bare models, the time period of flat slab building system is higher. Which indicates flat slab is more flexible. Addition of bracings on flat slab system increases its stiffness than unbraced models which consequently decreases the time period of structure. On Corner Bays bracings, the time period is lower for Chevron type bracings models. In G+5 Storied building, Corner bays bracing system decreases the time period about 46% to 57%. Similarly, middle bays bracing system reduces the time period nearly 51% to 62%. Alternate bays bracings reduces the time period about 47% to 57%. Likewise, Peripheral bays bracings system reduces about 65% to 75%.

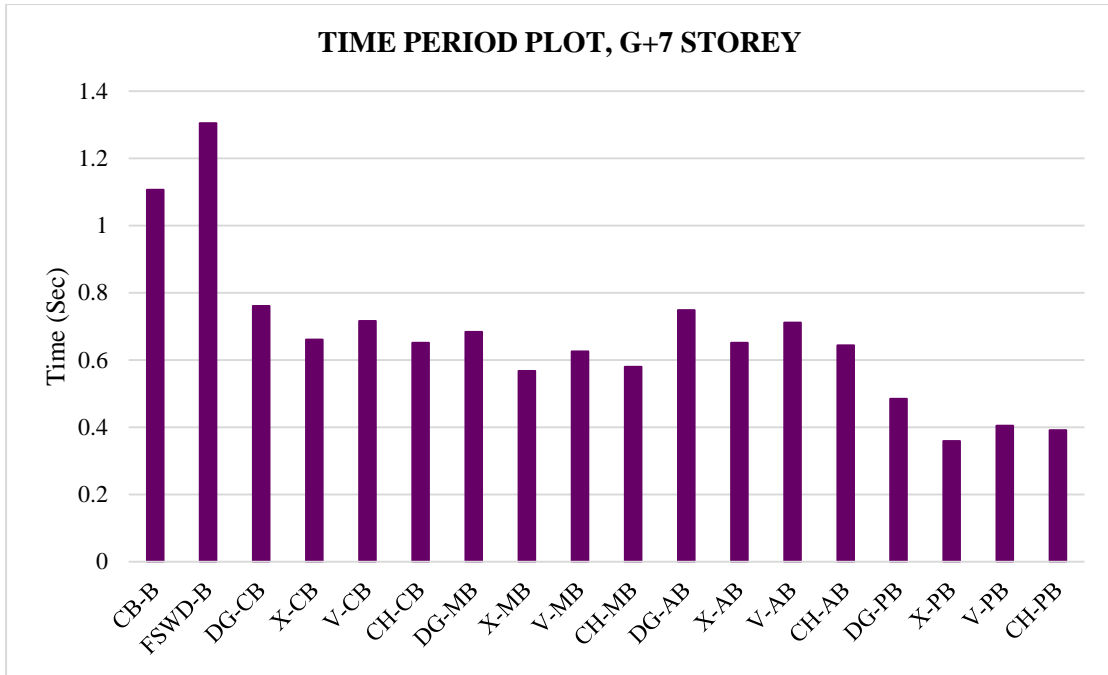


Figure 5: 24 Time Period, G+7 Storey

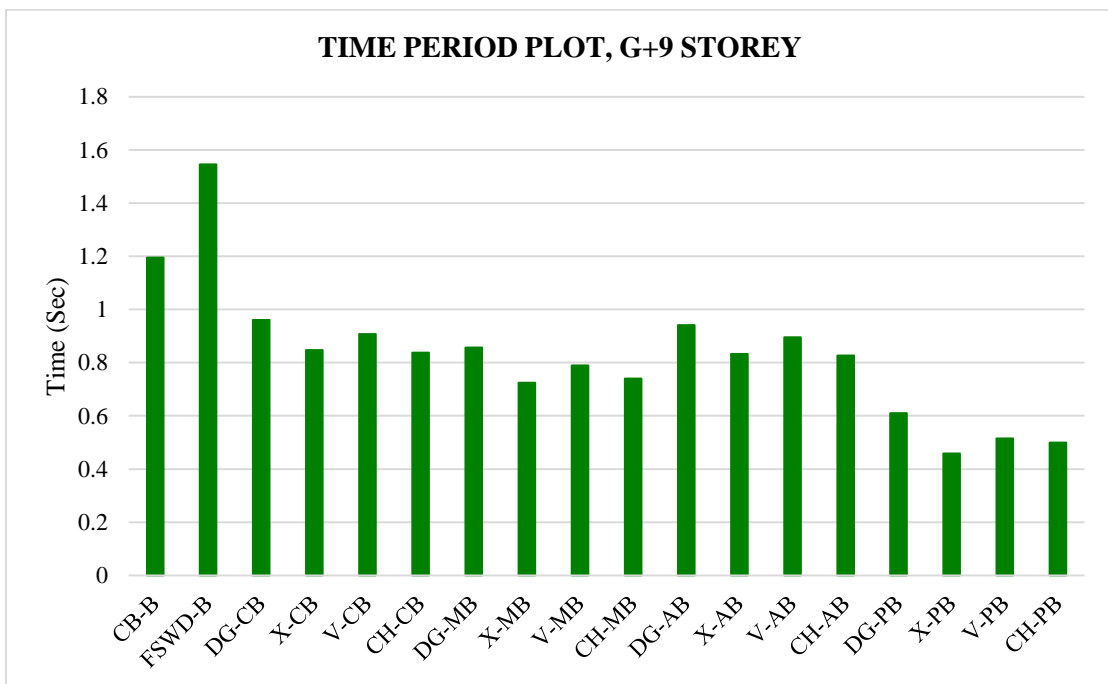


Figure 5: 25 Time Period, G+9 Storey

In G+7 Storied building, Corner bays bracing system decreases the time period about 41% to 50%. Similarly, middle bays bracing system reduces the time period nearly 47% to 56%. Alternate bays bracings reduces the time period about 42% to 50%. Likewise, Peripheral bays bracings system reduces 62% to 72%. In G+9 Storied building, Corner bays bracing system decreases the time period about 38% to 46%. Similarly, middle bays bracing system reduces the time period about 44% to 53%. Alternate bays bracings

reduces the time period about 39% to 46%. Likewise, Peripheral bays bracings system reduces 60% to 70%. Alternate bays bracings shows somehow similar behavior to corner bays bracings on time period also. But on middle bays and peripheral bays bracings, the time period is lower for X Bracings models. Similarly, for corner bays bracings, the time period is higher for V shaped bracings. But on the middle bays and peripheral bays bracing systems, the time period is higher for X bracings models. For middle bays bracings and peripheral bracings, the minimum value of time period is for X type bracings and maximum is for Diagonal type bracing system. The tabular data for time period is presented on APPENDIX I.

## 5.2 Comparative Study of Different Configurations of Braced Models

### 5.2.1 Maximum Storey Displacement

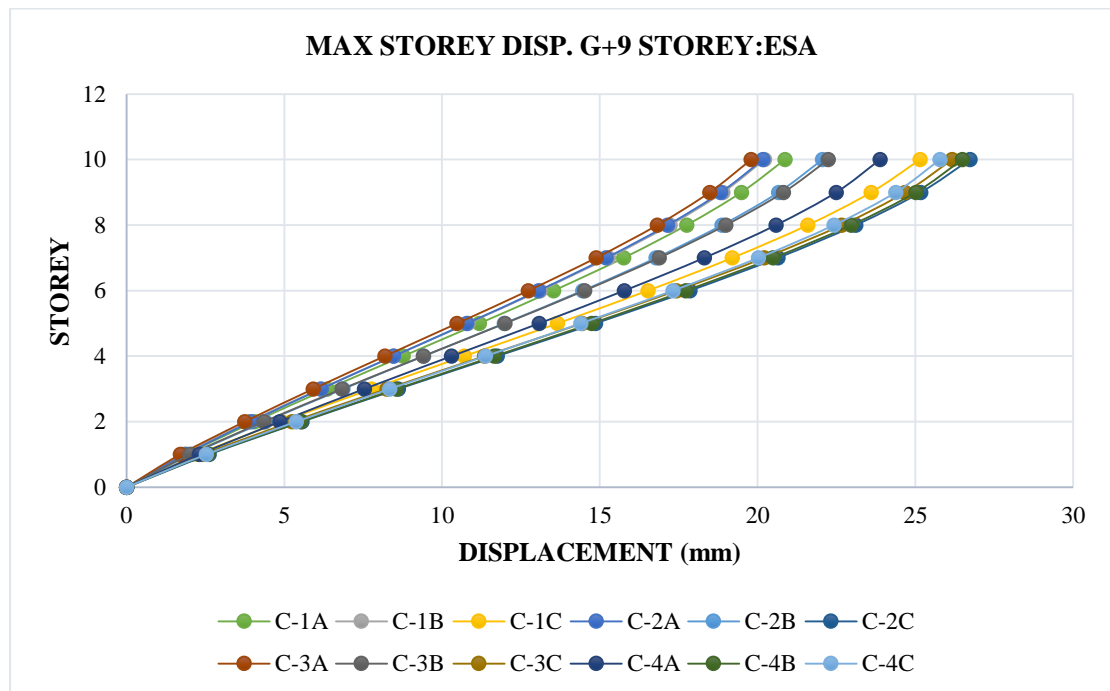


Figure 5: 26 Max. Storey Displacement for different bracings configurations due to ESA, G+9 Storey

Figure 5:26 and Figure 5:27 are the plot of storey displacement of G+9 storied building with different configurations of braces on peripheral bays. Instead of providing same types of bracings on all peripheral bays, this study wants to know about the seismic parameters of braced building after providing two different types of braces at a same time on the building. Different configurations are modelled and the analysis were performed. Among the different configurations, Configuration 3A shows the least values of storey displacement and C-2C shows the higher values of storey displacement.

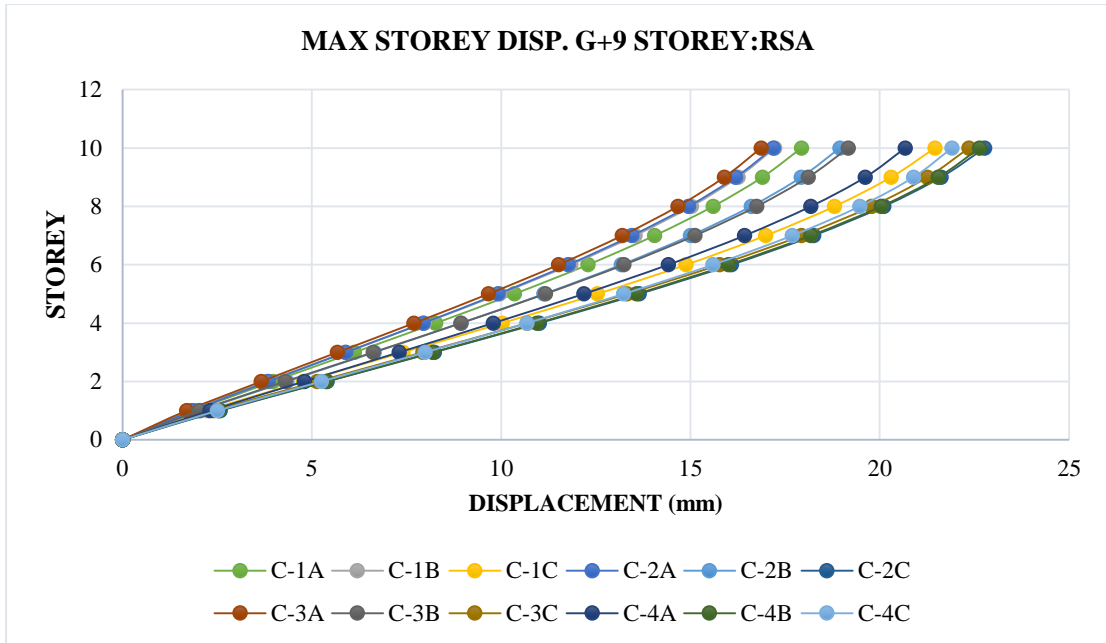


Figure 5: 27 Max. Storey Displacement for different bracings configurations due to RSA, G+9 Storey

Providing a different configurations of braces reduces storey displacements upto 80% to 86% on G+5 storey building, 70% to 80% on G+7 storey building and 61% to 72 % on G+9 stories building respectively. Results of G+5 and G+7 stories buildings are presented on APPENDIX C.

### 5.2.2 Maximum Storey Drift Ratio

Figure 5:28 and Figure 5:29 are the plot of drift ratio of G+9 storied building due to application of braces with different configurations on peripheral bays. Similar to storey displacement results, the analysis shows us about the inter storey drift ratio values for different bracing configurations. Configuration 3A shows the least values of inter storey drift ratios and C-2C shows the higher values of inter storey drift ratios among the various configurations take for study purpose. For, G+9 stories building, inter storey drift ratio values are obtained in the range of 0.0006 to 0.0011 by providing different configurations. Results of G+5 and G+7 stories buildings are presented on APPENDIX D.

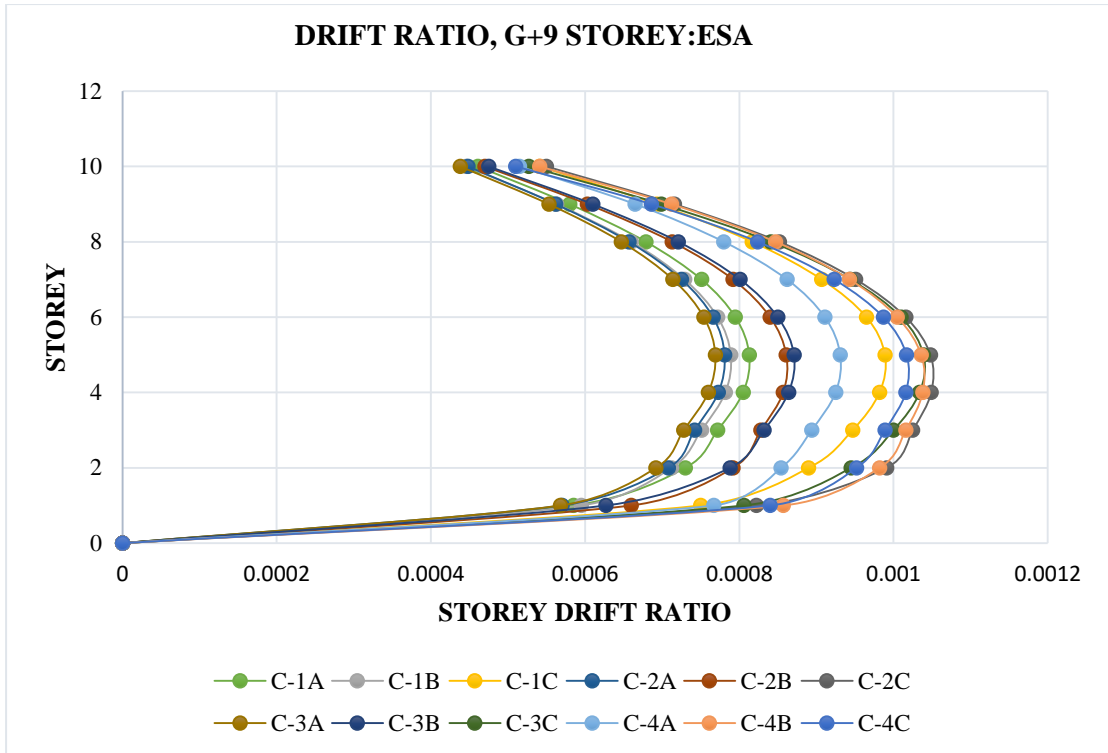


Figure 5: 28 Drift Ratio for different configuration of bracings due to ESA, G+9 Storey

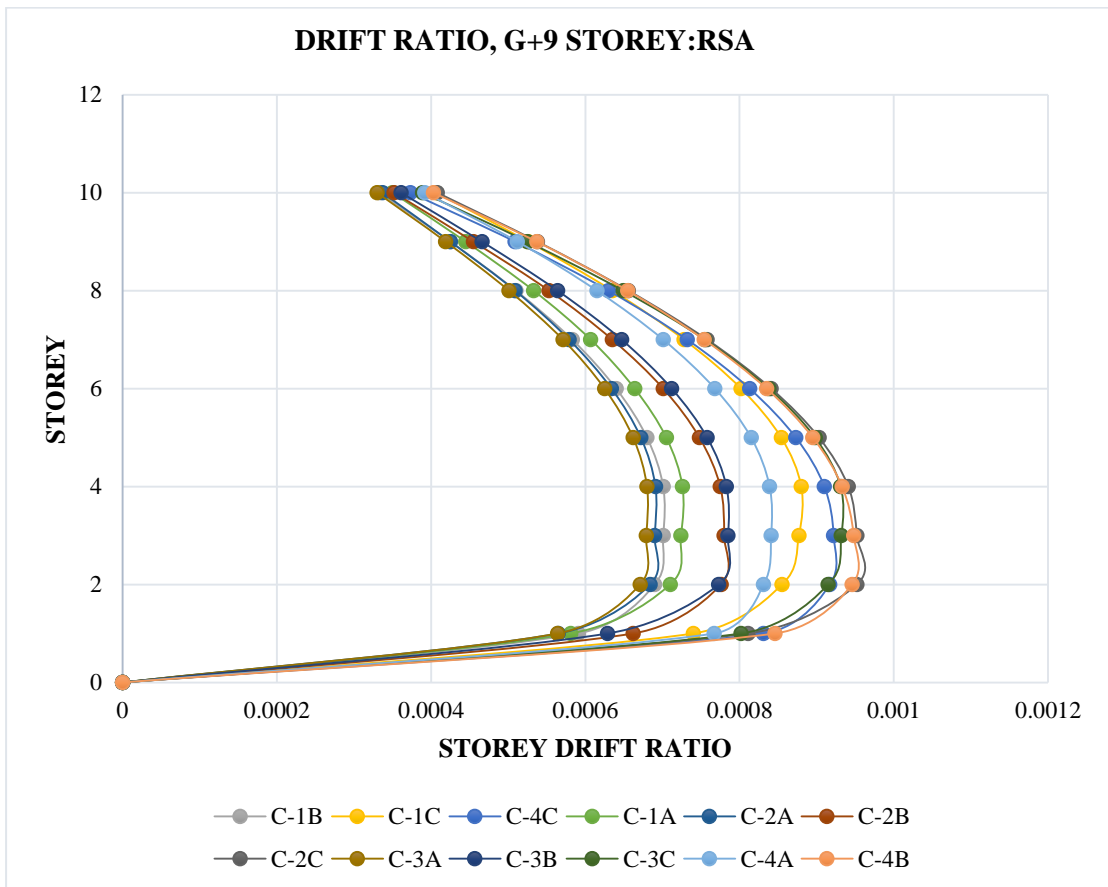


Figure 5: 29 Drift Ratio for different configuration of bracings due to RSA, G+9 Storey

### 5.2.3 Top Storey Displacement Reduction

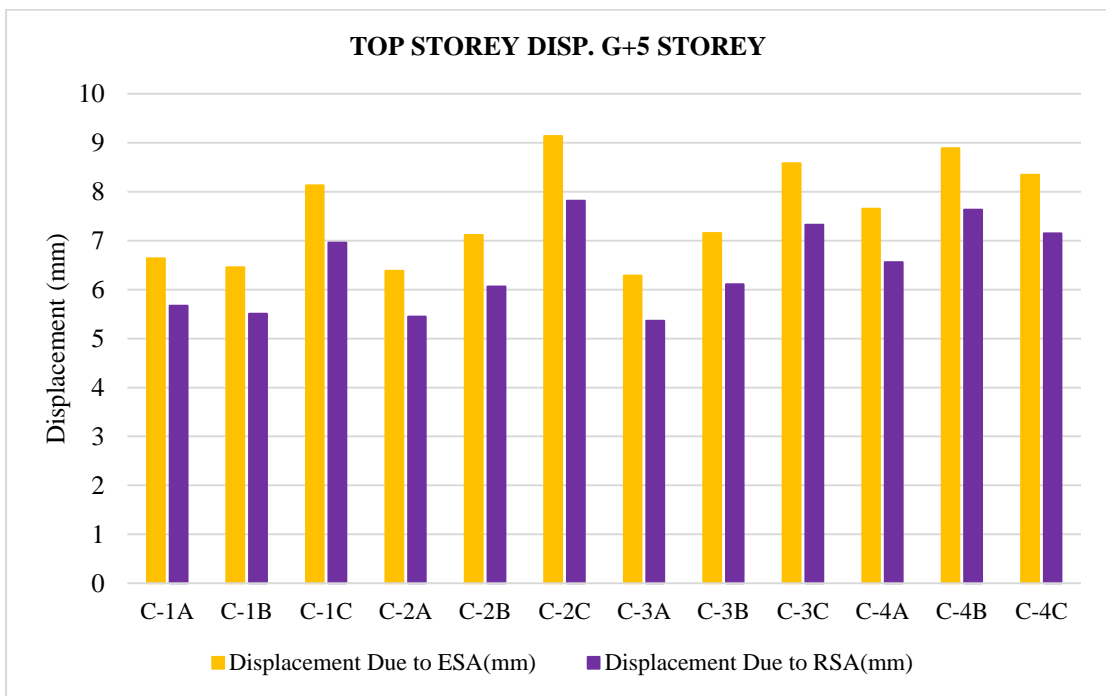


Figure 5: 30 Top Storey Displacement due to ESA & RSA, G+5 Storey

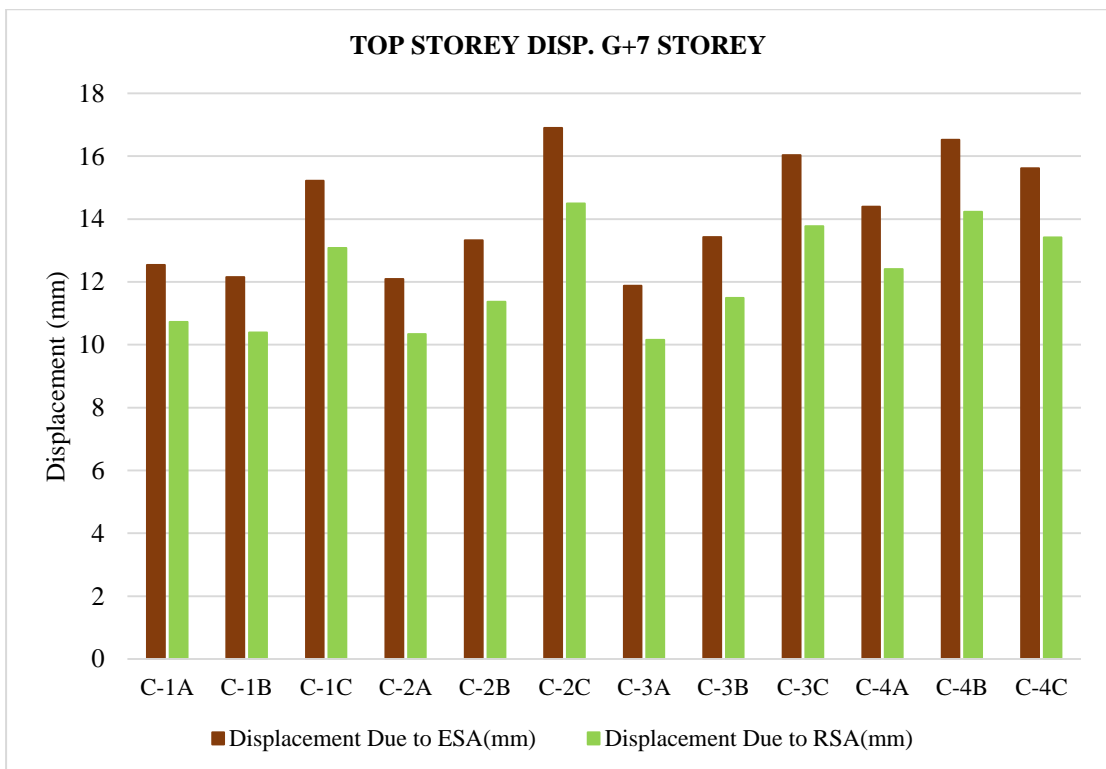


Figure 5: 31 Top Storey Displacement due to ESA & RSA, G+7 Storey

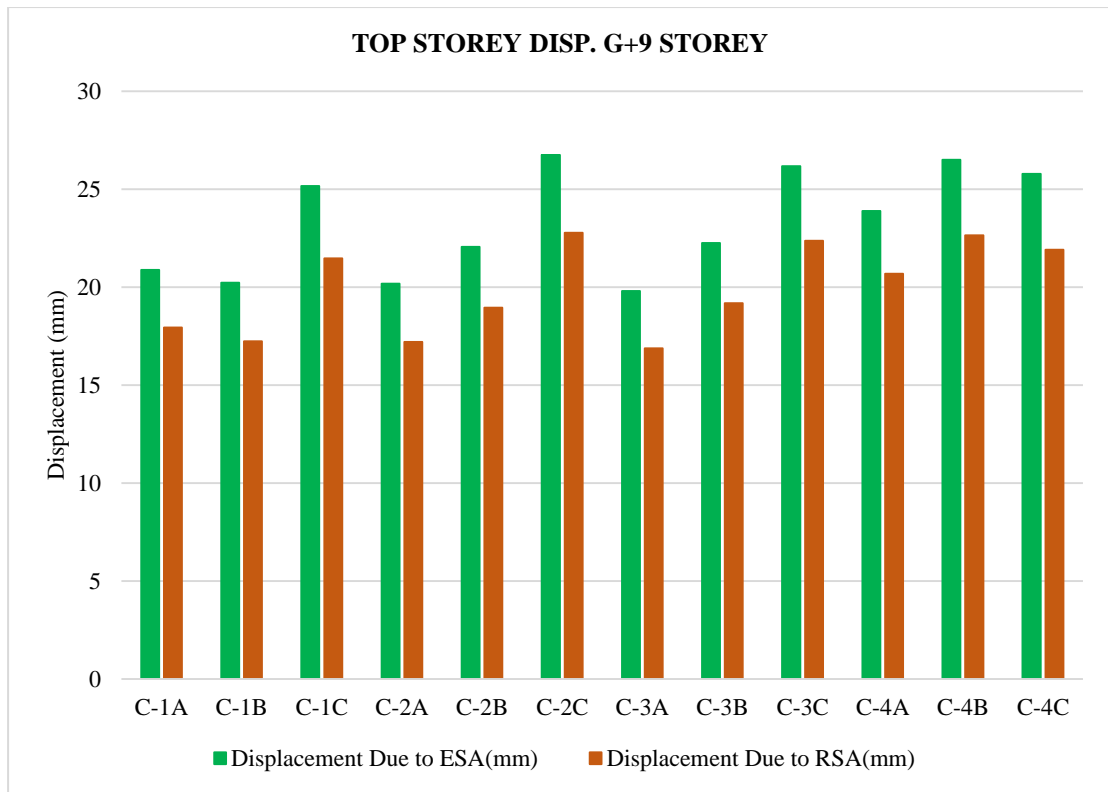


Figure 5: 32 Top Storey Displacement due to ESA & RSA, G+9 Storey

Figure 5:30, 5:31 and 5:32 are the plot of top storey displacements of G+5, G+7, G+9 stories flat slab building respectively after providing different configuration of braces on peripheral bays. On comparison with various configurations of steel bracings, Configuration-3A reduces maximum top storey displacements about 86.26 % in ESA and 86.07% in RSA of G+5 storey building. Similarly, for G+7 Storied building Configuration-3A reduces maximum top storey displacement about 79.36% in ESA and 78.62% in RSA. Likewise, for G+9 storied building, its value is about 71.59% in ESA and 70.05% in RSA. On comparison with various configurations of steel bracings, Configuration-2C reduces minimum top storey displacement about 80.03% in ESA and 79.69% in RSA of G+5 storey building. Similarly, for G+7 Storied building Configuration-2C reduces minimum about 70.64% in ESA and 69.50% in RSA. Likewise, for G+9 storied building, its corresponding value is 61.63% in ESA and 59.56% in RSA.

## 5.2.4 Base Shear

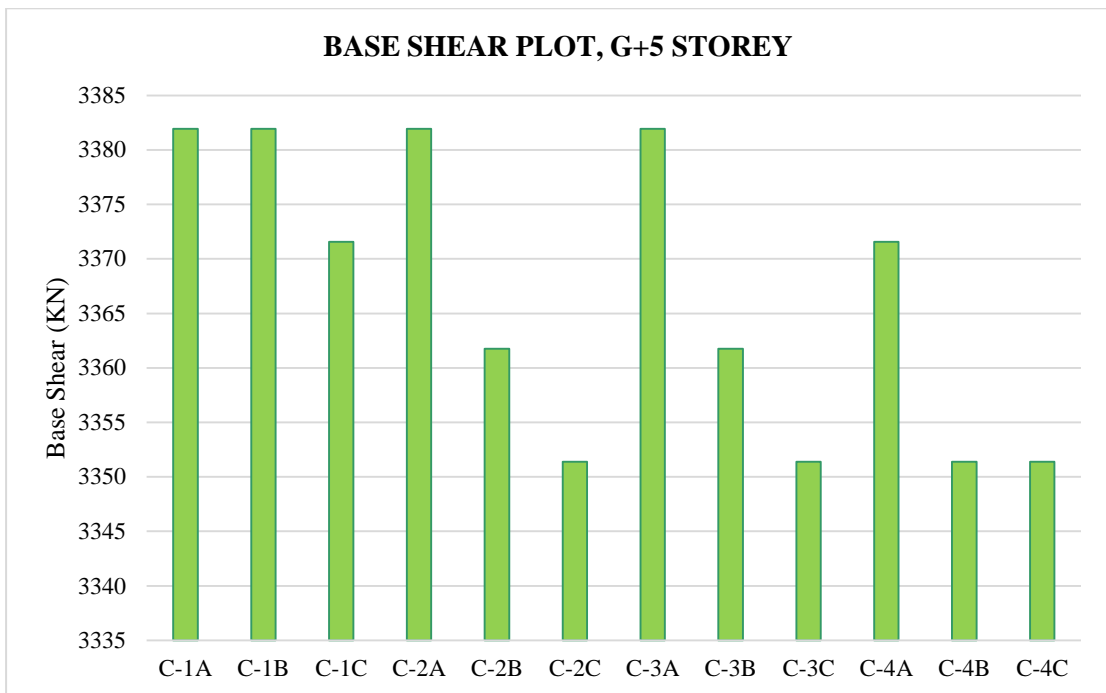


Figure 5: 33 Base Shear for different configuration of bracings, G+5 Storey

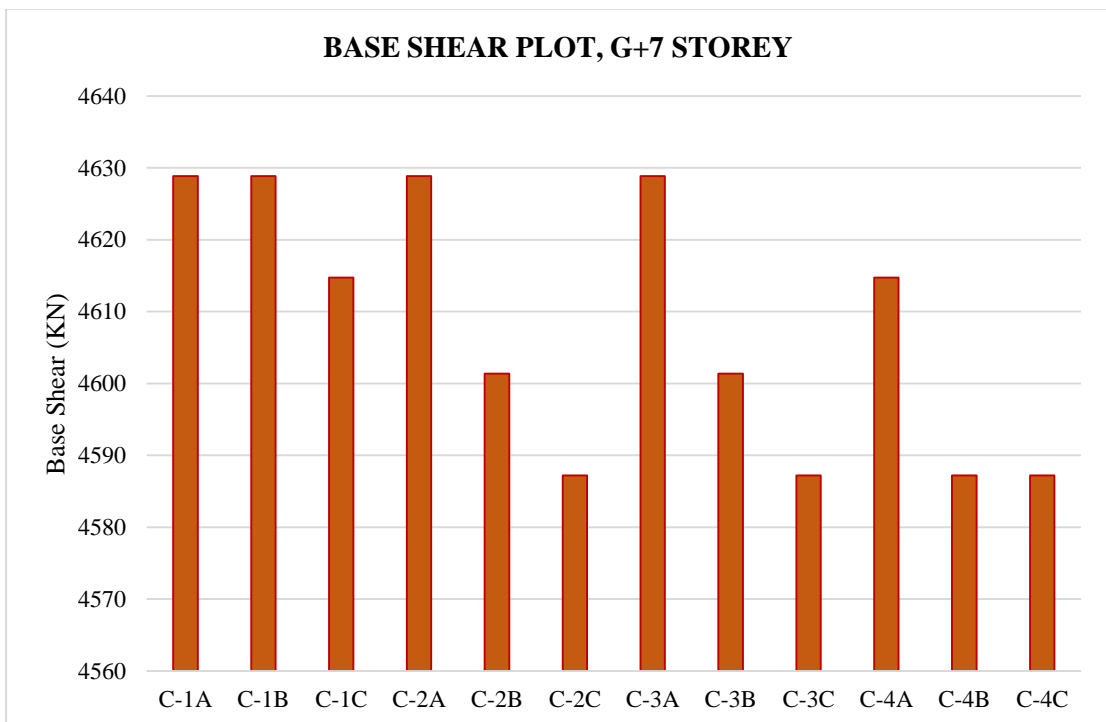


Figure 5: 34 Base Shear for different configuration of bracings, G+7 Storey

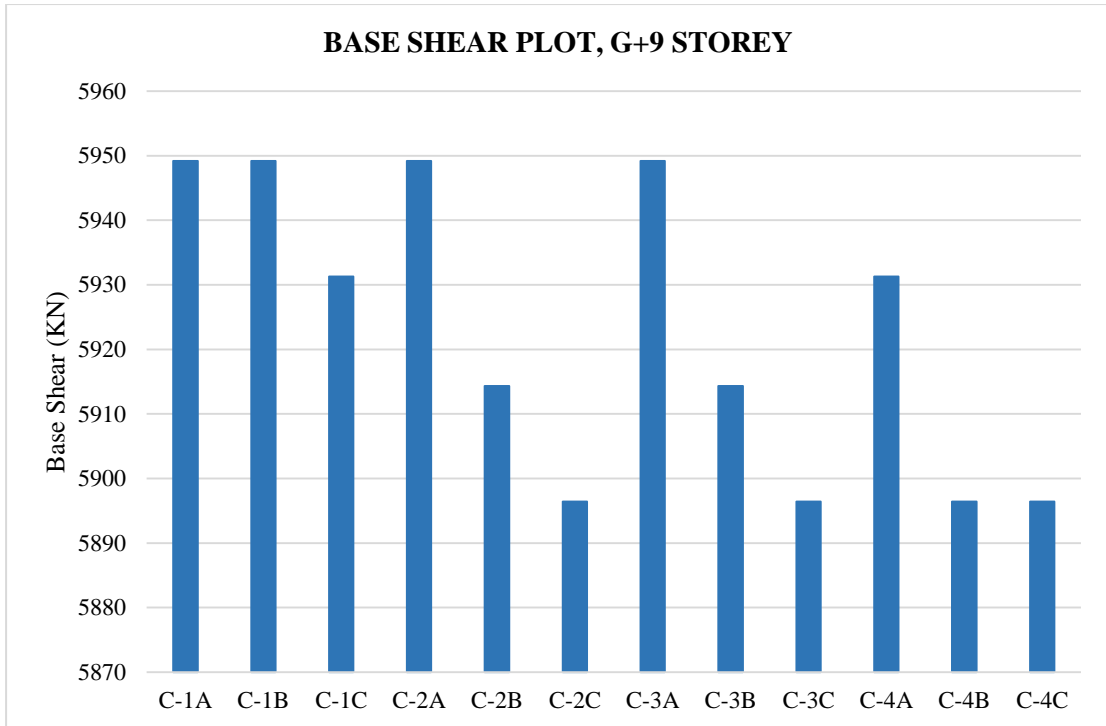


Figure 5: 35 Base Shear for different configuration of bracings, G+9 Storey

Figures 5:33, 5:34 and 5:35 are the plot of base shear of G+5, G+7 and G+9 stories building after application of steel braces on peripheral bays. After providing braces on structure, the stiffness of the structure increases which consequently increases the base shear of the structure because base shear is the function of mass and stiffness. Various configurations of braces are applied on structure. Up to 200% to 203% base shear value increase on G+5 stories flat slab building after providing the steel braces. Similarly, for G+7 stories near about 246% to 248% base shear value increases. Also for G+9 stories building, the base shear increases by 292% to 294%.

Providing different configurations of braces ultimately increases the global stiffness of the structure. So that there is no any significant change in base shear due to the placement of braces in case of peripheral bays bracings.

### 5.2.5 Time Period

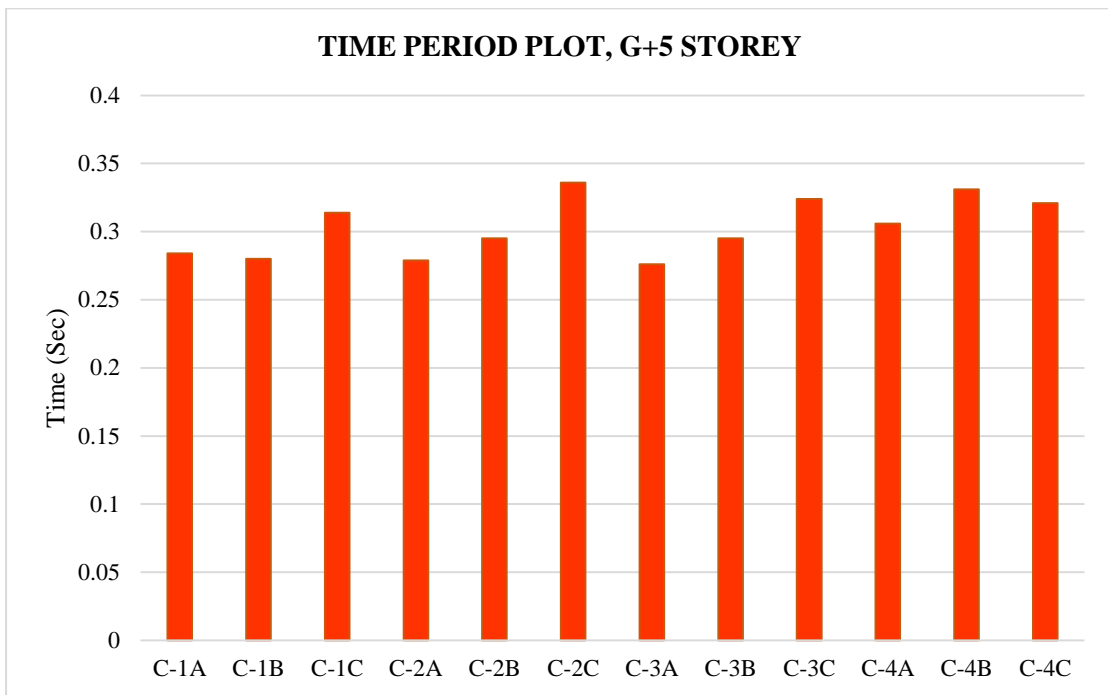


Figure 5: 36 Time Period for different configuration of bracings, G+5 Storey

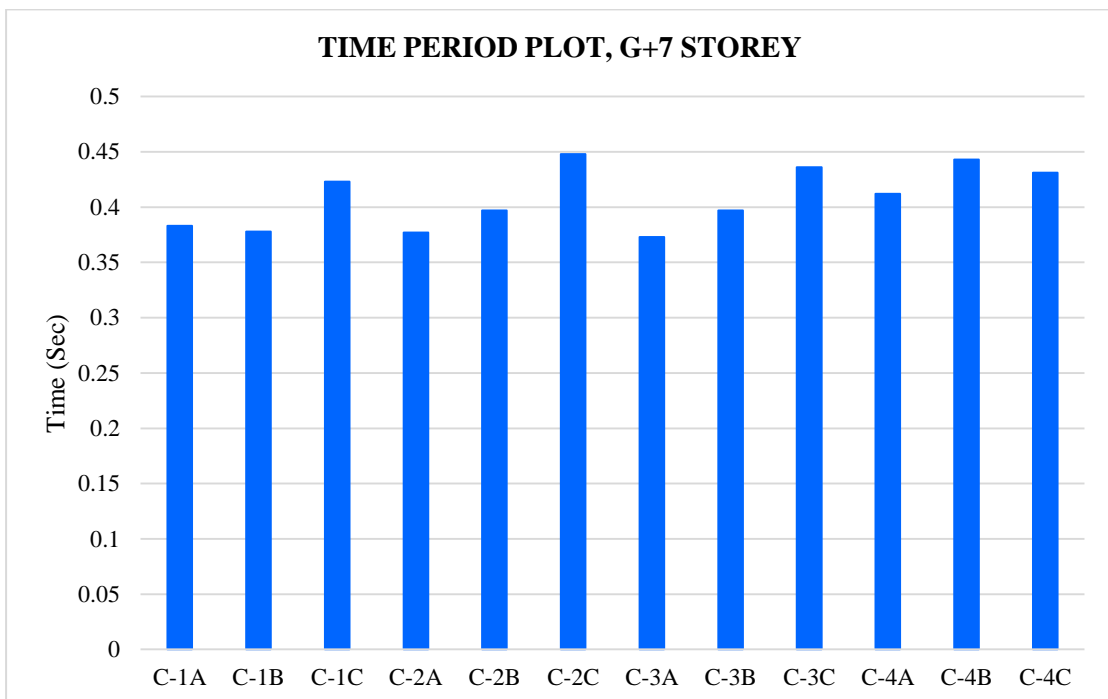


Figure 5: 37 Time Period for different configuration of bracings, G+7 Storey

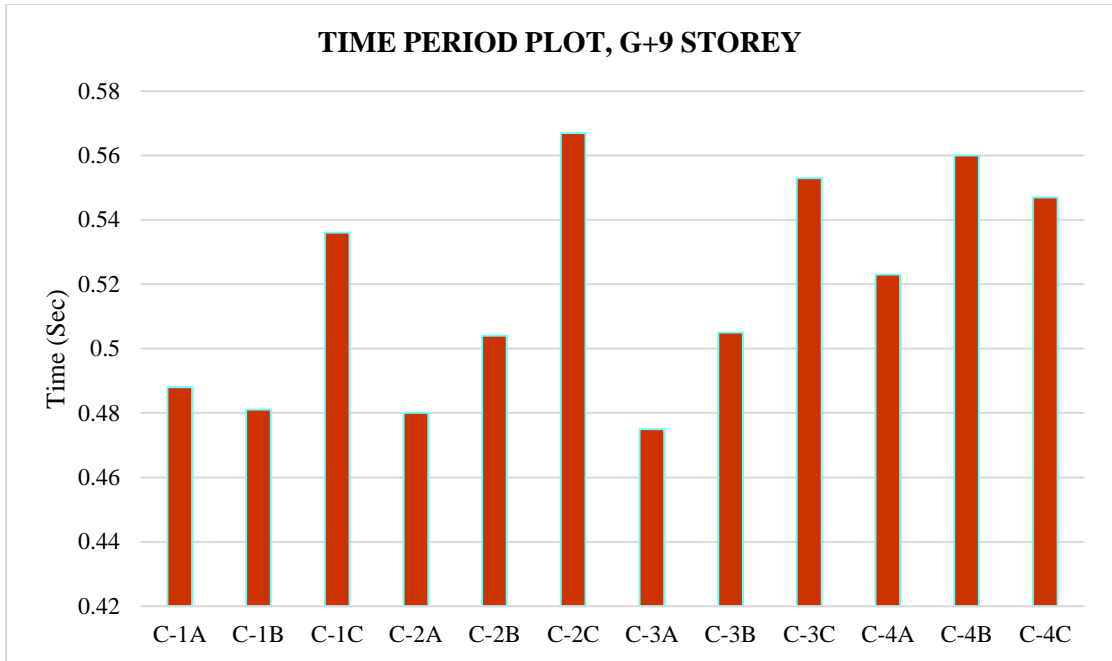


Figure 5: 38 Time Period for different configuration of bracings, G+9 Storey

Figures 5:36, 5:37 and 5:38 are the plot of fundamental natural period of G+5, G+7 and G+9 stories flat slab building having different configurations of braces on peripherally. Initially the flat slab structure is more flexible than the conventional structure. After the application of steel braces, the global stiffness of the structure increases significantly. Which ultimately reduces the fundamental natural time period of the structure. For G+5 stories building, the time period is reduced in the range of 68% to 75% after providing different configurations of braces. For G+7 stories building the time period reduced in the range of 65% to 72%. Similarly, for G+9 stories building, the fundamental natural time period reduces in the range of 63% to 70%. Among the various configurations of braces, the minimum value of fundamental natural period is obtained by configuration C-3A and maximum value is obtained by configuration C-2C.

## CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusions

Both linear static and linear dynamic analysis is carried out for conventional building and flat slab building having three different stories level. In flat slab building, different types of steel braces are provided at different bays. Various configurations of two different shaped braces are also modelled and analysis is carried out. Based on result and discussion, the following conclusions have been established.

- Application of steel braces on flat slab building reduces the overall response of the structure and structure becomes more stiff.
- The storey displacement and drift ratio of flat slab is decreased after the application of steel braces due to increase in stiffness of structure.
- The most effective braces for reduction in displacement and drift ratio is X and Chevron type brace placing at corner bays and alternate bays. For middle and peripheral bays bracing, X brace shows most effective result.
- The application of braces increases the base shear of structure due to increase in stiffness. X and Chevron brace are highly susceptible towards increasing the base shear values.
- Fundamental natural time period of flat slab structure decreases due to the application of braces. X and Chevron type braces reduces the most among the considered braces.
- Different Configurations of bracing shows that reduction in displacement, drift ratio and time period of the structure. Maximum reduction is obtained by Configuration-3A and minimum reduction is obtained by Configuration-2C.
- The steel braces could be an alternative for lateral load resisting system in flat slab building to enhance the seismic parameters.

## **6.2 Recommendations**

In this research work the comparative study of application of steel braces on RCC flat slab structure was performed. This thesis work focus only about the linear static and linear dynamic analysis of braced as well as unbraced RCC flat slab structure. The study recommends, steel braces are an alternative option for resisting lateral loads, enhancing seismic strength in flat slab structure. The use of different steel braces on different bays gives somehow better architectural appearance on a building. Use of standard section gives uniformity in structure.

There are certain limitations of this study which can be extended further for another research works. The following work can be extended further:

- Consideration of different irregular plan and configurations, shapes, sizes and stories level.
- Research can be extended considering the soil structure interaction of flat slab system.
- Research can be extended to find the nonlinear static as well as nonlinear dynamic behavior of this system.
- Research can be done with the cost analysis between bracings, shear walls and lift core walls options.
- Research can be extended as cost comparison between bracings.

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## APPENDIX A

Maximum Storey Displacement plots for various braced models with storey level G+5 and G+7 are presented here.

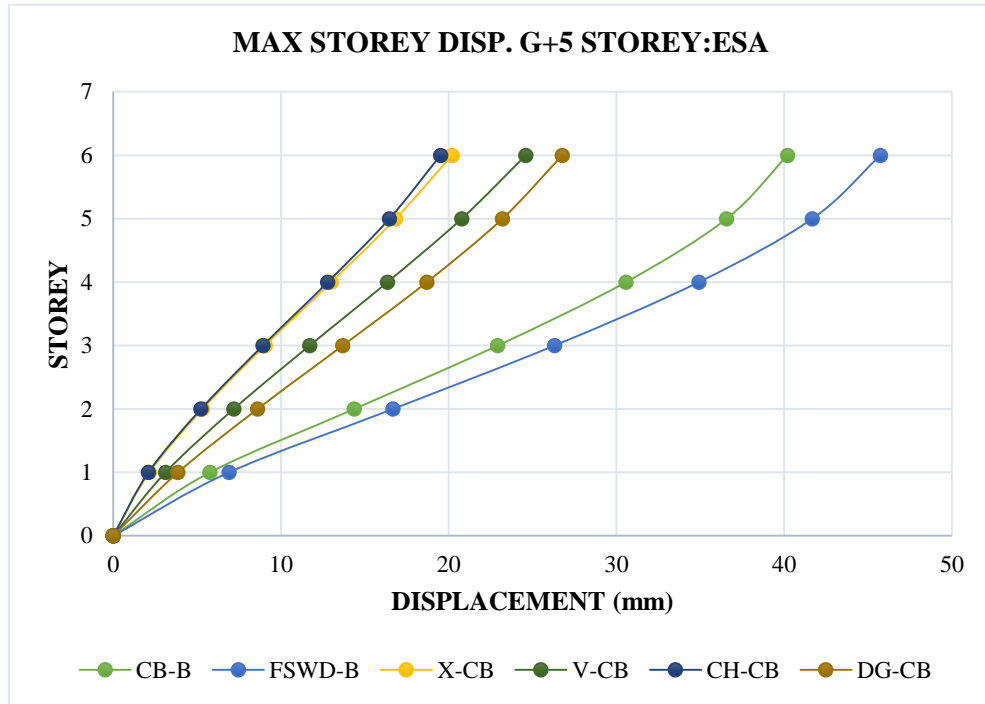


Figure A: 1 Max. Storey Displacement, Corner Bays Bracings, G+5 Storey due to ESA

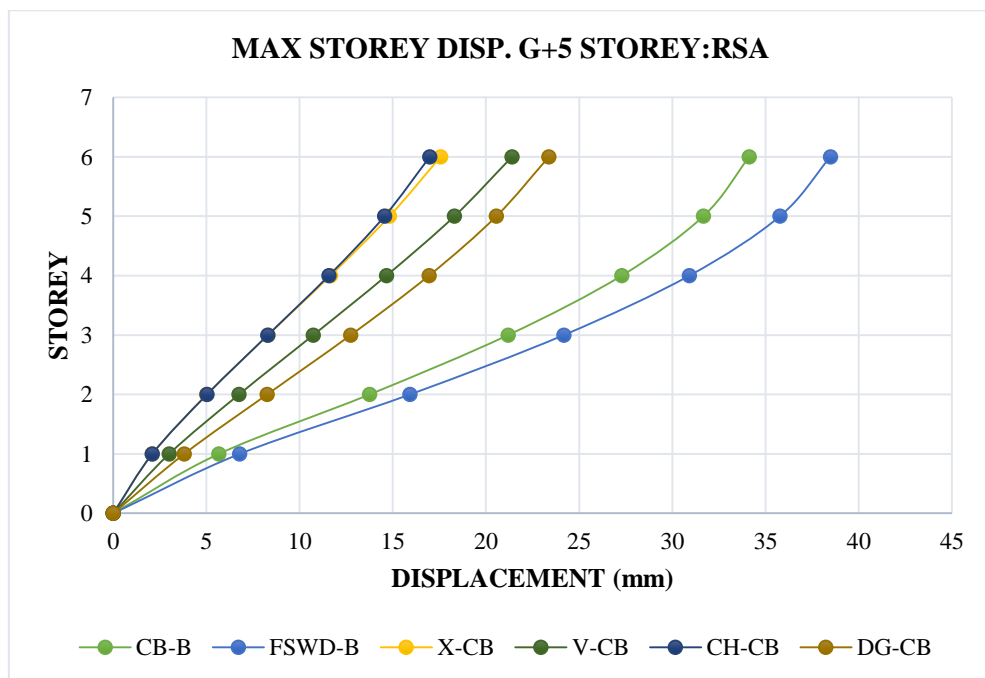


Figure A: 2 Max. Storey Displacement, Corner Bays Bracings, G+5 Storey due to RSA

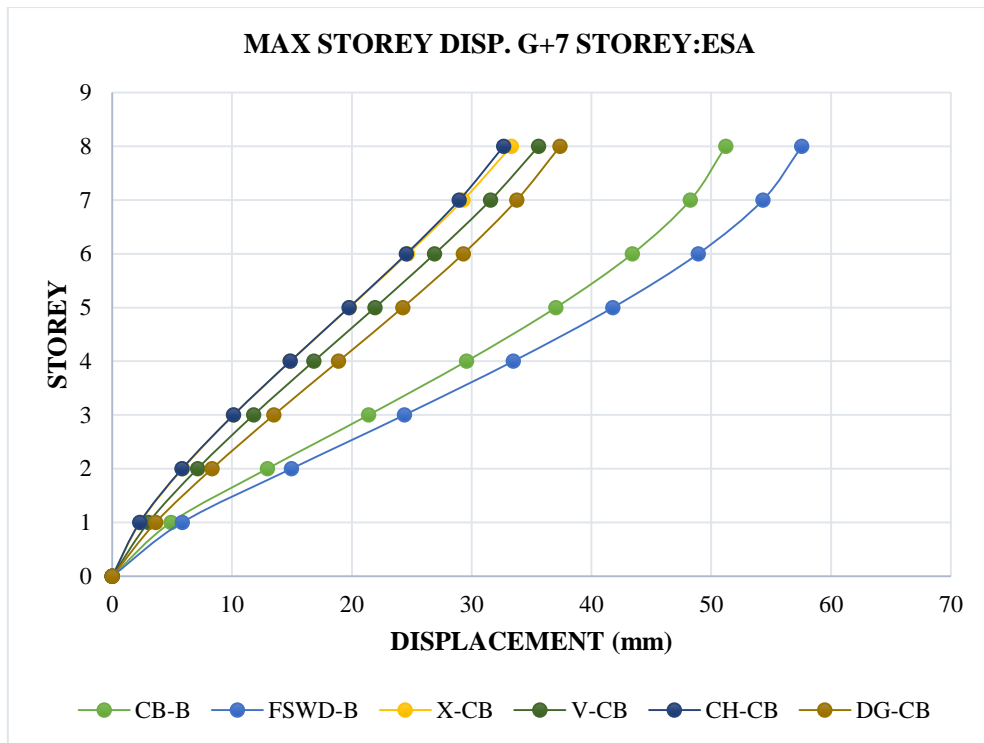


Figure A: 3 Max. Storey Displacement, Corner Bays Bracings, G+7 Storey due to ESA

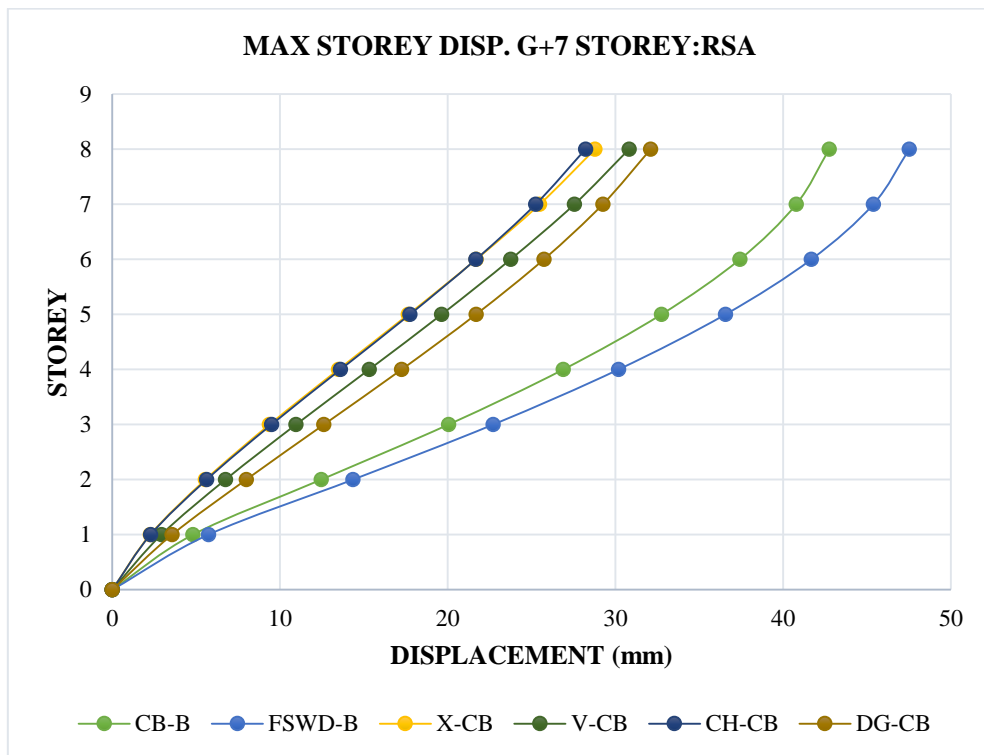


Figure A: 4 Max. Storey Displacement, Corner Bays Bracings, G+7 Storey due to RSA

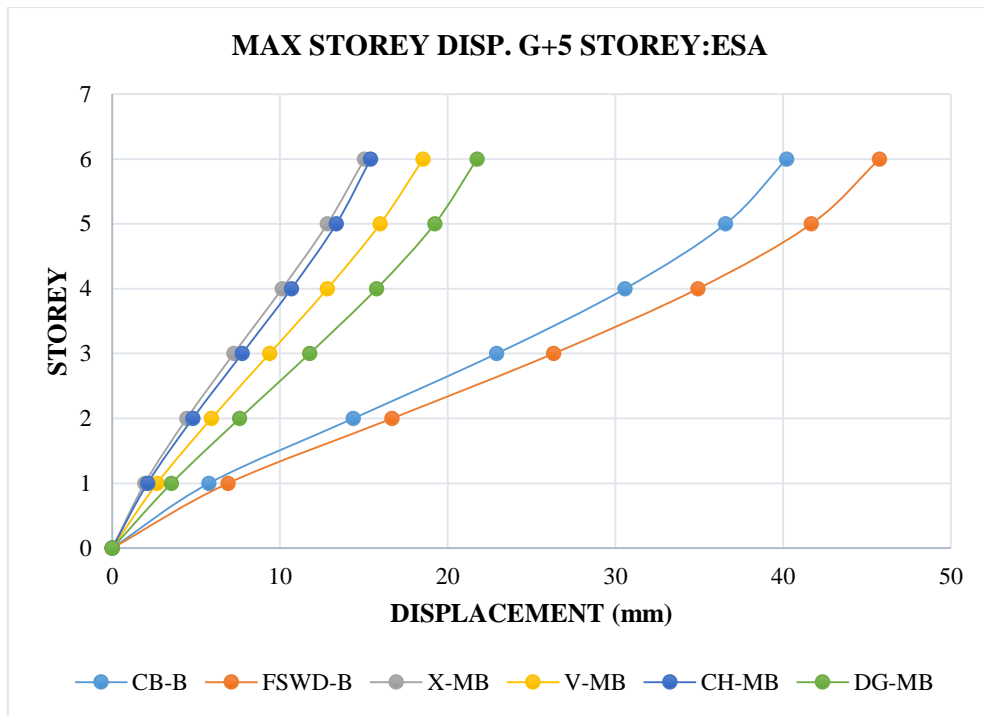


Figure A: 5 Max. Storey Displacement, Middle Bays Bracings, G+5 Storey due to ESA

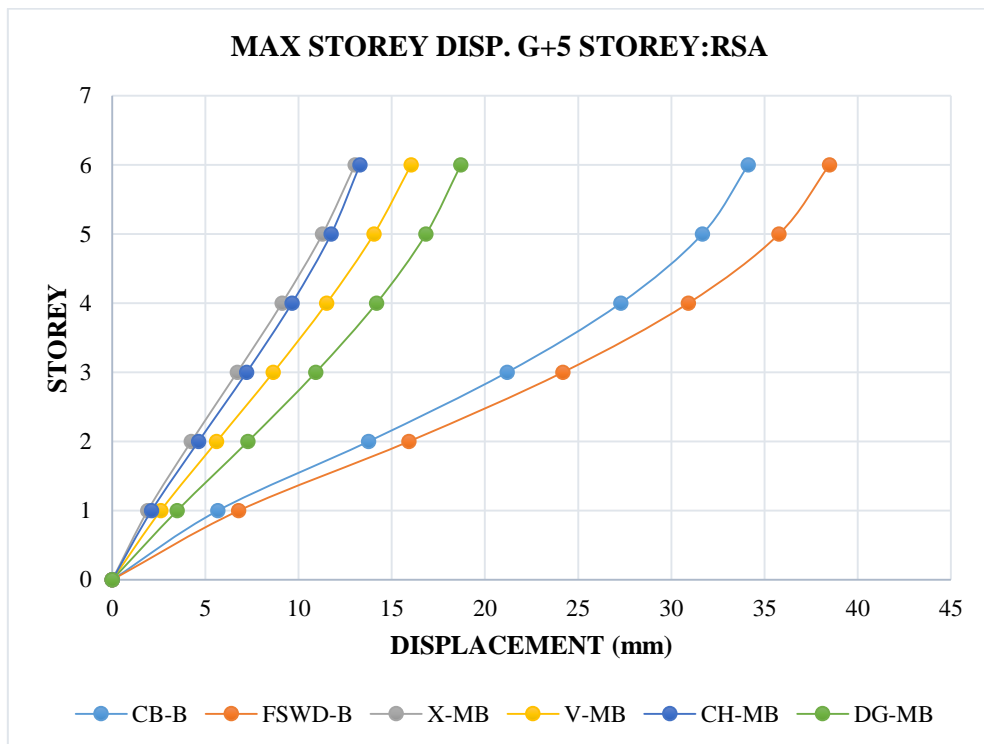


Figure A: 6 Max. Storey Displacement, Middle Bays Bracings, G+5 Storey due to RSA

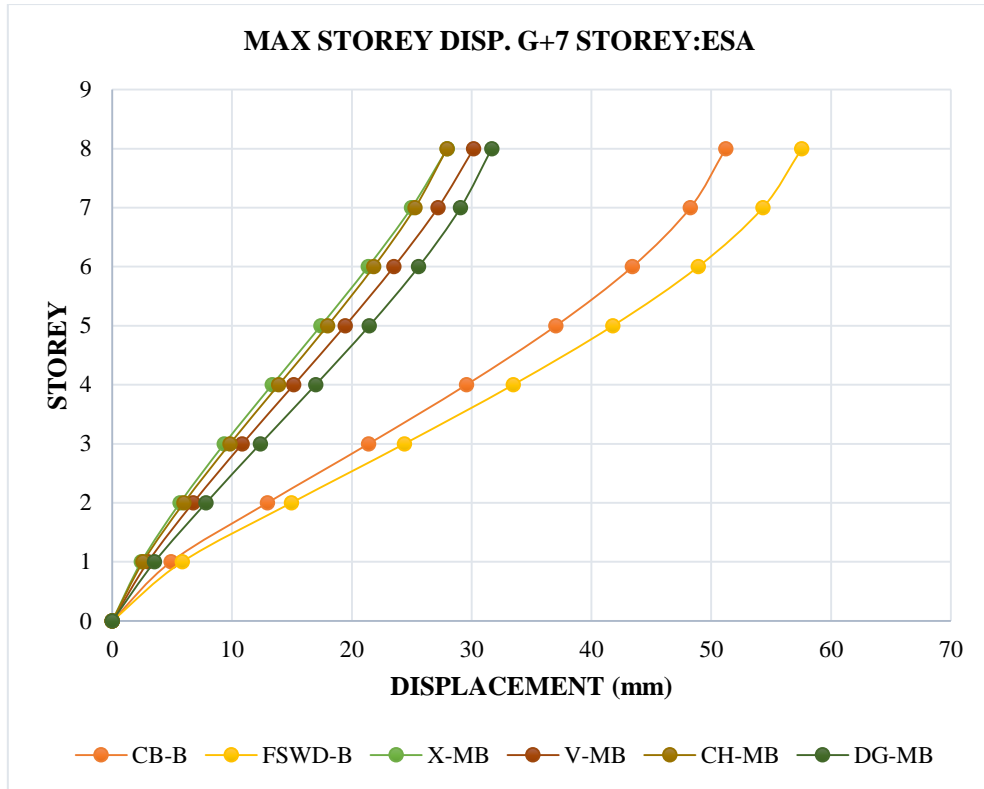


Figure A: 7 Max. Storey Displacement, Middle Bays Bracings, G+7 Storey due to ESA

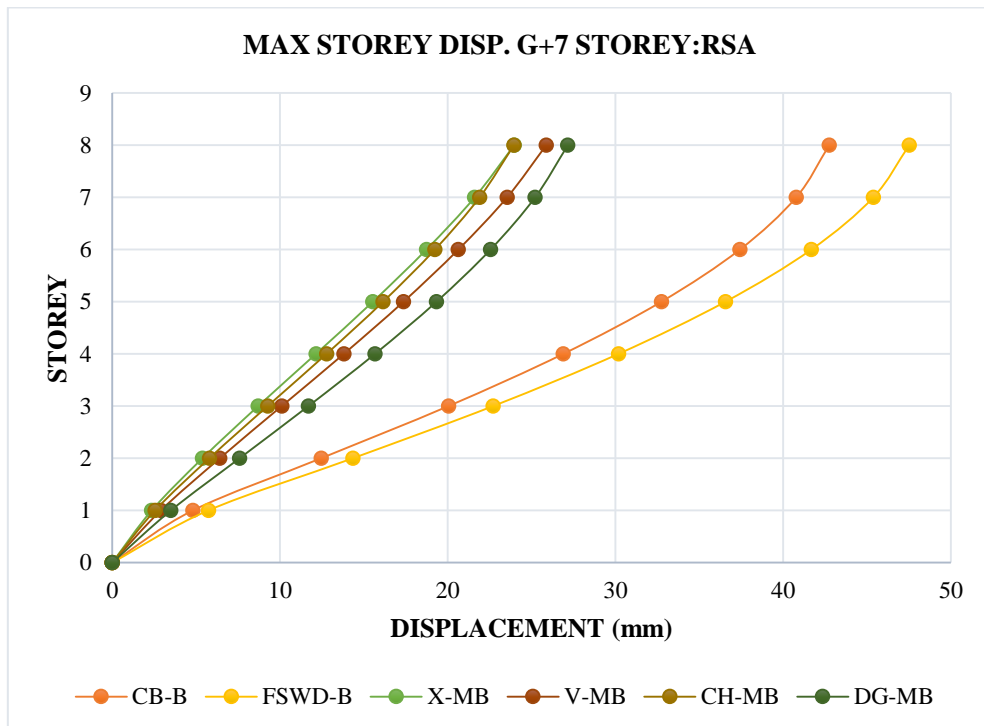


Figure A: 8 Max. Storey Displacement, Middle Bays Bracings, G+7 Storey due to RSA

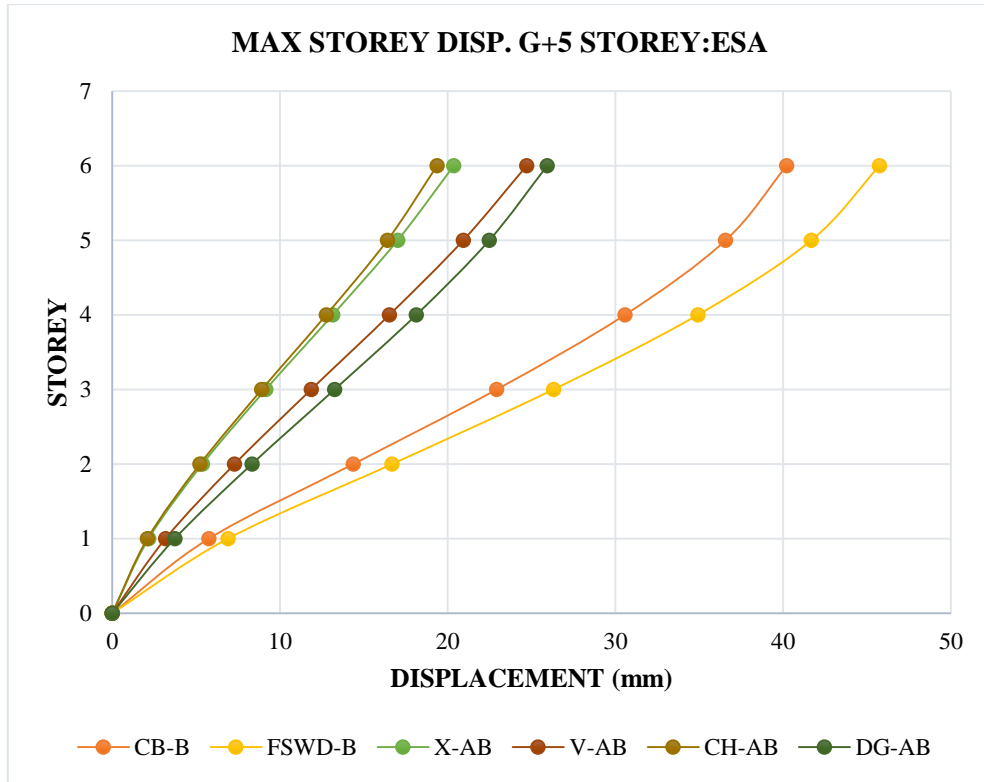


Figure A: 9 Max. Storey Displacement, Alternate Bays Bracings, G+5 Storey due to ESA

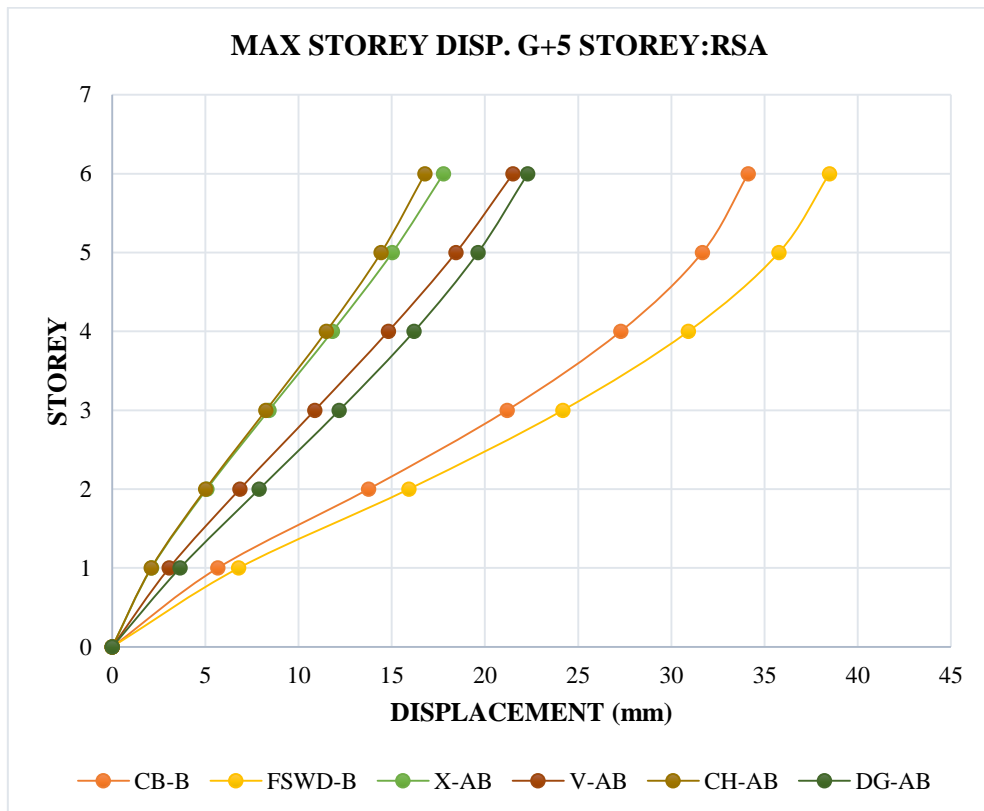


Figure A: 10 Max. Storey Displacement, Alternate Bays Bracings, G+5 Storey due to RSA

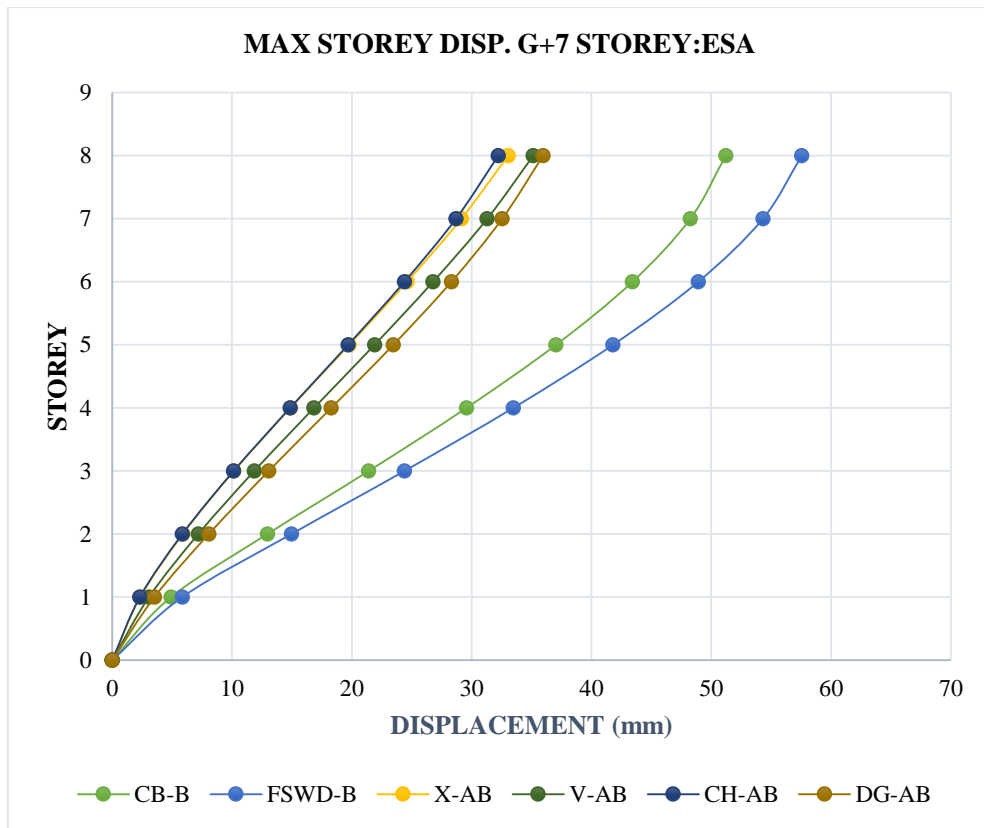


Figure A: 11 Max. Storey Displacement, Alternate Bays Bracings, G+7 Storey due to ESA

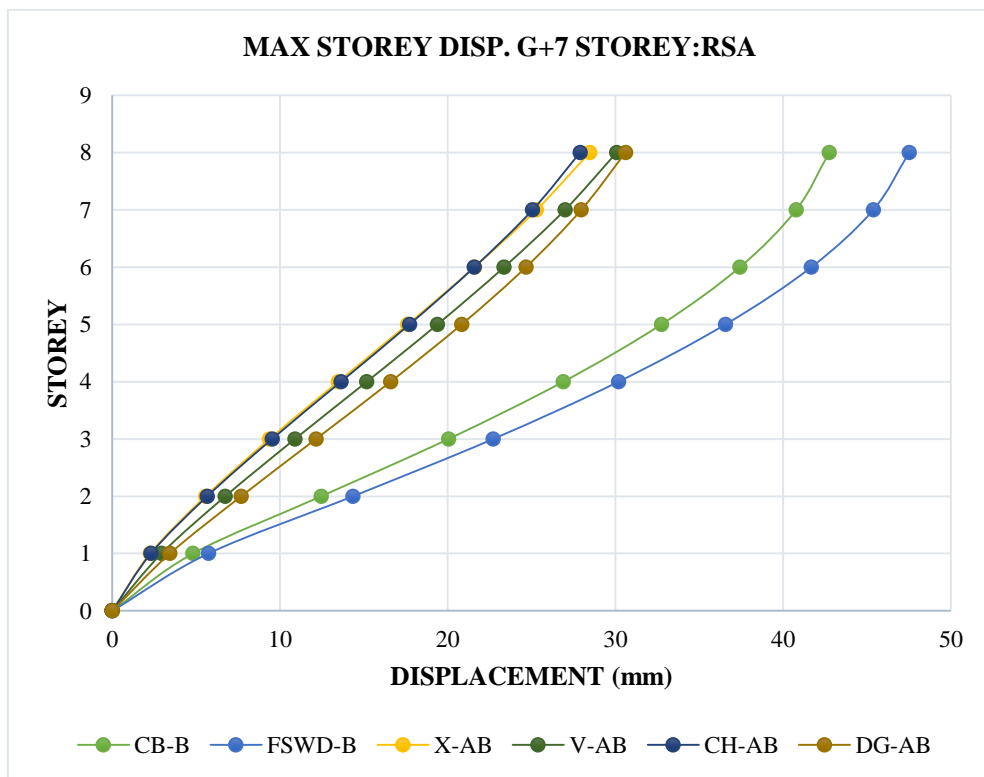


Figure A: 12 Max. Storey Displacement, Alternate Bays Bracings, G+7 Storey due to RSA

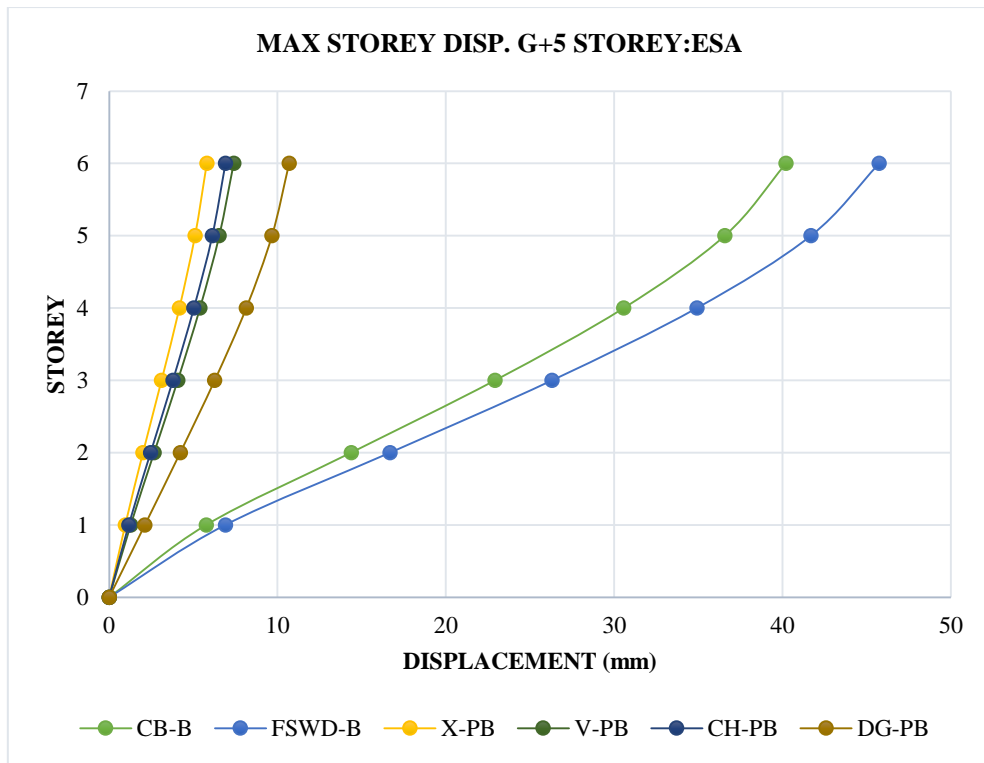


Figure A: 13 Max. Storey Displacement, Peripheral Bays Bracings, G+5 Storey due to ESA

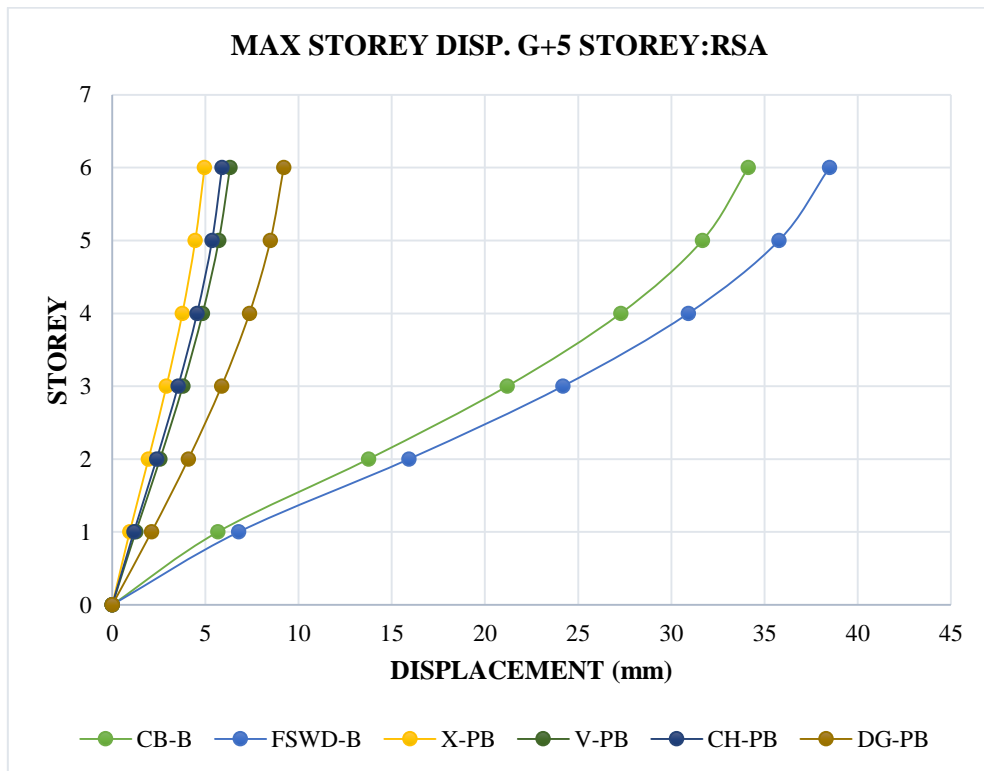


Figure A: 14 Max. Storey Displacement, Alternate Bays Bracings, G+5 Storey due to RSA

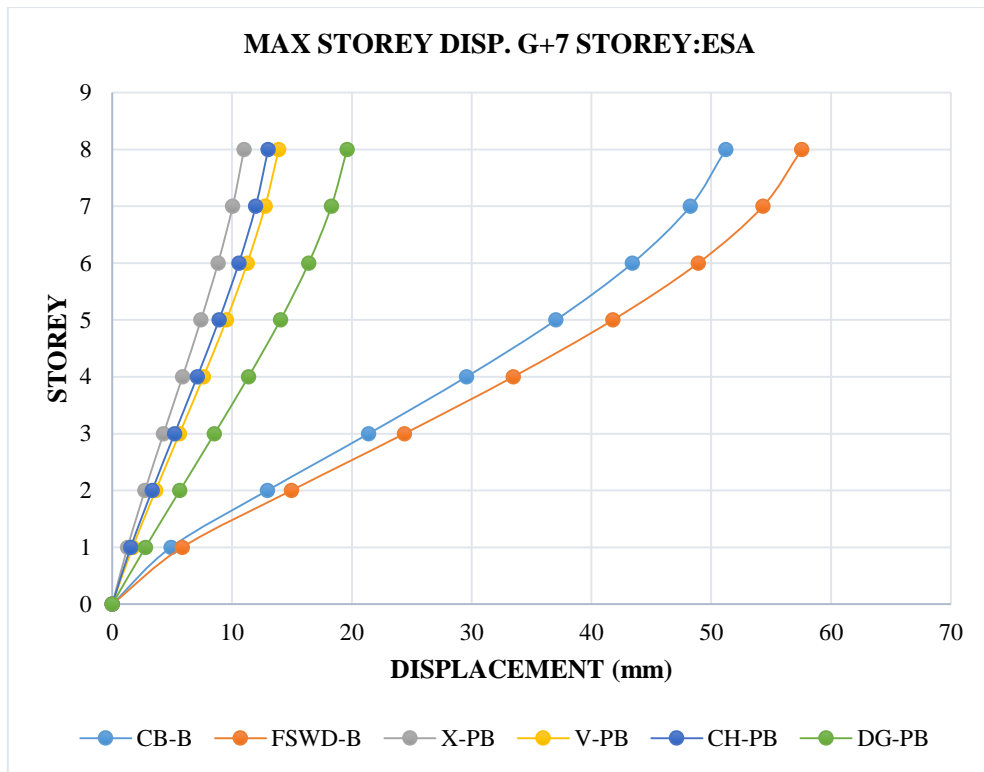


Figure A: 15 Max. Storey Displacement, Peripheral Bays Bracings, G+7 Storey due to ESA

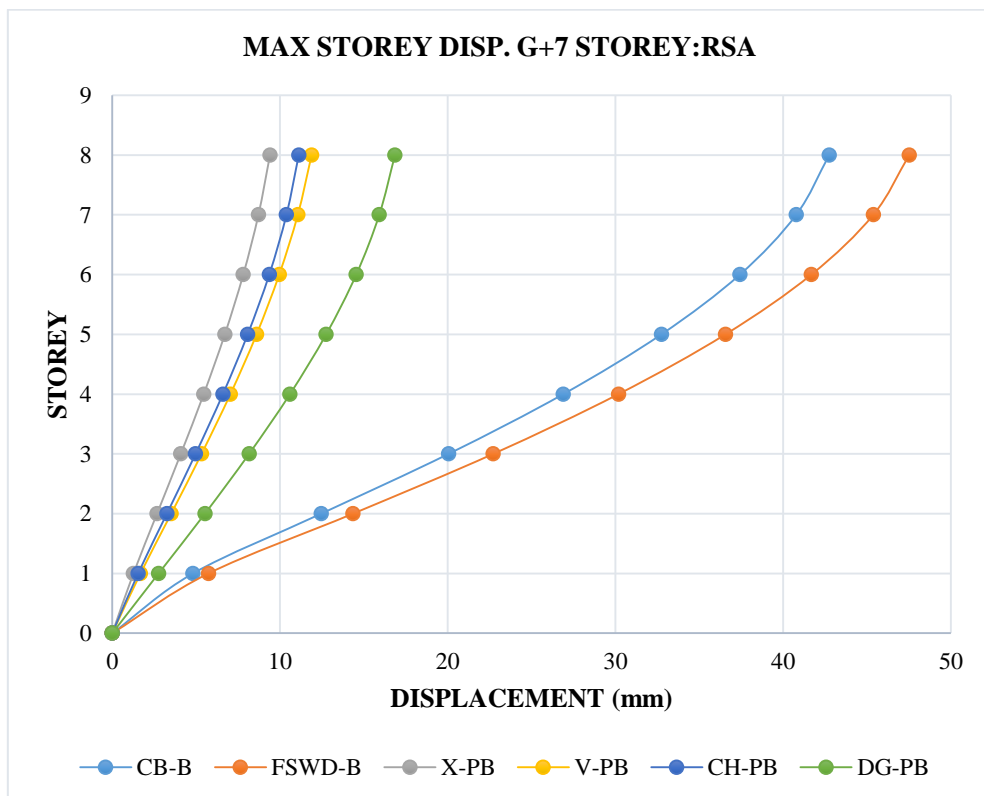


Figure A: 16 Max. Storey Displacement, Peripheral Bays Bracings, G+7 Storey due to RSA

## APPENDIX B

Inter storey drift ratio plots for various braced models with storey level G+5 and G+7 are presented here.

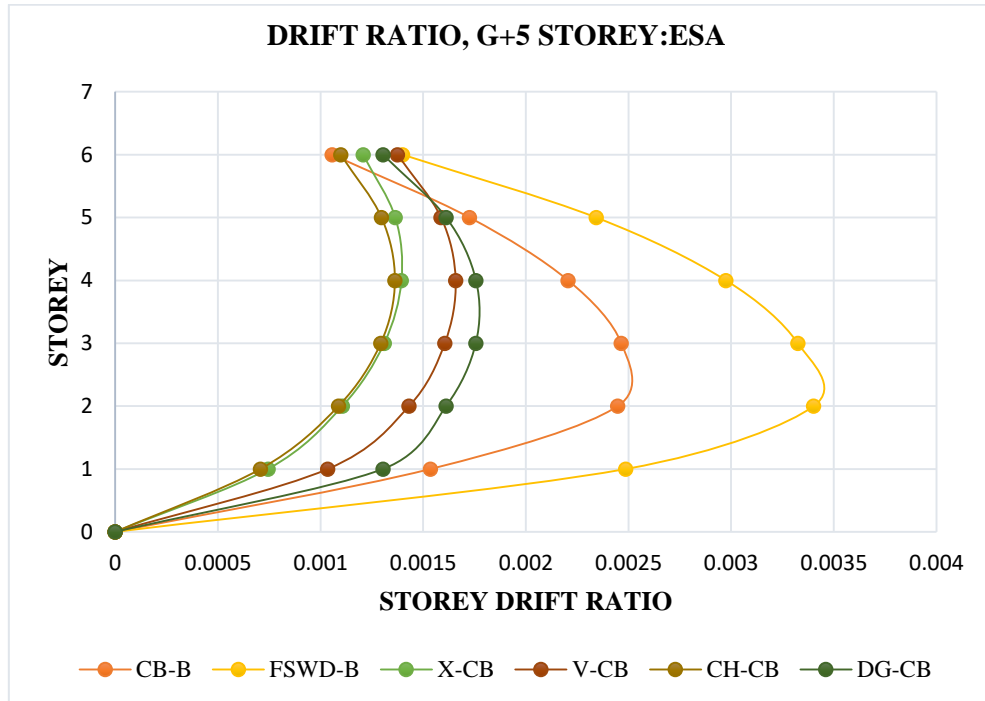


Figure B: 1 Drift Ratio, Corner Bays Bracings, G+5 Storey due to ESA

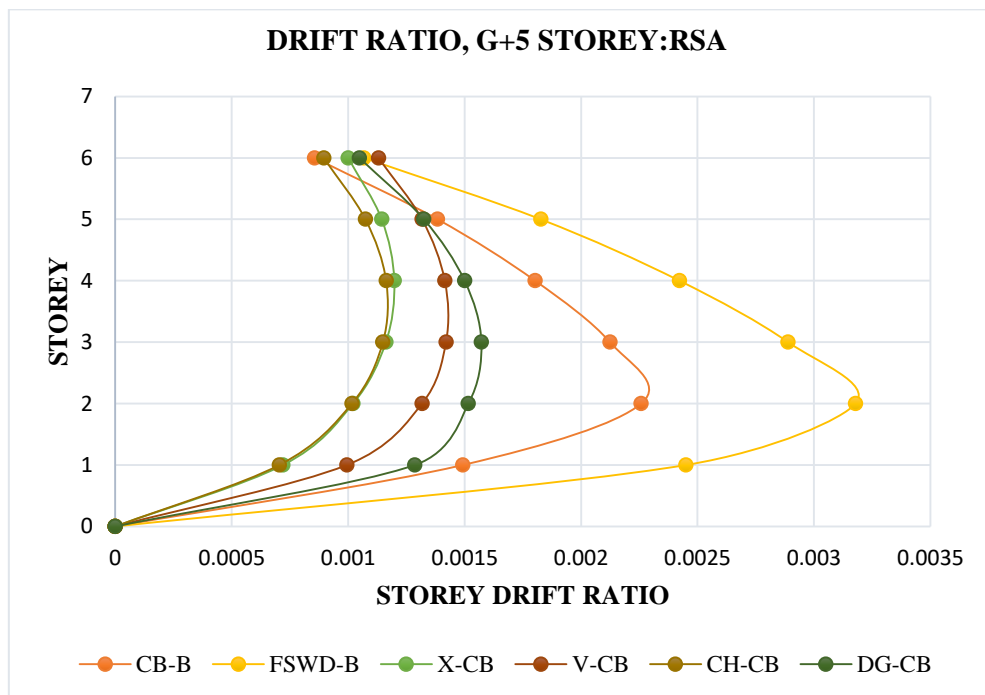


Figure B: 2 Drift Ratio, Corner Bays Bracings, G+5 Storey due to RSA

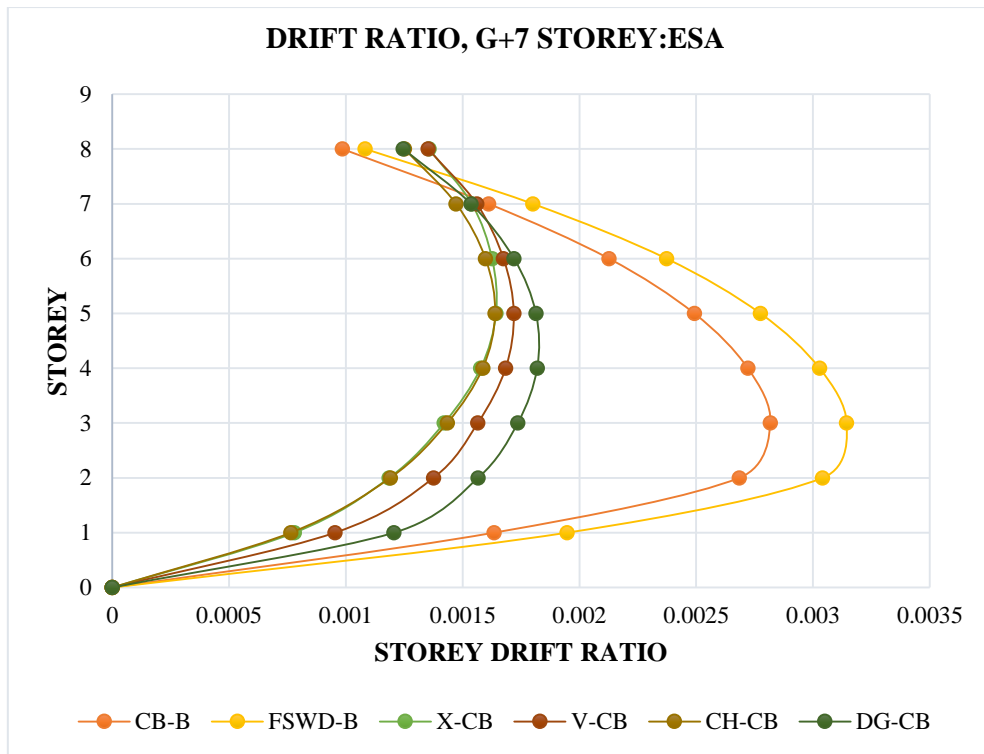


Figure B: 3 Drift Ratio, Corner Bays Bracings, G+7 Storey due to ESA

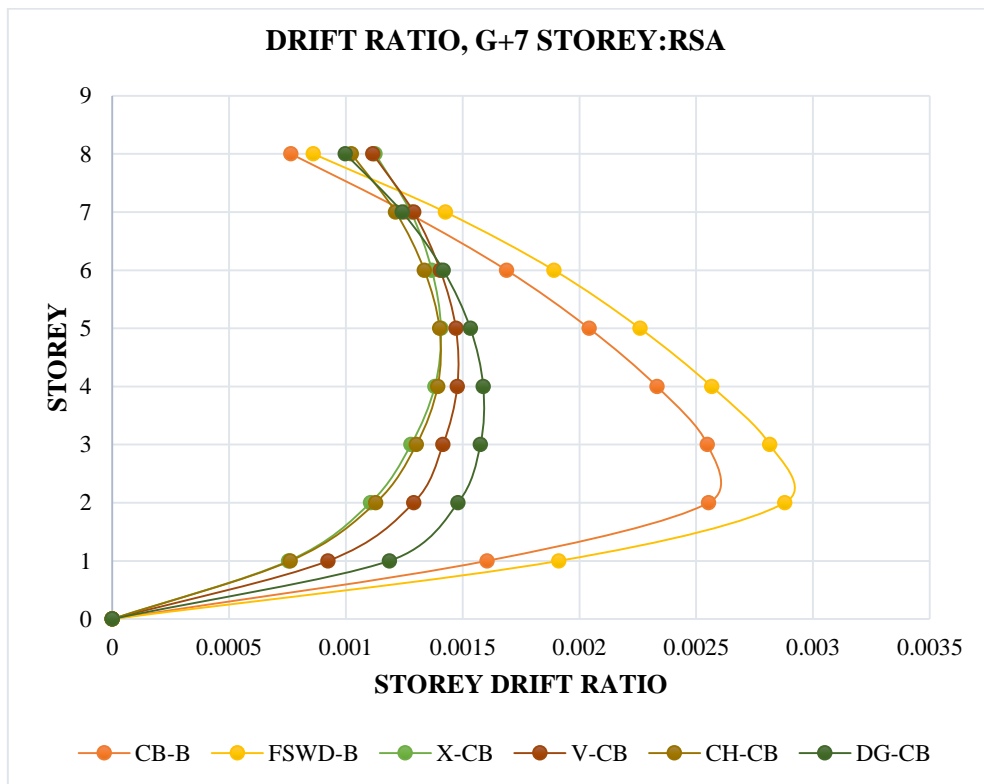


Figure B: 4 Drift Ratio, Corner Bays Bracings, G+7 Storey due to RSA

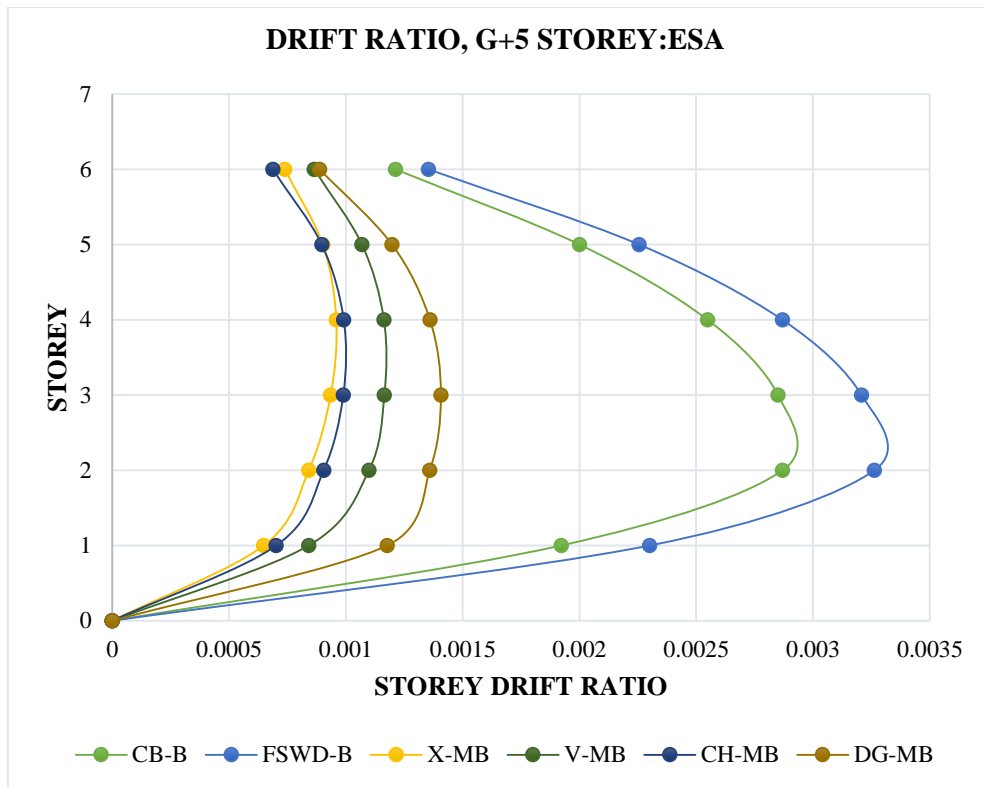


Figure B: 5 Drift Ratio, Middle Bays Bracings, G+5 Storey due to ESA

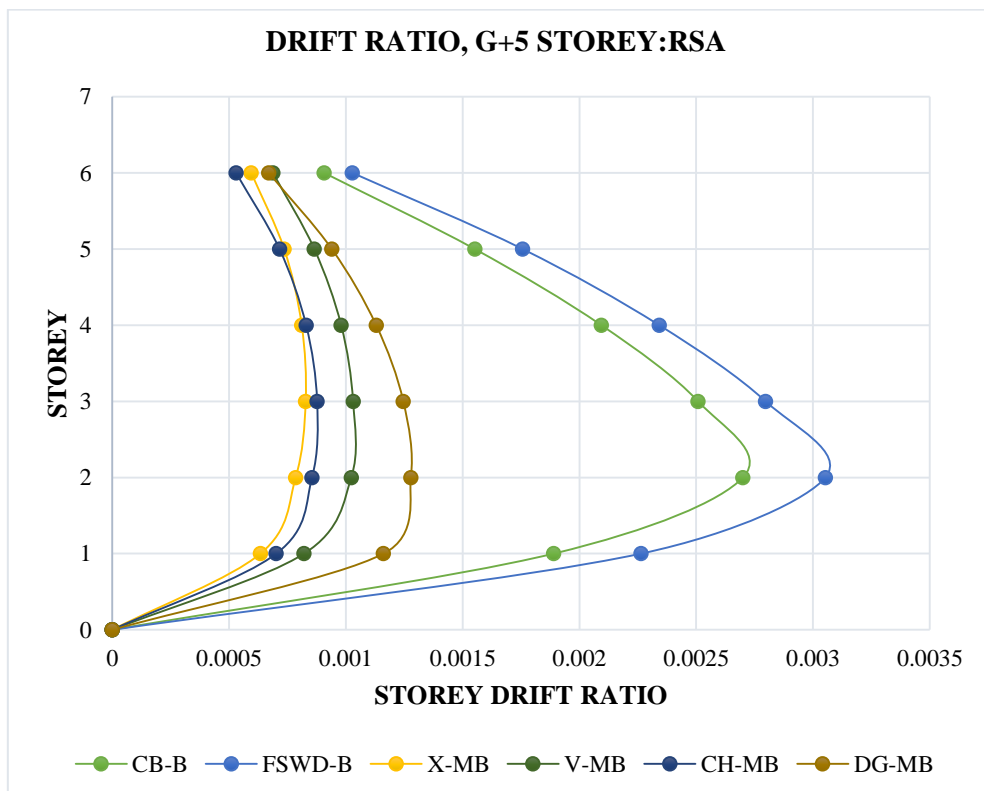


Figure B: 6 Drift Ratio, Middle Bays Bracings, G+5 Storey due to RSA

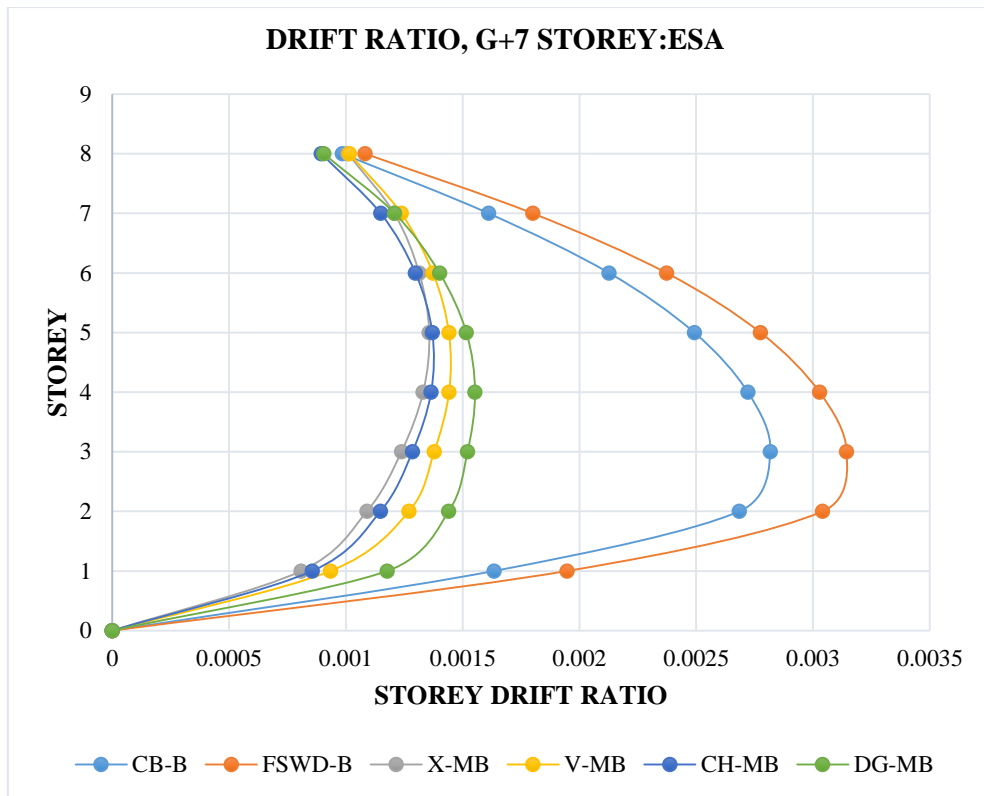


Figure B: 7 Drift Ratio, Middle Bays Bracings, G+7 Storey due to ESA

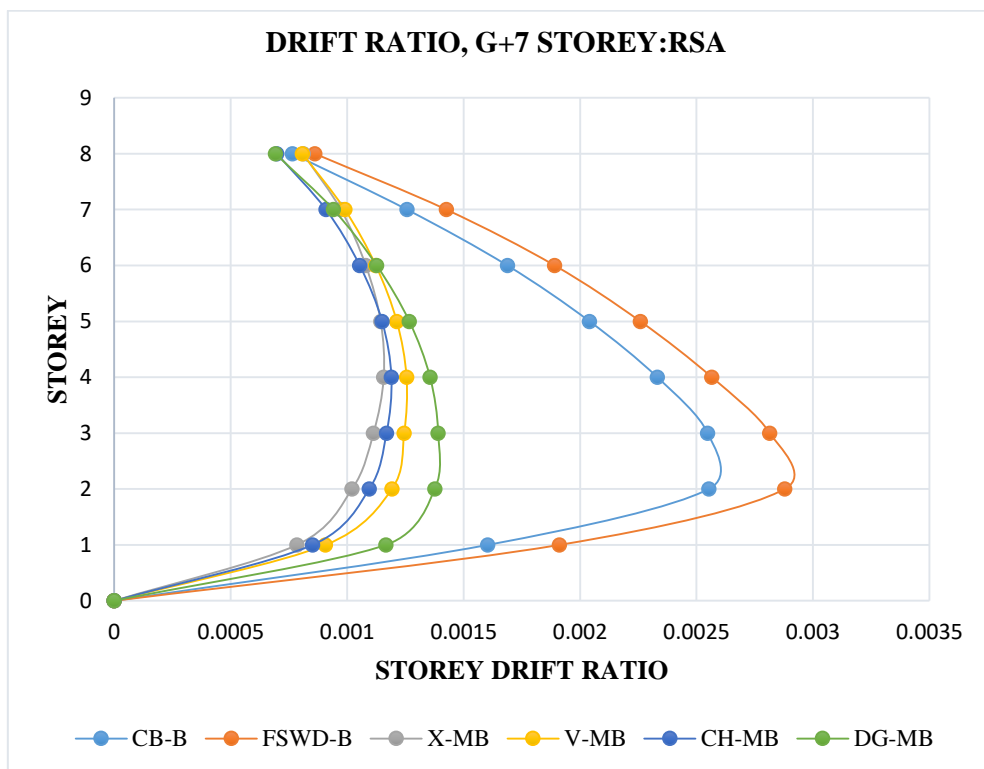


Figure B: 8 Drift Ratio, Middle Bays Bracings, G+7 Storey due to RSA

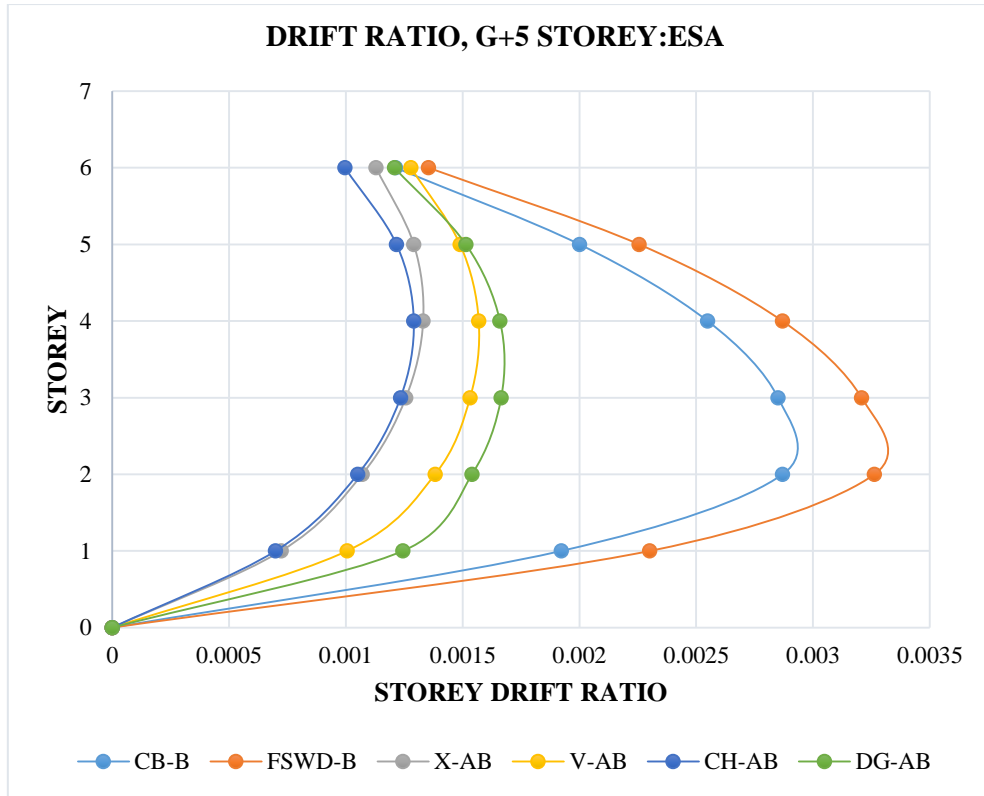


Figure B: 9 Drift Ratio, Alternate Bays Bracings, G+5 Storey due to ESA

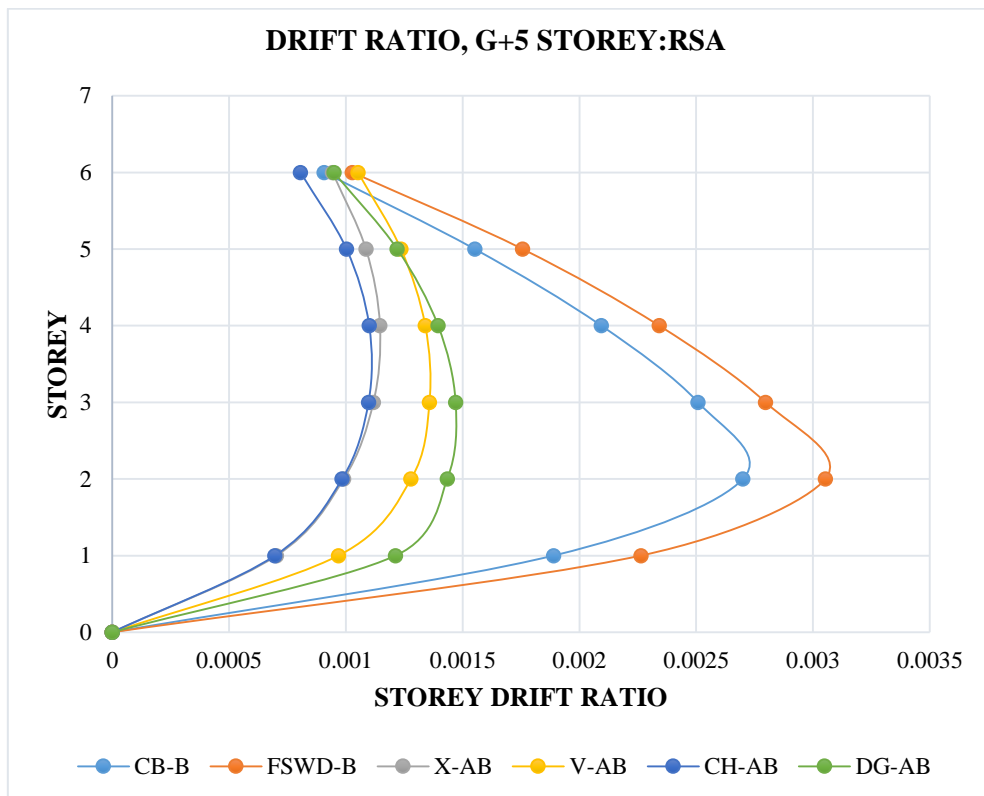


Figure B: 10 Drift Ratio, Alternate Bays Bracings, G+5 Storey due to RSA

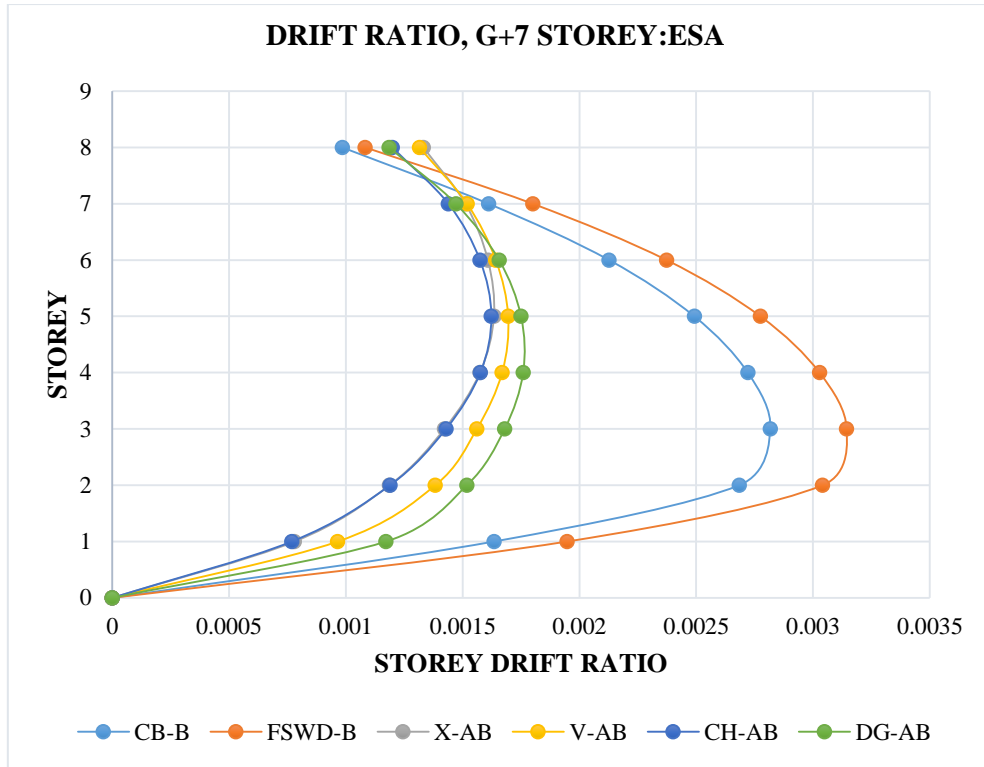


Figure B: 11 Drift Ratio, Alternate Bays Bracings, G+7 Storey due to ESA

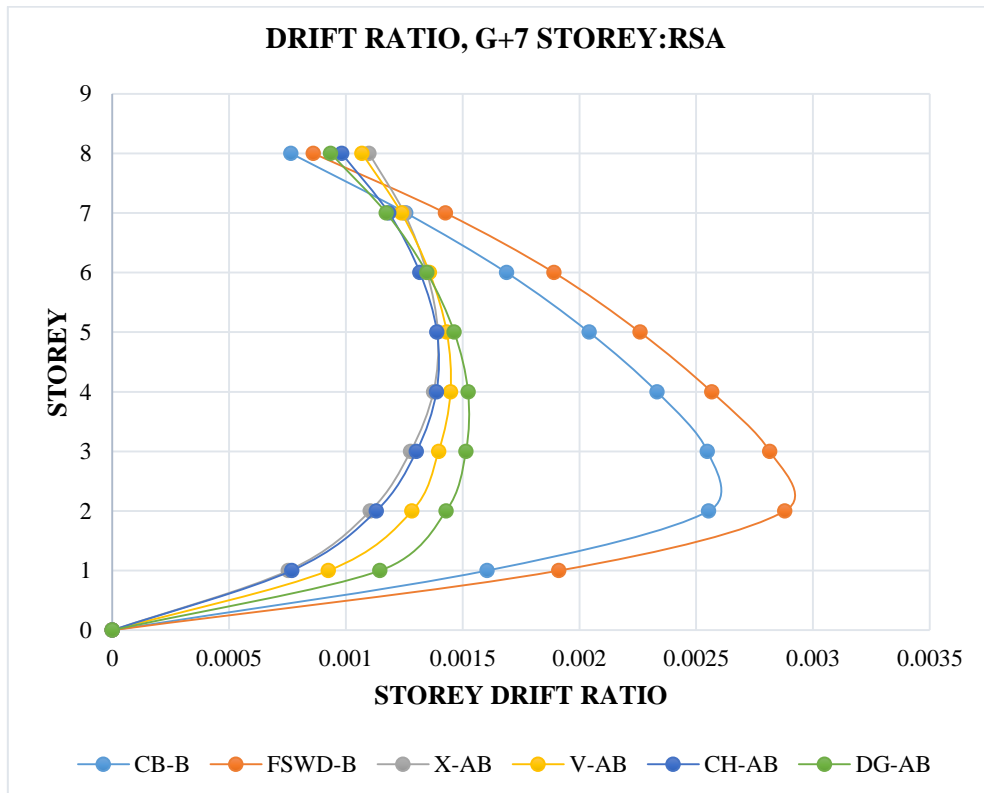


Figure B: 12 Drift Ratio, Alternate Bays Bracings, G+7 Storey due to RSA

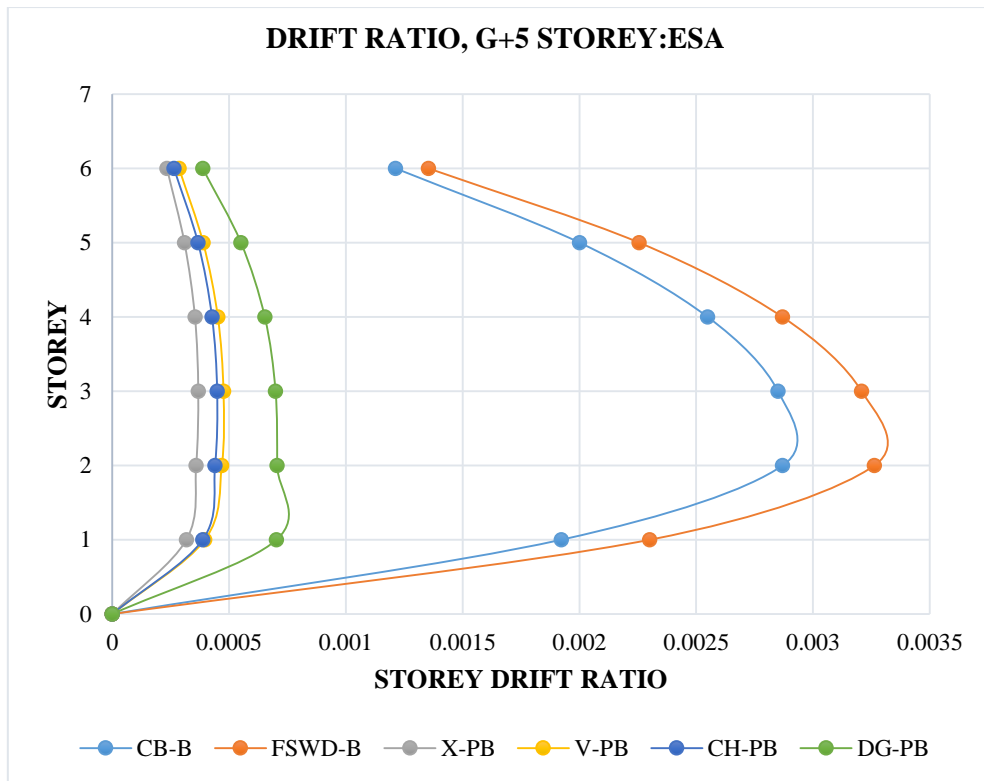


Figure B: 13 Drift Ratio, Peripheral Bays Bracings, G+5 Storey due to ESA

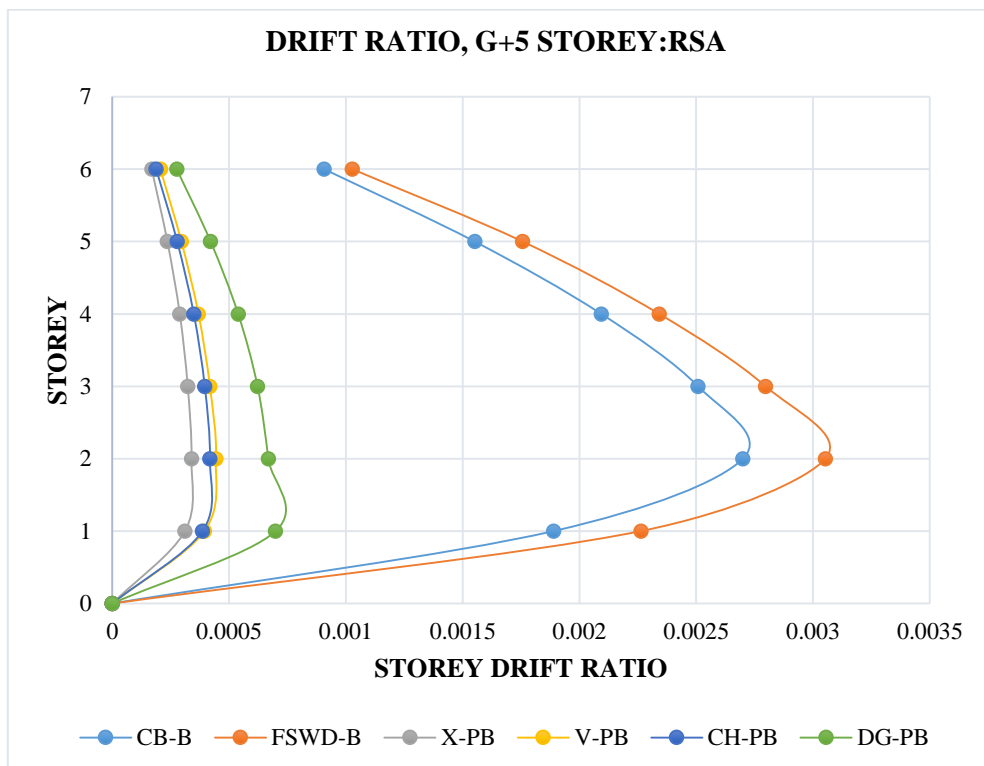


Figure B: 14 Drift Ratio, Peripheral Bays Bracings, G+5 Storey due to RSA

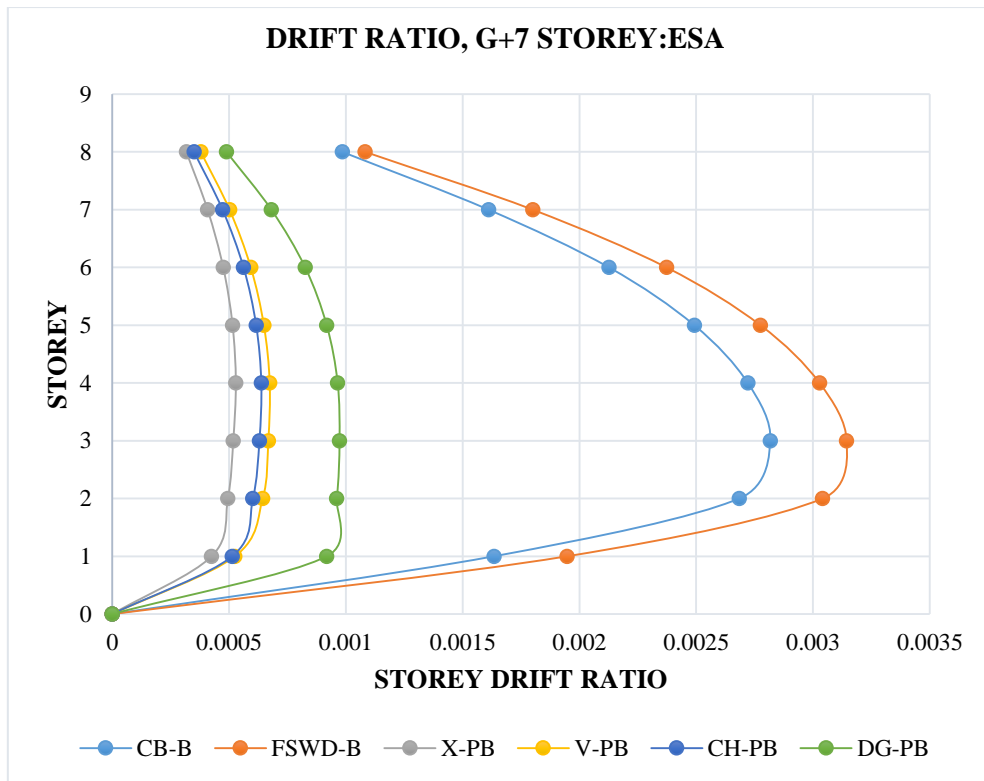


Figure B: 15 Drift Ratio, Peripheral Bays Bracings, G+7 Storey due to ESA

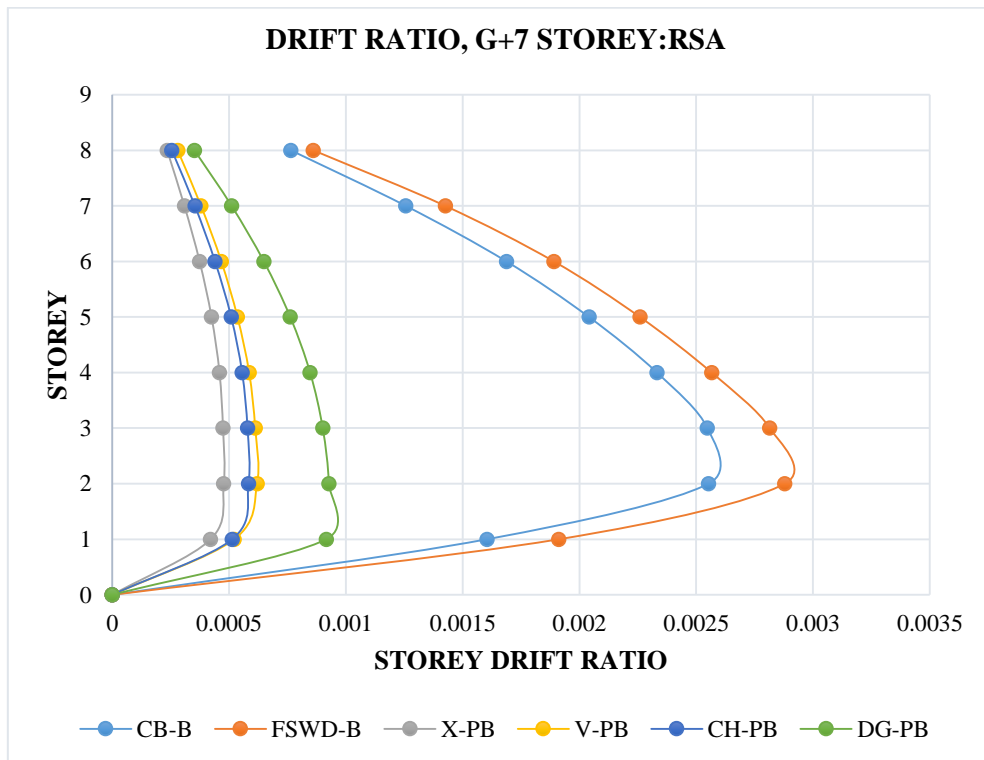


Figure B: 16 Drift Ratio, Peripheral Bays Bracings, G+7 Storey due to RSA

## APPENDIX C

Maximum Storey Displacement plots for various braced models with different configurations of two different types of bracings for storey level G+5 and G+7 are presented here.

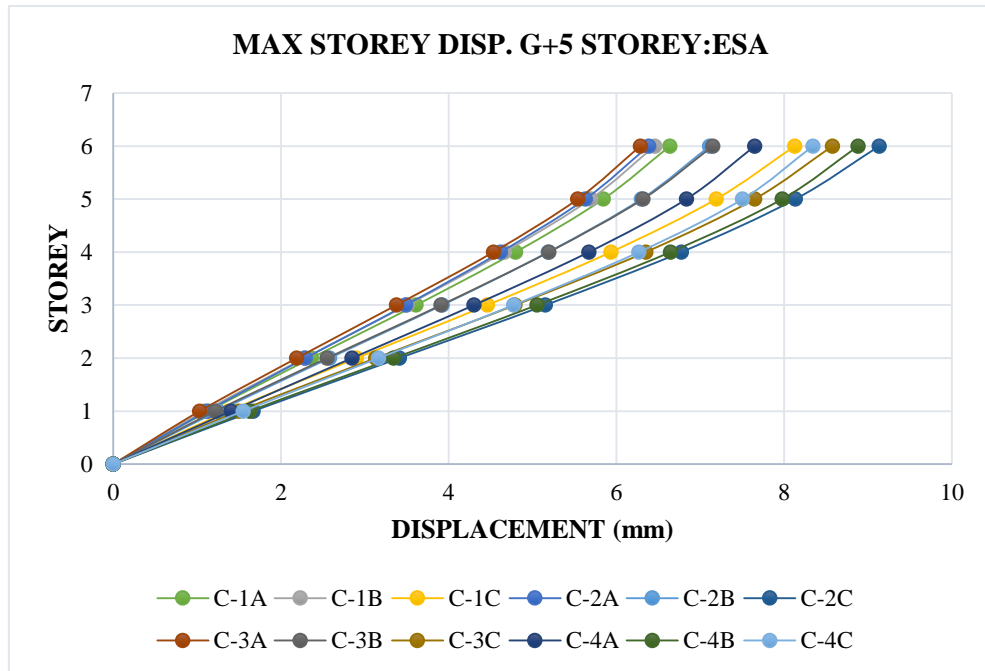


Figure C: 1 Max. Storey Displacement for different bracings configurations due to ESA, G+5 Storey

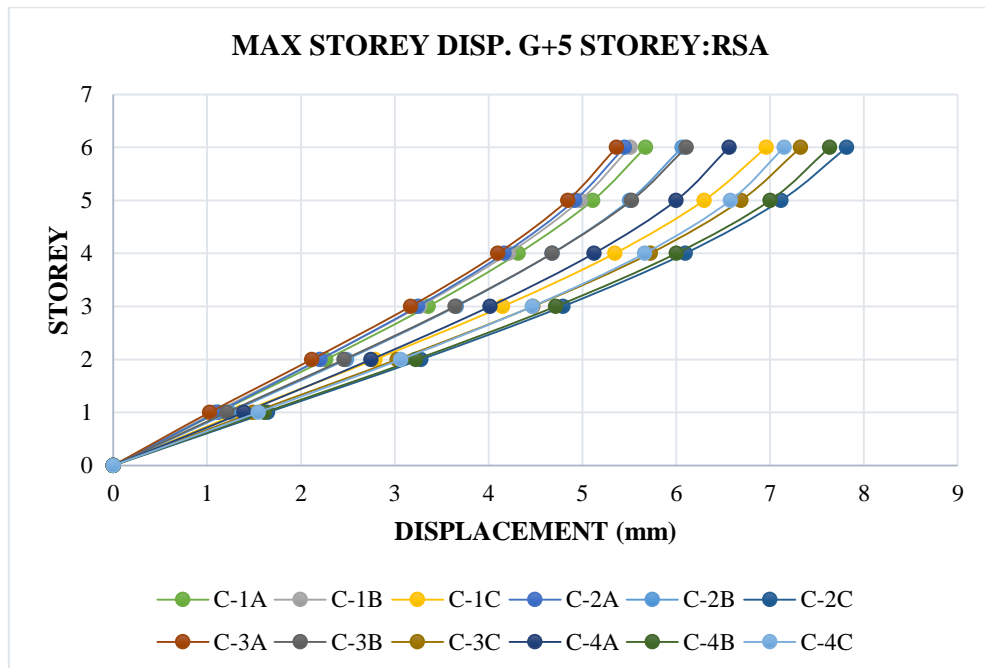


Figure C: 2 Max. Storey Displacement for different bracings configurations due to RSA, G+5 Storey

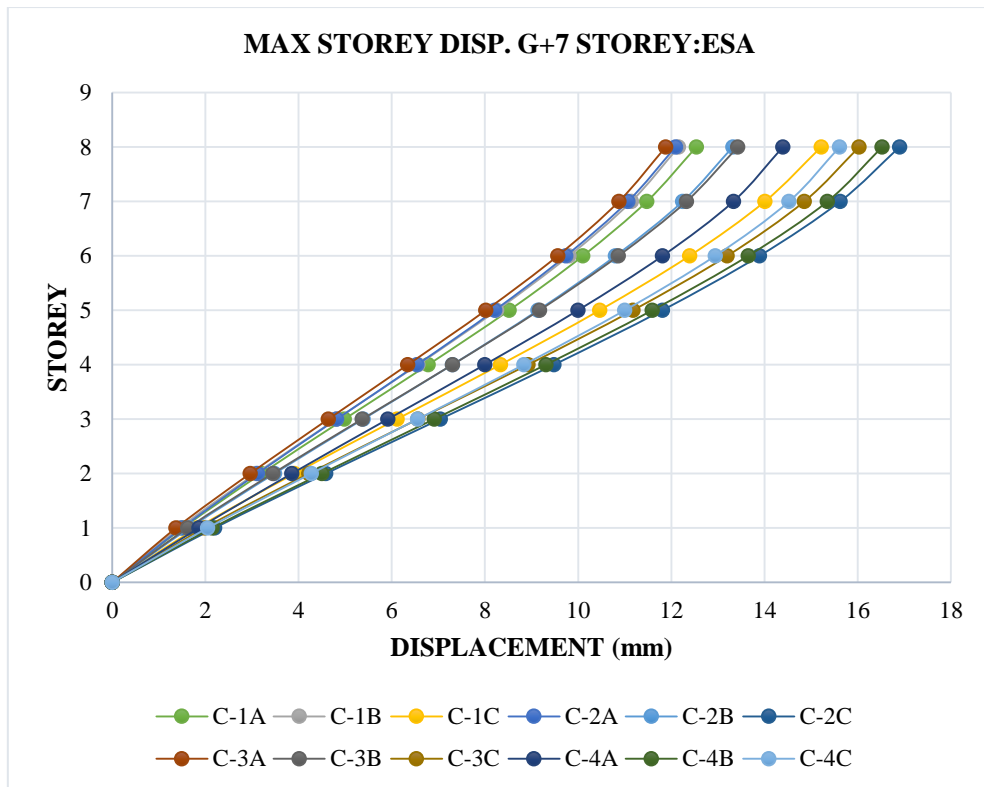


Figure C: 3 Max. Storey Displacement for different bracings configurations due to ESA, G+7 Storey

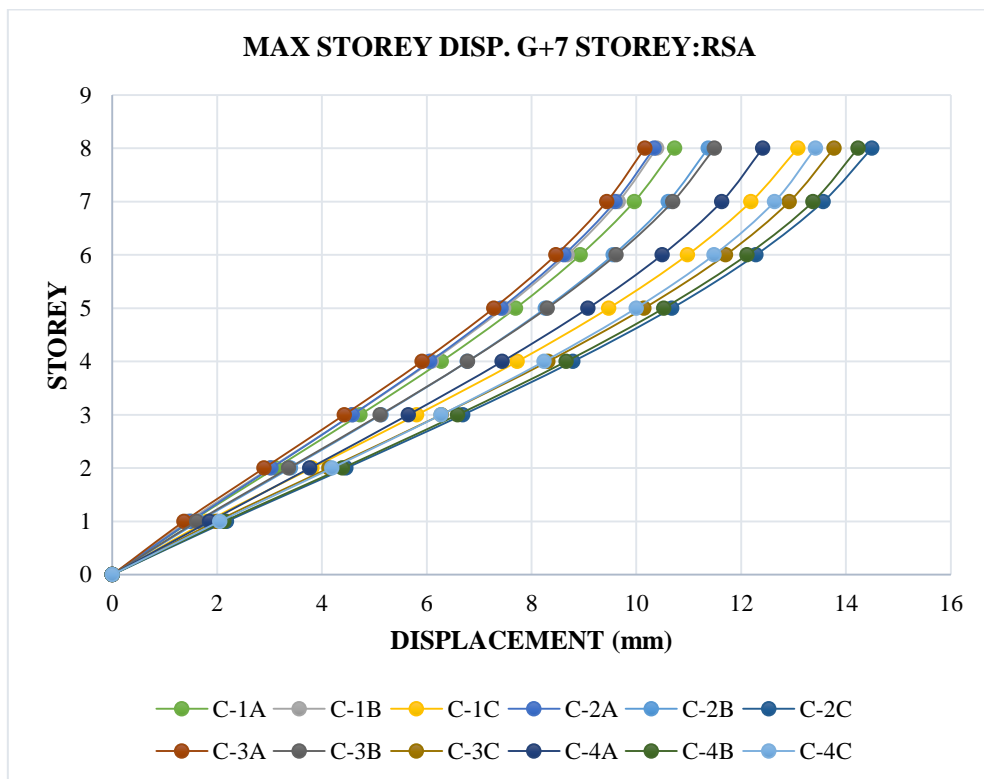


Figure C: 4 Max. Storey Displacement for different bracings configurations due to RSA, G+7 Storey

## APPENDIX D

Inter storey drift ratio plots for various configuration of bracings with storey level G+5 and G+7 are presented here.

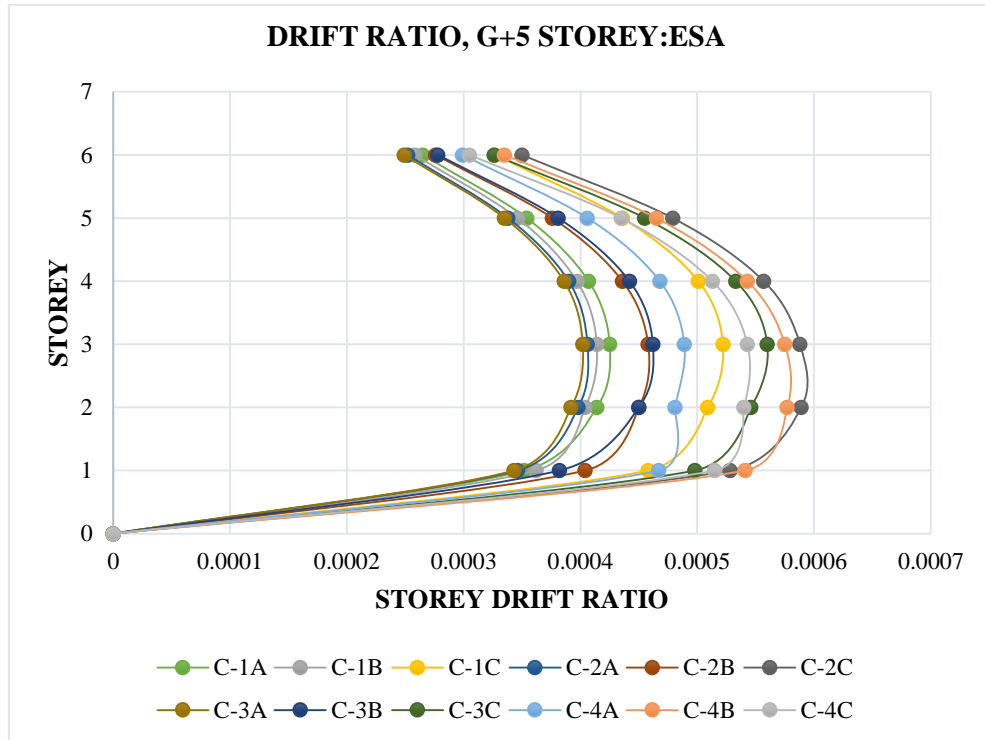


Figure D: 1 Drift Ratio for different configuration of bracings due to ESA, G+5 Storey

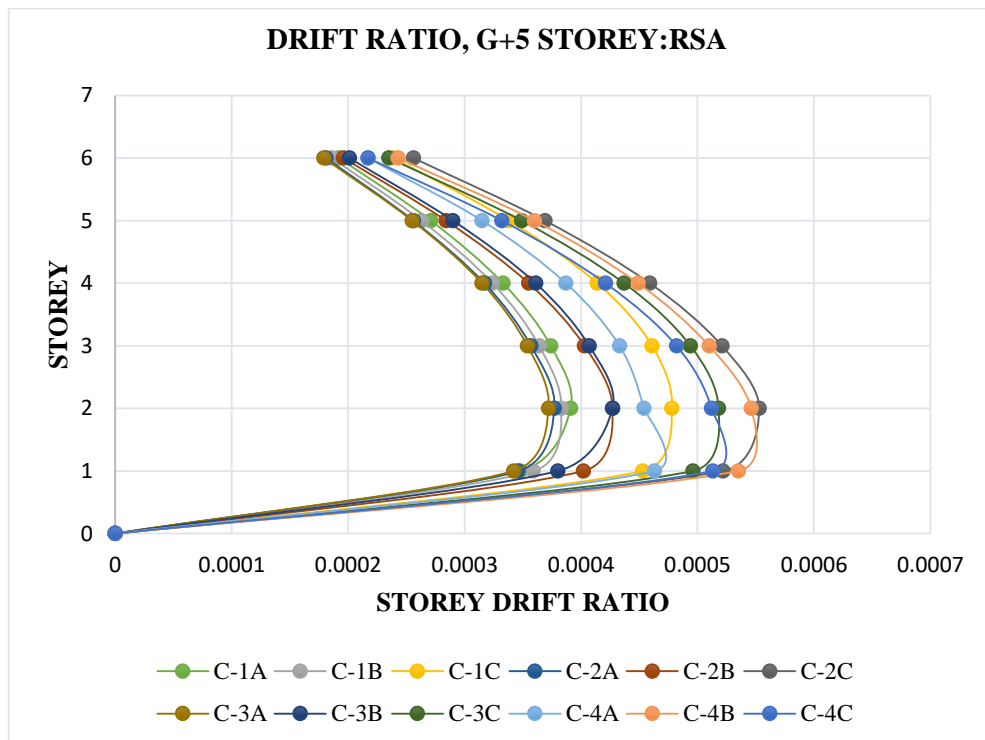


Figure D: 2 Drift Ratio for different configuration of bracings due to RSA, G+5 Storey

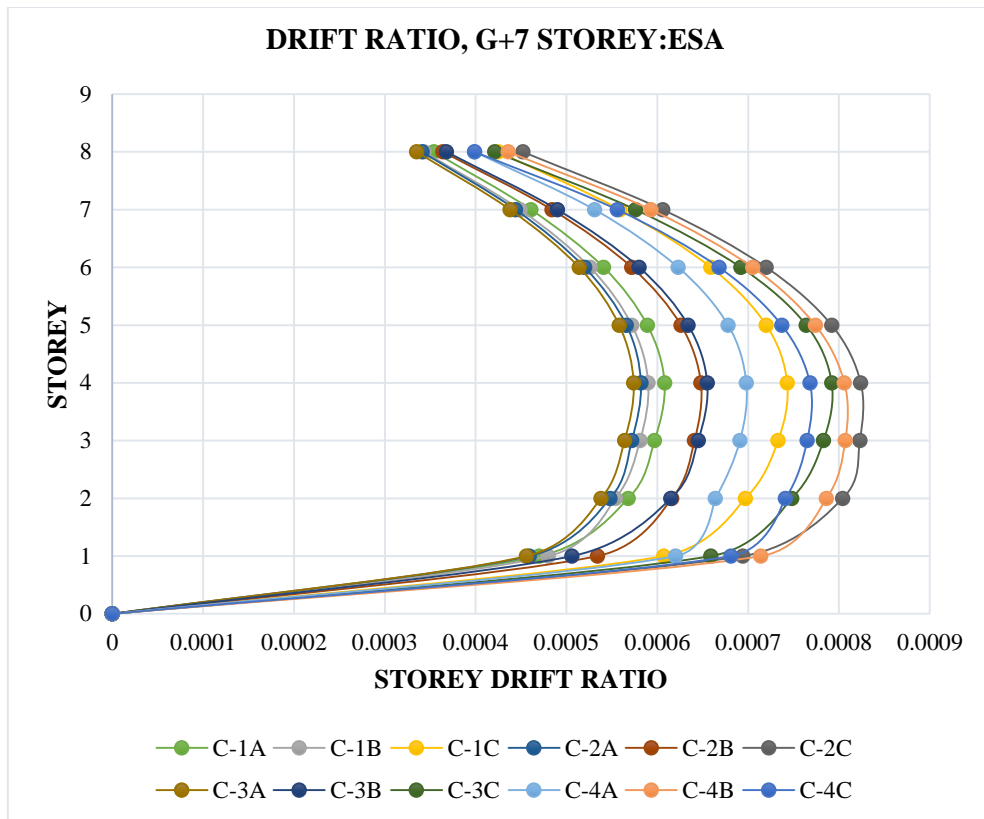


Figure D: 3 Drift Ratio for different configuration of bracings due to ESA, G+7 Storey

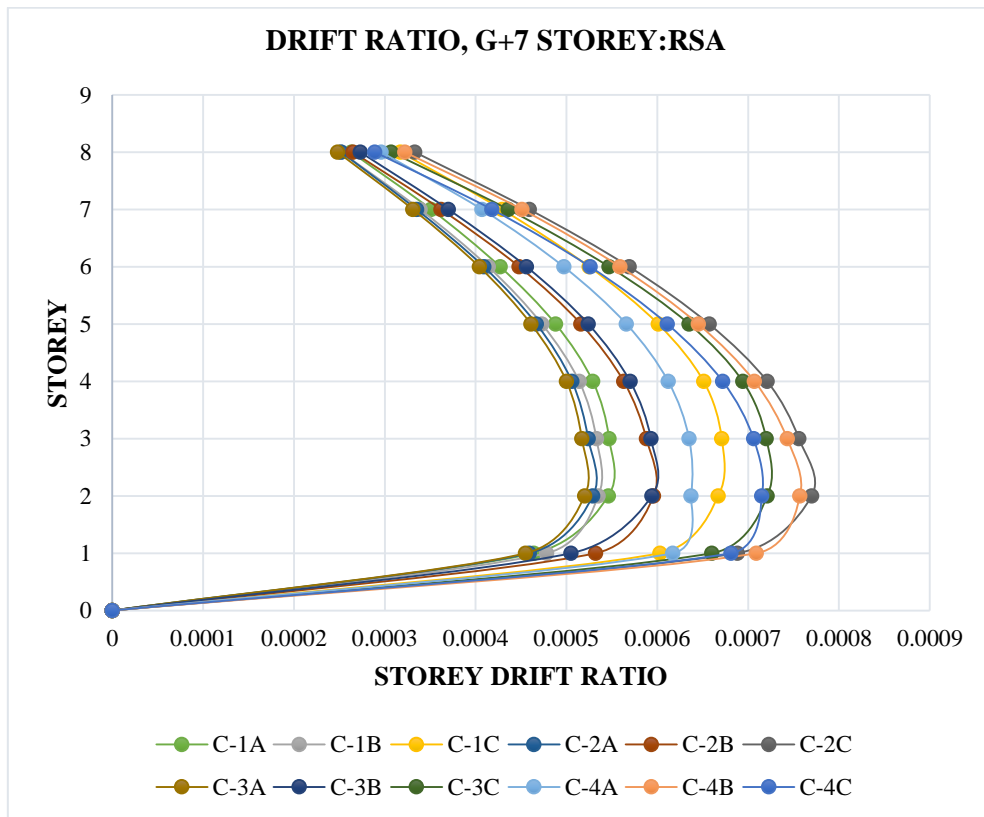


Figure D: 4 Drift Ratio for different configuration of bracings due to RSA, G+7 Storey

## APPENDIX E

The maximum storey displacement values for each storey level and different types of braces at different bays are presented here.

Table E: 1 Maximum Storey Displacement (mm), Corner Bays Bracings, G+5 storey due to ESA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
6	40.213	45.751	26.777	20.2	24.6	19.513
5	36.574	41.689	23.208	16.839	20.778	16.467
4	30.573	34.919	18.701	13.001	16.352	12.792
3	22.925	26.31	13.686	9.055	11.714	8.922
2	14.376	16.687	8.61	5.328	7.184	5.235
1	5.766	6.902	3.861	2.161	3.117	2.098
0	0	0	0	0	0	0

Table E: 2 Maximum Storey Displacement (mm), Corner Bays Bracings, G+5 storey due to RSA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
6	34.134	38.491	23.379	17.565	21.401	16.989
5	31.667	35.778	20.561	14.825	18.31	14.559
4	27.286	30.919	16.944	11.655	14.66	11.571
3	21.191	24.18	12.743	8.305	10.735	8.294
2	13.75	15.918	8.256	5.02	6.747	5.029
1	5.666	6.789	3.809	2.097	3.001	2.097
0	0	0	0	0	0	0

Table E: 3 Maximum Storey Displacement (mm), Corner Bays Bracings, G+7 storey due to ESA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
8	51.21	57.562	37.385	33.32	35.592	32.664
7	48.256	54.314	33.764	29.286	31.58	28.967
6	43.423	48.915	29.299	24.67	26.916	24.552
5	37.043	41.796	24.245	19.792	21.94	19.759
4	29.567	33.47	18.882	14.862	16.818	14.857
3	21.404	24.387	13.484	10.132	11.794	10.118
2	12.953	14.956	8.324	5.872	7.117	5.833
1	4.901	5.84	3.627	2.336	3.022	2.292
0	0	0	0	0	0	0

Table E: 4 Maximum Storey Displacement (mm), Corner Bays Bracings, G+7 storey due to RSA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
8	42.752	47.522	32.102	28.784	30.815	28.217
7	40.782	45.38	29.249	25.485	27.558	25.246
6	37.427	41.688	25.739	21.704	23.753	21.684
5	32.745	36.565	21.689	17.657	19.642	17.75
4	26.896	30.187	17.257	13.484	15.32	13.611
3	20.051	22.714	12.621	9.375	10.956	9.493
2	12.462	14.354	7.989	5.556	6.752	5.63
1	4.813	5.737	3.567	2.264	2.931	2.287

0	0	0	0	0	0	0
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Table E: 5 Maximum Storey Displacement (mm), Corner Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
10	53.523	69.682	48.301	43.882	46.233	43.159
9	51.344	66.864	44.643	39.744	42.179	39.361
8	47.831	62.307	40.239	35.024	37.477	34.876
7	43.149	56.209	35.245	29.999	32.44	29.982
6	37.562	48.906	29.848	24.793	27.152	24.835
5	31.316	40.718	24.234	19.568	21.773	19.63
4	24.627	31.931	18.595	14.503	16.473	14.551
3	17.682	22.798	13.12	9.787	11.43	9.804
2	10.682	13.611	8	5.627	6.829	5.606
1	4.077	5.053	3.389	2.2	2.841	2.167
0	0	0	0	0	0	0

Table E: 6 Maximum Storey Displacement (mm), Corner Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
10	44.428	56.314	40.534	36.365	38.471	35.895
9	42.987	54.456	37.685	33.096	35.283	32.921
8	40.611	51.411	34.287	29.378	31.601	29.422
7	37.322	47.232	30.413	25.407	27.626	25.586
6	33.212	42.048	26.162	21.253	23.42	21.499
5	28.371	35.96	21.638	17.021	19.068	17.283
4	22.882	29.034	16.956	12.835	14.681	13.08
3	16.833	21.342	12.242	8.839	10.388	9.032
2	10.386	13.078	7.646	5.201	6.34	5.319
1	4.026	4.952	3.316	2.086	2.698	2.129
0	0	0	0	0	0	0

Table E: 7 Maximum Storey Displacement (mm), Middle Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
6	40.213	45.751	21.75	15.04	18.536	15.408
5	36.574	41.689	19.228	12.827	15.977	13.359
4	30.573	34.919	15.766	10.123	12.822	10.679
3	22.925	26.31	11.764	7.246	9.382	7.743
2	14.376	16.687	7.591	4.441	5.916	4.798
1	5.766	6.902	3.53	1.943	2.673	2.107
0	0	0	0	0	0	0

Table E: 8 Maximum Storey Displacement (mm), Middle Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
6	34.134	38.491	18.706	13.027	16.037	13.289
5	31.667	35.778	16.835	11.283	14.041	11.743
4	27.286	30.919	14.183	9.11	11.508	9.644
3	21.191	24.18	10.923	6.705	8.643	7.211
2	13.75	15.918	7.28	4.239	5.605	4.628

1	5.666	6.789	3.482	1.902	2.601	2.106
0	0	0	0	0	0	0

Table E: 9 Maximum Storey Displacement (mm), Middle Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
8	51.21	57.562	31.677	27.966	30.175	27.944
7	48.256	54.314	29.077	24.981	27.189	25.273
6	43.423	48.915	25.579	21.36	23.511	21.832
5	37.043	41.796	21.463	17.417	19.443	17.974
4	29.567	33.47	16.978	13.346	15.156	13.894
3	21.404	24.387	12.361	9.354	10.856	9.821
2	12.953	14.956	7.83	5.653	6.743	5.978
1	4.901	5.84	3.53	2.424	2.985	2.567
0	0	0	0	0	0	0

Table E: 10 Maximum Storey Displacement (mm), Middle Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
8	42.752	47.522	27.165	23.97	25.879	23.952
7	40.782	45.38	25.213	21.611	23.543	21.905
6	37.427	41.688	22.557	18.734	20.638	19.241
5	32.745	36.565	19.336	15.54	17.367	16.151
4	26.896	30.187	15.669	12.146	13.811	12.778
3	20.051	22.714	11.7	8.702	10.107	9.263
2	12.462	14.354	7.596	5.381	6.415	5.791
1	4.813	5.737	3.498	2.353	2.898	2.554
0	0	0	0	0	0	0

Table E: 11 Maximum Storey Displacement (mm), Middle Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
10	53.523	69.682	40.704	36.621	39.001	36.594
9	51.344	66.864	38.141	33.58	36.018	33.881
8	47.831	62.307	34.758	29.925	32.369	30.454
7	43.149	56.209	30.778	25.927	28.329	26.584
6	37.562	48.906	26.362	21.706	23.993	22.416
5	31.316	40.718	21.68	17.404	19.505	18.095
4	24.627	31.931	16.895	13.166	15.008	13.782
3	17.682	22.798	12.155	9.14	10.644	9.635
2	10.682	13.611	7.602	5.481	6.549	5.81
1	4.077	5.053	3.321	2.303	2.839	2.444
0	0	0	0	0	0	0

Table E: 12 Maximum Storey Displacement (mm), Middle Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
10	44.428	56.314	34.106	31.14	32.736	31.022
9	42.987	54.456	32.194	28.731	30.428	28.931
8	40.611	51.411	29.675	25.842	27.605	26.294
7	37.322	47.232	26.677	22.656	24.462	23.266

6	33.212	42.048	23.264	19.239	21.029	19.946
5	28.371	35.96	19.524	15.679	17.388	16.41
4	22.882	29.034	15.55	12.08	13.631	12.765
3	16.833	21.342	11.442	8.556	9.861	9.131
2	10.386	13.078	7.313	5.238	6.19	5.641
1	4.026	4.952	3.255	2.242	2.735	2.431
0	0	0	0	0	0	0

Table E: 13 Maximum Storey Displacement (mm), Alternate Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
6	40.213	45.751	25.936	20.365	24.707	19.37
5	36.574	41.689	22.482	17.016	20.929	16.402
4	30.573	34.919	18.129	13.143	16.525	12.761
3	22.925	26.31	13.26	9.151	11.863	8.918
2	14.376	16.687	8.329	5.379	7.296	5.234
1	5.766	6.902	3.732	2.169	3.177	2.096
0	0	0	0	0	0	0

Table E: 14 Maximum Storey Displacement (mm), Alternate Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
6	34.134	38.491	22.3	17.784	21.507	16.785
5	31.667	35.778	19.63	15.033	18.445	14.432
4	27.286	30.919	16.197	11.814	14.815	11.486
3	21.191	24.18	12.183	8.408	10.869	8.248
2	13.75	15.918	7.888	5.074	6.847	5.007
1	5.666	6.789	3.639	2.109	3.054	2.088
0	0	0	0	0	0	0

Table E: 15 Maximum Storey Displacement (mm), Alternate Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
8	51.21	57.562	35.963	33.042	35.147	32.227
7	48.256	54.314	32.552	29.141	31.299	28.694
6	43.423	48.915	28.309	24.606	26.779	24.388
5	37.043	41.796	23.459	19.781	21.894	19.686
4	29.567	33.47	18.283	14.879	16.838	14.839
3	21.404	24.387	13.058	10.157	11.852	10.127
2	12.953	14.956	8.059	5.891	7.182	5.852
1	4.901	5.84	3.518	2.339	3.065	2.303
0	0	0	0	0	0	0

Table E: 16 Maximum Storey Displacement (mm), Alternate Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
8	42.752	47.522	30.606	28.465	30.075	27.896
7	40.782	45.38	27.966	25.291	26.997	25.062
6	37.427	41.688	24.672	21.594	23.366	21.592
5	32.745	36.565	20.833	17.606	19.391	17.723
4	26.896	30.187	16.598	13.469	15.178	13.635

3	20.051	22.714	12.147	9.377	10.895	9.531
2	12.462	14.354	7.69	5.564	6.742	5.665
1	4.813	5.737	3.44	2.26	2.939	2.304
0	0	0	0	0	0	0

Table E: 17 Maximum Storey Displacement (mm), Alternate Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
10	53.523	69.682	46.255	43.104	45.236	42.26
9	51.344	66.864	42.881	39.18	41.411	38.701
8	47.831	62.307	38.744	34.637	36.94	34.408
7	43.149	56.209	34.012	29.758	32.084	29.676
6	37.562	48.906	28.855	24.665	26.948	24.667
5	31.316	40.718	23.462	19.52	21.687	19.553
4	24.627	31.931	18.022	14.503	16.471	14.536
3	17.682	22.798	12.727	9.81	11.478	9.824
2	10.682	13.611	7.767	5.651	6.891	5.638
1	4.077	5.053	3.302	2.216	2.881	2.184
0	0	0	0	0	0	0

Table E: 18 Maximum Storey Displacement (mm), Alternate Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
10	44.428	56.314	38.608	36.219	38.049	35.211
9	42.987	54.456	36.024	33.078	35.013	32.432
8	40.611	51.411	32.866	29.467	31.487	29.095
7	37.322	47.232	29.236	25.571	27.644	25.389
6	33.212	42.048	25.21	21.459	23.528	21.411
5	28.371	35.96	20.891	17.235	19.231	17.273
4	22.882	29.034	16.394	13.029	14.865	13.109
3	16.833	21.342	11.848	8.991	10.561	9.077
2	10.386	13.078	7.407	5.301	6.472	5.36
1	4.026	4.952	3.223	2.128	2.763	2.148
0	0	0	0	0	0	0

Table E: 19 Maximum Storey Displacement (mm), Peripheral Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
6	40.213	45.751	10.691	5.8	7.397	6.909
5	36.574	41.689	9.671	5.099	6.54	6.127
4	30.573	34.919	8.144	4.172	5.395	5.033
3	22.925	26.31	6.27	3.111	4.075	3.784
2	14.376	16.687	4.223	2.008	2.671	2.46
1	5.766	6.902	2.121	0.952	1.277	1.16
0	0	0	0	0	0	0

Table E: 20 Maximum Storey Displacement (mm), Peripheral Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
6	34.134	38.491	9.201	4.952	6.32	5.892
5	31.667	35.778	8.486	4.454	5.717	5.355

4	27.286	30.919	7.361	3.761	4.849	4.551
3	21.191	24.18	5.864	2.906	3.785	3.534
2	13.75	15.918	4.084	1.943	2.564	2.381
1	5.666	6.789	2.107	0.934	1.259	1.157
0	0	0	0	0	0	0

Table E: 21 Maximum Storey Displacement (mm), Peripheral Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
8	51.21	57.562	19.597	11.002	13.895	13.013
7	48.256	54.314	18.288	10.052	12.757	11.977
6	43.423	48.915	16.396	8.829	11.267	10.569
5	37.043	41.796	14.038	7.406	9.528	8.911
4	29.567	33.47	11.369	5.862	7.61	7.091
3	21.404	24.387	8.53	4.277	5.611	5.198
2	12.953	14.956	5.646	2.729	3.62	3.324
1	4.901	5.84	2.77	1.274	1.701	1.539
0	0	0	0	0	0	0

Table E: 22 Maximum Storey Displacement (mm), Peripheral Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
8	42.752	47.522	16.856	9.406	11.887	11.121
7	40.782	45.38	15.92	8.716	11.063	10.385
6	37.427	41.688	14.549	7.811	9.954	9.361
5	32.745	36.565	12.754	6.711	8.605	8.075
4	26.896	30.187	10.597	5.453	7.044	6.597
3	20.051	22.714	8.157	4.086	5.324	4.967
2	12.462	14.354	5.527	2.669	3.515	3.257
1	4.813	5.737	2.762	1.262	1.683	1.54
0	0	0	0	0	0	0

Table E: 23 Maximum Storey Displacement (mm), Peripheral Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
10	53.523	69.682	28.732	18.408	23.008	21.617
9	51.344	66.864	27.243	17.154	21.537	20.274
8	47.831	62.307	25.181	15.597	19.67	18.52
7	43.149	56.209	22.618	13.788	17.497	16.444
6	37.562	48.906	19.679	11.799	15.071	14.138
5	31.316	40.718	16.482	9.703	12.484	11.676
4	24.627	31.931	13.135	7.57	9.821	9.145
3	17.682	22.798	9.735	5.465	7.162	6.628
2	10.682	13.611	6.374	3.463	4.577	4.198
1	4.077	5.053	3.052	1.59	2.115	1.909
0	0	0	0	0	0	0

Table E: 24 Maximum Storey Displacement (mm), Peripheral Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
10	44.428	56.314	24.533	15.685	19.786	18.407

9	42.987	54.456	23.454	14.753	18.69	17.432
8	40.611	51.411	21.969	13.595	17.294	16.155
7	37.322	47.232	20.069	12.219	15.625	14.587
6	33.212	42.048	17.801	10.653	13.705	12.781
5	28.371	35.96	15.217	8.938	11.574	10.776
4	22.882	29.034	12.381	7.118	9.286	8.621
3	16.833	21.342	9.361	5.245	6.902	6.378
2	10.386	13.078	6.239	3.376	4.489	4.118
1	4.026	4.952	3.029	1.568	2.105	1.903
0	0	0	0	0	0	0

Table E: 25 Maximum Storey Displacement, Configuration Bracings, G+5 Storey due to ESA

Storey	C-1A	C-1B	C-1C	C-2A	C-2B	C-2C	C-3A	C-3B	C-3C	C-4A	C-4B	C-4C
6	6.638	6.457	8.128	6.385	7.113	9.135	6.286	7.151	8.577	7.65	8.884	8.344
5	5.844	5.693	7.19	5.629	6.298	8.136	5.539	6.317	7.648	6.835	7.977	7.505
4	4.799	4.663	5.934	4.619	5.188	6.775	4.533	5.194	6.35	5.672	6.644	6.269
3	3.612	3.502	4.461	3.487	3.924	5.154	3.376	3.909	4.792	4.301	5.052	4.773
2	2.361	2.28	2.902	2.291	2.579	3.413	2.188	2.55	3.13	2.847	3.345	3.164
1	1.134	1.085	1.375	1.118	1.25	1.667	1.03	1.217	1.495	1.404	1.625	1.549
0	0	0	0	0	0	0	0	0	0	0	0	0

Table E: 26 Maximum Storey Displacement, Configuration Bracings, G+5 Storey due to RSA

Storey	C-1A	C-1B	C-1C	C-2A	C-2B	C-2C	C-3A	C-3B	C-3C	C-4A	C-4B	C-4C
6	5.672	5.507	6.96	5.446	6.061	7.816	5.363	6.106	7.325	6.561	7.634	7.148
5	5.11	4.975	6.295	4.917	5.5	7.116	4.842	5.523	6.688	5.998	7	6.577
4	4.316	4.212	5.344	4.166	4.676	6.094	4.097	4.676	5.722	5.122	6	5.663
3	3.355	3.263	4.149	3.242	3.655	4.791	3.168	3.641	4.471	4.014	4.715	4.465
2	2.266	2.199	2.789	2.203	2.487	3.278	2.115	2.459	3.025	2.747	3.224	3.064
1	1.12	1.077	1.36	1.106	1.24	1.645	1.025	1.209	1.489	1.392	1.608	1.543
0	0	0	0	0	0	0	0	0	0	0	0	0

Table E: 27 Maximum Storey Displacement, Configuration Bracings, G+7 Storey due to ESA

Storey	C-1A	C-1B	C-1C	C-2A	C-2B	C-2C	C-3A	C-3B	C-3C	C-4A	C-4B	C-4C
8	12.537	12.156	15.217	12.09	13.319	16.899	11.88	13.427	16.032	14.4	16.525	15.611
7	11.476	11.142	14.009	11.068	12.244	15.626	10.875	12.324	14.856	13.33	15.352	14.527
6	10.102	9.805	12.392	9.737	10.803	13.894	9.561	10.865	13.201	11.81	13.651	12.944
5	8.52	8.254	10.462	8.21	9.14	11.809	8.02	9.17	11.178	9.996	11.593	11.002
4	6.783	6.563	8.331	6.543	7.301	9.483	6.344	7.303	8.924	7.996	9.308	8.833
3	4.982	4.811	6.111	4.818	5.386	7.039	4.638	5.364	6.564	5.917	6.91	6.554
2	3.204	3.082	3.911	3.115	3.482	4.585	2.961	3.445	4.218	3.855	4.502	4.271
1	1.515	1.439	1.82	1.495	1.658	2.199	1.369	1.619	1.978	1.863	2.144	2.048
0	0	0	0	0	0	0	0	0	0	0	0	0

Table E: 28 Maximum Storey Displacement, Configuration Bracings, G+7 Storey due to RSA

Storey	C-1A	C-1B	C-1C	C-2A	C-2B	C-2C	C-3A	C-3B	C-3C	C-4A	C-4B	C-4C
8	10.73 1	10.38 7	13.08 1	10.33 7	11.37	14.49 2	10.1 6	11.48 9	13.77 1	12.4 1	14.22 8	13.41 5
7	9.958	9.658	12.18 7	9.597	10.60 6	13.56 5	9.43 4	10.69 4	12.92	11.6 3	13.37 1	12.63 8
6	8.931	8.678	10.97 5	8.614	9.557	12.28 1	8.46 5	9.614	11.70 4	10.4 9	12.11 2	11.48 3
5	7.695	7.468	9.472	7.417	8.264	10.67 7	7.27 7	8.298	10.14 6	9.07 7	10.52 1	9.995
4	6.277	6.09	7.727	6.059	6.775	8.789	5.91 2	6.778	8.311	7.44 1	8.658	8.236
3	4.726	4.582	5.81	4.577	5.13	6.688	4.42 6	5.109	6.276	5.64 6	6.588	6.274
2	3.112	3.008	3.807	3.031	3.399	4.458	2.89 4	3.363	4.134	3.76 6	4.391	4.189
1	1.501	1.434	1.808	1.483	1.65	2.178	1.36 6	1.613	1.98	1.85 5	2.129	2.048
0	0	0	0	0	0	0	0	0	0	0	0	0

Table E: 29 Maximum Storey Displacement, Configuration Bracings, G+9 Storey due to ESA

Storey	C-1A	C-1B	C-1C	C-2A	C-2B	C-2C	C-3A	C-3B	C-3C	C-4A	C-4B	C-4C
10	20.86 9	20.22 1	25.15 4	20.17 5	22.05 8	26.73 4	19.79 9	22.24 5	26.17 1	23.8 9	26.49	25.78 2
9	19.48 7	18.90 2	23.60 1	18.83 2	20.66 7	25.17 1	18.48 4	20.82 1	24.68	22.4 9	25.01 6	24.38
8	17.75 2	17.22 5	21.59	17.14 7	18.87 3	23.10 9	16.82 5	18.99 5	22.66 5	20.5 8	22.96 9	22.42
7	15.75 6	15.26 7	19.2	15.20 3	16.78 5	20.64 4	14.88 3	16.87 9	20.21	18.3 1	20.49 9	20.02 6
6	13.53 8	13.11	16.52 4	13.06 1	14.45 7	17.85 9	12.73 9	14.51 5	17.43	15.7 8	17.72 3	17.31 5
5	11.18 2	10.81 7	13.66 1	10.79	11.97 2	14.86	10.47 7	11.99 5	14.43 8	13.0 8	14.74 4	14.39 8
4	8.765	8.468	10.70 9	8.468	9.415	11.74 9	8.185	9.407	11.34 2	10.3	11.66	11.37 6
3	6.366	6.136	7.763	6.166	6.865	8.619	5.919	6.834	8.246	7.53 8	8.558	8.341
2	4.057	3.893	4.921	3.95	4.395	5.558	3.746	4.351	5.25	4.86 5	5.522	5.382
1	1.888	1.786	2.25	1.864	2.056	2.618	1.704	2.013	2.418	2.30 5	2.576	2.527
0	0	0	0	0	0	0	0	0	0	0	0	0

Table E: 30 Maximum Storey Displacement, Configuration Bracings, G+9 Storey due to RSA

Storey	C-1A	C-1B	C-1C	C-2A	C-2B	C-2C	C-3A	C-3B	C-3C	C-4A	C-4B	C-4C
10	17.93 3	17.22 6	21.45 9	17.19 1	18.94 6	22.77 2	16.86 6	19.16 9	22.35 5	20.6 7	22.63 6	21.90 7
9	16.89 9	16.25 8	20.3	16.19 6	17.92 5	21.62 1	15.89 4	18.11	21.25 9	19.6 2	21.54 5	20.89 1
8	15.59 6	15.02 5	18.80 4	14.94 7	16.60 4	20.10 6	14.66 8	16.75	19.78 3	18.1 8	20.03 8	19.47 1
7	14.05 3	13.53 6	16.98 7	13.45 4	15.00 3	18.25 1	13.19 7	15.11 9	17.93 7	16.4 3	18.17 6	17.68 9
6	12.29 2	11.83 7	14.88 4	11.77	13.17	16.08 3	11.51 5	13.24 5	15.76 6	14.4 1	16.00 6	15.59 2
5	10.34 8	9.964	12.54 2	9.915	11.13	13.64 9	9.665	11.16 6	13.32 7	12.1 8	13.57 8	13.23 4

4	8.273	7.962	10.02 6	7.939	8.936	11.00 9	7.698	8.938	10.68 9	9.78 9	10.95 3	10.67 7
3	6.126	5.886	7.41	5.896	6.649	8.233	5.676	6.624	7.93	7.30 4	8.195	7.989
2	3.974	3.805	4.782	3.847	4.337	5.403	3.661	4.297	5.145	4.8	5.379	5.251
1	1.879	1.773	2.221	1.843	2.059	2.581	1.691	2.02	2.407	2.30 7	2.543	2.501
0	0	0	0	0	0	0	0	0	0	0	0	0

## APPENDIX F

Corresponding values of inter storey drift ratios for braced as well as unbraced models are presented here.

Table F: 1 Drift Ratio, Corner Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
6	0.001213	0.001354	0.001242	0.001119	0.001275	0.001025
5	0.002001	0.002256	0.001556	0.001279	0.001489	0.001225
4	0.002549	0.002869	0.001707	0.001315	0.001565	0.001295
3	0.00285	0.003208	0.001716	0.001243	0.001522	0.001237
2	0.00287	0.003263	0.001587	0.00106	0.001366	0.001055
1	0.001922	0.002301	0.001284	0.00072	0.000988	0.000699
0	0	0	0	0	0	0

Table F: 2 Drift Ratio, Corner Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
6	0.000907	0.001028	0.000992	0.000923	0.001046	0.000835
5	0.001552	0.001757	0.001273	0.001069	0.001235	0.001014
4	0.002094	0.002342	0.001456	0.001127	0.001336	0.001108
3	0.002508	0.002797	0.001537	0.001101	0.00135	0.001104
2	0.0027	0.003053	0.001495	0.00098	0.001265	0.000992
1	0.001889	0.002263	0.001266	0.000698	0.000953	0.000699
0	0	0	0	0	0	0

Table F: 3 Drift Ratio, Corner Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
8	0.000985	0.001083	0.001246	0.001356	0.001352	0.001251
7	0.001611	0.0018	0.001536	0.001539	0.00156	0.001472
6	0.002127	0.002373	0.00172	0.001626	0.001675	0.001598
5	0.002492	0.002775	0.001814	0.001643	0.001719	0.001639
4	0.002721	0.003028	0.001819	0.001577	0.001684	0.001586
3	0.002817	0.003144	0.001736	0.001421	0.001565	0.001434
2	0.002684	0.003041	0.001566	0.001185	0.001375	0.00119
1	0.001634	0.001947	0.001206	0.000779	0.000953	0.000764
0	0	0	0	0	0	0

Table F: 4 Drift Ratio, Corner Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
8	0.000765	0.000861	0.000998	0.001125	0.001115	0.001024
7	0.001257	0.001426	0.001241	0.001278	0.00129	0.001213
6	0.001688	0.001891	0.001417	0.001368	0.001404	0.001336
5	0.002041	0.002259	0.001533	0.001407	0.001471	0.001401
4	0.002332	0.002566	0.001588	0.001381	0.001477	0.001393
3	0.002548	0.002815	0.001576	0.001279	0.001416	0.001302
2	0.002553	0.002879	0.00148	0.001105	0.00129	0.001128
1	0.001604	0.001912	0.001186	0.000755	0.000924	0.000762
0	0	0	0	0	0	0

Table F: 5 Drift Ratio, Corner Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
10	0.000726	0.00094	0.001247	0.001403	0.001375	0.00129
9	0.001172	0.001519	0.00151	0.001574	0.001567	0.001497
8	0.001561	0.002032	0.001698	0.001675	0.001692	0.001631
7	0.001862	0.002434	0.001825	0.001735	0.001774	0.001716
6	0.002082	0.002729	0.001892	0.001742	0.001802	0.00174
5	0.00223	0.002929	0.001896	0.001689	0.001774	0.001697
4	0.002315	0.003044	0.001839	0.001572	0.001686	0.001586
3	0.002334	0.003062	0.00172	0.001388	0.001538	0.001403
2	0.002205	0.002855	0.001537	0.001152	0.001343	0.001157
1	0.001359	0.001684	0.001126	0.000733	0.00089	0.000722
0	0	0	0	0	0	0

Table F: 6 Drift Ratio, Corner Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-CB	X-CB	V-CB	CH-CB
10	0.000562	0.000787	0.000997	0.001129	0.001104	0.001035
9	0.000912	0.001256	0.001213	0.001267	0.00126	0.001205
8	0.001225	0.001654	0.001374	0.001356	0.001369	0.001321
7	0.001484	0.001962	0.001494	0.001415	0.001447	0.001402
6	0.0017	0.002207	0.001573	0.001436	0.001489	0.001439
5	0.001885	0.002422	0.001612	0.001414	0.001491	0.00143
4	0.002044	0.002621	0.001609	0.001344	0.001451	0.001369
3	0.002159	0.002775	0.001559	0.001219	0.001363	0.001251
2	0.002125	0.002713	0.001447	0.001048	0.001232	0.001079
1	0.001342	0.001651	0.001102	0.000695	0.000843	0.00071
0	0	0	0	0	0	0

Table F: 7 Drift Ratio, Middle Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
6	0.001213	0.001354	0.000888	0.000739	0.000865	0.000687
5	0.002001	0.002256	0.001198	0.000901	0.001069	0.000897
4	0.002549	0.002869	0.00136	0.000959	0.001163	0.000991
3	0.00285	0.003208	0.001407	0.000935	0.001165	0.000989
2	0.00287	0.003263	0.001359	0.000841	0.001099	0.000905
1	0.001922	0.002301	0.001177	0.000648	0.000841	0.000702
0	0	0	0	0	0	0

Table F: 8 Drift Ratio, Middle Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
6	0.000907	0.001028	0.00067	0.000595	0.000688	0.00053
5	0.001552	0.001757	0.00094	0.000736	0.000865	0.000716
4	0.002094	0.002342	0.00113	0.000811	0.00098	0.00083
3	0.002508	0.002797	0.001246	0.000828	0.001031	0.000877
2	0.0027	0.003053	0.001278	0.000785	0.001023	0.000855
1	0.001889	0.002263	0.001161	0.000634	0.000821	0.000702
0	0	0	0	0	0	0

Table F: 9 Drift Ratio, Middle Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
8	0.000985	0.001083	0.000905	0.001009	0.001015	0.000895
7	0.001611	0.0018	0.001209	0.001207	0.001237	0.001149
6	0.002127	0.002373	0.001401	0.001314	0.001373	0.001298
5	0.002492	0.002775	0.001516	0.001357	0.001441	0.00137
4	0.002721	0.003028	0.001553	0.001331	0.001442	0.001365
3	0.002817	0.003144	0.001521	0.001238	0.001378	0.001285
2	0.002684	0.003041	0.00144	0.00109	0.00127	0.001148
1	0.001634	0.001947	0.001177	0.000808	0.000934	0.000856
0	0	0	0	0	0	0

Table F: 10 Drift Ratio, Middle Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
8	0.000765	0.000861	0.000692	0.000811	0.000808	0.000698
7	0.001257	0.001426	0.000941	0.000973	0.00099	0.000909
6	0.001688	0.001891	0.001127	0.00108	0.001123	0.001054
5	0.002041	0.002259	0.001267	0.001144	0.001213	0.00115
4	0.002332	0.002566	0.001356	0.001157	0.001255	0.00119
3	0.002548	0.002815	0.001391	0.001113	0.001245	0.001169
2	0.002553	0.002879	0.001376	0.001021	0.001192	0.001095
1	0.001604	0.001912	0.001166	0.000784	0.000907	0.000851
0	0	0	0	0	0	0

Table F: 11 Drift Ratio, Middle Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
10	0.000726	0.00094	0.000886	0.001035	0.001018	0.000912
9	0.001172	0.001519	0.001164	0.001218	0.001222	0.001145
8	0.001561	0.002032	0.001355	0.001333	0.001363	0.001297
7	0.001862	0.002434	0.001494	0.001407	0.001458	0.001399
6	0.002082	0.002729	0.001577	0.001434	0.001506	0.001447
5	0.00223	0.002929	0.001608	0.001413	0.001506	0.001443
4	0.002315	0.003044	0.001589	0.001344	0.001461	0.001386
3	0.002334	0.003062	0.001525	0.001225	0.00137	0.001278
2	0.002205	0.002855	0.001434	0.001075	0.00125	0.001135
1	0.001359	0.001684	0.001107	0.000768	0.000882	0.000815
0	0	0	0	0	0	0

Table F: 12 Drift Ratio, Middle Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-MB	X-MB	V-MB	CH-MB
10	0.000562	0.000787	0.000679	0.000836	0.000836	0.000721
9	0.000912	0.001256	0.0009	0.000983	0.000983	0.000908
8	0.001225	0.001654	0.001067	0.001085	0.001085	0.001042
7	0.001484	0.001962	0.0012	0.001162	0.001162	0.001144
6	0.0017	0.002207	0.001299	0.001206	0.001206	0.00121
5	0.001885	0.002422	0.001365	0.001214	0.001214	0.001238
4	0.002044	0.002621	0.001398	0.001184	0.001184	0.001227
3	0.002159	0.002775	0.001396	0.001113	0.001113	0.001173
2	0.002125	0.002713	0.001363	0.001014	0.001014	0.001087
1	0.001342	0.001651	0.001085	0.000747	0.000747	0.00081
0	0	0	0	0	0	0

Table F: 13 Drift Ratio, Alternate Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
6	0.001213	0.001354	0.001208	0.001129	0.001279	0.000996
5	0.002001	0.002256	0.001514	0.001291	0.001489	0.001217
4	0.002549	0.002869	0.00166	0.001331	0.001569	0.001291
3	0.00285	0.003208	0.001665	0.001257	0.001532	0.001234
2	0.00287	0.003263	0.00154	0.00107	0.001382	0.001051
1	0.001922	0.002301	0.001244	0.000723	0.001005	0.000699
0	0	0	0	0	0	0

Table F: 14 Drift Ratio, Alternate Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
6	0.000907	0.001028	0.000949	0.000943	0.001052	0.000806
5	0.001552	0.001757	0.00122	0.001086	0.001236	0.001003
4	0.002094	0.002342	0.001395	0.001146	0.00134	0.0011
3	0.002508	0.002797	0.00147	0.001118	0.001358	0.001097
2	0.0027	0.003053	0.001434	0.000991	0.001279	0.000984
1	0.001889	0.002263	0.001213	0.000703	0.000968	0.000696
0	0	0	0	0	0	0

Table F: 15 Drift Ratio, Alternate Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
8	0.000985	0.001083	0.001185	0.001332	0.001315	0.001199
7	0.001611	0.0018	0.001471	0.001512	0.001519	0.001439
6	0.002127	0.002373	0.001656	0.001608	0.001642	0.001574
5	0.002492	0.002775	0.00175	0.001634	0.001695	0.001623
4	0.002721	0.003028	0.001759	0.001574	0.001669	0.001576
3	0.002817	0.003144	0.00168	0.001422	0.001561	0.001429
2	0.002684	0.003041	0.001518	0.001187	0.001383	0.001189
1	0.001634	0.001947	0.001172	0.00078	0.000965	0.000768
0	0	0	0	0	0	0

Table F: 16 Drift Ratio, Alternate Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
8	0.000765	0.000861	0.000935	0.001099	0.001069	0.000982
7	0.001257	0.001426	0.001173	0.00125	0.001238	0.001184
6	0.001688	0.001891	0.001347	0.001347	0.001358	0.001317
5	0.002041	0.002259	0.001464	0.001394	0.001432	0.00139
4	0.002332	0.002566	0.001523	0.001375	0.001448	0.001388
3	0.002548	0.002815	0.001514	0.001277	0.001397	0.001302
2	0.002553	0.002879	0.001429	0.001104	0.001283	0.00113
1	0.001604	0.001912	0.001146	0.000753	0.000925	0.000768
0	0	0	0	0	0	0

Table F: 17 Drift Ratio, Alternate Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
10	0.000726	0.00094	0.001164	0.001346	0.001309	0.001218
9	0.001172	0.001519	0.001425	0.001514	0.001498	0.001434
8	0.001561	0.002032	0.001615	0.001626	0.001631	0.001582
7	0.001862	0.002434	0.001746	0.001698	0.001722	0.001677
6	0.002082	0.002729	0.001817	0.001715	0.001761	0.00171

5	0.00223	0.002929	0.001828	0.001672	0.001744	0.001677
4	0.002315	0.003044	0.001776	0.001564	0.001669	0.001574
3	0.002334	0.003062	0.001664	0.001387	0.001533	0.001398
2	0.002205	0.002855	0.001491	0.001154	0.001349	0.001158
1	0.001359	0.001684	0.0011	0.000738	0.000902	0.000728
0	0	0	0	0	0	0

Table F: 18 Drift Ratio, Alternate Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-AB	X-AB	V-AB	CH-AB
10	0.000562	0.000787	0.000919	0.001095	0.001058	0.000975
9	0.000912	0.001256	0.00113	0.001232	0.001211	0.001151
8	0.001225	0.001654	0.001293	0.001331	0.001328	0.001278
7	0.001484	0.001962	0.001415	0.001401	0.001416	0.001369
6	0.0017	0.002207	0.001501	0.001433	0.001469	0.001417
5	0.001885	0.002422	0.001546	0.001421	0.001483	0.001416
4	0.002044	0.002621	0.001549	0.001358	0.001453	0.001364
3	0.002159	0.002775	0.001505	0.001236	0.001374	0.001251
2	0.002125	0.002713	0.001403	0.001066	0.001252	0.001082
1	0.001342	0.001651	0.001074	0.000709	0.000864	0.000716
0	0	0	0	0	0	0

Table F: 19 Drift Ratio, Peripheral Bays Bracings, G+5 Storey due to ESA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
6	0.001213	0.001354	0.000387	0.000234	0.000286	0.000264
5	0.002001	0.002256	0.000551	0.000309	0.000389	0.000367
4	0.002549	0.002869	0.000653	0.000354	0.000452	0.000427
3	0.00285	0.003208	0.000699	0.000368	0.000476	0.000449
2	0.00287	0.003263	0.000706	0.000359	0.000469	0.00044
1	0.001922	0.002301	0.000703	0.000317	0.000396	0.000387
0	0	0	0	0	0	0

Table F: 20 Drift Ratio, Peripheral Bays Bracings, G+5 Storey due to RSA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
6	0.000907	0.001028	0.000276	0.000169	0.000206	0.000188
5	0.001552	0.001757	0.000421	0.000236	0.000296	0.000278
4	0.002094	0.002342	0.000539	0.000289	0.000369	0.000349
3	0.002508	0.002797	0.000622	0.000323	0.000418	0.000396
2	0.0027	0.003053	0.000668	0.000339	0.000444	0.000418
1	0.001889	0.002263	0.000699	0.000311	0.000394	0.000386
0	0	0	0	0	0	0

Table F: 21 Drift Ratio, Peripheral Bays Bracings, G+7 Storey due to ESA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
8	0.000985	0.001083	0.000489	0.000317	0.000379	0.00035
7	0.001611	0.0018	0.000681	0.000408	0.000502	0.000472
6	0.002127	0.002373	0.000826	0.000475	0.000593	0.000562
5	0.002492	0.002775	0.000918	0.000515	0.000649	0.000616
4	0.002721	0.003028	0.000965	0.000529	0.000674	0.000638
3	0.002817	0.003144	0.000973	0.000518	0.000668	0.00063
2	0.002684	0.003041	0.000961	0.000495	0.000644	0.000602
1	0.001634	0.001947	0.000918	0.000425	0.000525	0.000513
0	0	0	0	0	0	0

Table F: 22 Drift Ratio, Peripheral Bays Bracings, G+7 Storey due to RSA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
8	0.000765	0.000861	0.000352	0.000235	0.00028	0.000255
7	0.001257	0.001426	0.000511	0.000309	0.00038	0.000354
6	0.001688	0.001891	0.000649	0.000374	0.000467	0.00044
5	0.002041	0.002259	0.000762	0.000425	0.000536	0.000509
4	0.002332	0.002566	0.000847	0.000459	0.000586	0.000556
3	0.002548	0.002815	0.000901	0.000474	0.000612	0.000579
2	0.002553	0.002879	0.000927	0.000477	0.00062	0.000583
1	0.001604	0.001912	0.000916	0.000421	0.000522	0.000513
0	0	0	0	0	0	0

Table F: 23 Drift Ratio, Peripheral Bays Bracings, G+9 Storey due to ESA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
10	0.000726	0.00094	0.000548	0.000418	0.00049	0.000453
9	0.001172	0.001519	0.000742	0.000519	0.000626	0.000588
8	0.001561	0.002032	0.000898	0.000603	0.000738	0.0007
7	0.001862	0.002434	0.001014	0.000663	0.00082	0.00078
6	0.002082	0.002729	0.001091	0.000699	0.000872	0.000829
5	0.00223	0.002929	0.001134	0.000711	0.000895	0.00085
4	0.002315	0.003044	0.001146	0.000702	0.000892	0.000844
3	0.002334	0.003062	0.001129	0.000672	0.000864	0.000814
2	0.002205	0.002855	0.001107	0.000639	0.000828	0.000773
1	0.001359	0.001684	0.001012	0.00053	0.00065	0.000636
0	0	0	0	0	0	0

Table F: 24 Drift Ratio, Peripheral Bays Bracings, G+9 Storey due to RSA

Storey	CB-B	FSWD-B	DG-PB	X-PB	V-PB	CH-PB
10	0.000562	0.000787	0.000399	0.000316	0.000371	0.000335
9	0.000912	0.001256	0.00055	0.000394	0.000478	0.00044
8	0.001225	0.001654	0.000688	0.000468	0.000577	0.000538
7	0.001484	0.001962	0.000806	0.000531	0.000661	0.000621
6	0.0017	0.002207	0.000904	0.000579	0.000728	0.000686
5	0.001885	0.002422	0.000981	0.000612	0.000776	0.000732
4	0.002044	0.002621	0.001034	0.000628	0.000806	0.000758
3	0.002159	0.002775	0.00106	0.000625	0.000812	0.000761
2	0.002125	0.002713	0.001071	0.000617	0.000807	0.000752
1	0.001342	0.001651	0.001004	0.000523	0.000648	0.000634
0	0	0	0	0	0	0

## APPENDIX G

Top storey displacement values and their reduction percentage among unbraced and braced models are presented here.

Table G: 1 Top Storey Displacement Reduction due to ESA and RSA, G+5 Storey

Building Type	Displacement Due to ESA(mm)	Displacement Due to RSA(mm)	Reduction (ESA)	Reduction (RSA)
FSWD-B	45.751	38.491	-	-
DG-CB	26.777	23.379	41.47%	39.26%
X-CB	20.2	17.565	55.85%	54.37%
V-CB	24.6	21.401	46.23%	44.40%
CH-CB	19.513	16.989	57.35%	55.86%
DG-MB	21.75	18.706	52.46%	51.40%
X-MB	15.04	13.027	67.13%	66.16%
V-MB	18.536	16.037	59.49%	58.34%
CH-MB	15.408	13.289	66.32%	65.48%
DG-AB	25.936	22.3	43.31%	42.06%
X-AB	20.365	17.784	55.49%	53.80%
V-AB	24.707	21.507	46.00%	44.12%
CH-AB	19.37	16.785	57.66%	56.39%
DG-PB	10.691	9.201	76.63%	76.10%
X-PB	5.8	4.952	87.32%	87.13%
V-PB	7.397	6.32	83.83%	83.58%
CH-PB	6.909	5.892	84.90%	84.69%

Table G: 2 Top Storey Displacement Reduction due to ESA and RSA, G+7 Storey

Building Type	Displacement Due to ESA(mm)	Displacement Due to RSA(mm)	Reduction (ESA)	Reduction (RSA)
FSWD-B	57.562	47.522	-	-
DG-CB	37.385	32.102	35.05%	32.45%
X-CB	33.32	28.784	42.11%	39.43%
V-CB	35.592	30.815	38.17%	35.16%
CH-CB	32.664	28.217	43.25%	40.62%
DG-MB	31.677	27.165	44.97%	42.84%
X-MB	27.966	23.97	51.42%	49.56%
V-MB	30.18	25.879	47.58%	45.54%
CH-MB	27.944	23.952	51.45%	49.60%
DG-AB	35.963	30.606	37.52%	35.60%
X-AB	33.042	28.465	42.60%	40.10%
V-AB	35.147	30.075	38.94%	36.71%
CH-AB	32.227	27.896	44.01%	41.30%
DG-PB	19.597	16.856	65.95%	64.53%
X-PB	11.002	9.406	80.89%	80.21%
V-PB	13.895	11.887	75.86%	74.99%
CH-PB	13.013	11.121	77.39%	76.60%

Table G: 3 Top Storey Displacement Reduction due to ESA and RSA, G+9 Storey

Building Type	Displacement Due to ESA(mm)	Displacement Due to RSA(mm)	Reduction (ESA)	Reduction (RSA)
FSWD-B	69.682	56.314	-	-
DG-CB	48.301	40.534	30.68%	28.02%
X-CB	43.882	36.365	37.03%	35.42%
V-CB	46.233	38.471	33.65%	31.68%
CH-CB	43.159	35.895	38.06%	36.26%
DG-MB	40.704	34.106	41.59%	39.44%
X-MB	36.621	31.14	47.45%	44.70%
V-MB	39.001	32.736	44.03%	41.87%
CH-MB	36.594	31.022	47.48%	44.91%
DG-AB	46.255	38.608	33.62%	31.44%
X-AB	43.104	36.219	38.14%	35.68%
V-AB	45.236	38.049	35.08%	32.43%
CH-AB	42.26	35.211	39.35%	37.47%
DG-PB	28.732	24.533	58.77%	56.44%
X-PB	18.408	15.685	73.58%	72.15%
V-PB	23.008	19.786	66.98%	64.86%
CH-PB	21.617	18.407	68.98%	67.31%

Table G: 4 Top Storey Displacement Reduction due to ESA and RSA, G+5 Storey

Building Type	Displacement Due to ESA(mm)	Displacement Due to RSA(mm)	Reduction (ESA)	Reduction (RSA)
FSWD-B	45.751	38.491	-	-
C-1A	6.638	5.672	85.49%	85.26%
C-1B	6.457	5.507	85.89%	85.69%
C-1C	8.128	6.96	82.23%	81.92%
C-2A	6.385	5.446	86.04%	85.85%
C-2B	7.113	6.061	84.45%	84.25%
<b>C-2C</b>	9.135	7.816	<b>80.03%</b>	<b>79.69%</b>
<b>C-3A</b>	6.286	5.363	<b>86.26%</b>	<b>86.07%</b>
C-3B	7.151	6.106	84.37%	84.14%
C-3C	8.577	7.325	81.25%	80.97%
C-4A	7.65	6.561	83.28%	82.95%
C-4B	8.884	7.634	80.58%	80.17%
C-4C	8.344	7.148	81.76%	81.43%

Table G: 5 Top Storey Displacement Reduction due to ESA and RSA, G+7 Storey

Building Type	Displacement Due to ESA(mm)	Displacement Due to RSA(mm)	Reduction (ESA)	Reduction (RSA)
FSWD-B	57.562	47.522	-	-
C-1A	12.537	10.731	78.22%	77.42%
C-1B	12.156	10.387	78.88%	78.14%
C-1C	15.217	13.081	73.56%	72.47%
C-2A	12.09	10.337	79.00%	78.25%
C-2B	13.319	11.37	76.86%	76.07%
C-2C	16.899	14.492	<b>70.64%</b>	<b>69.50%</b>
C-3A	11.88	10.16	<b>79.36%</b>	<b>78.62%</b>
C-3B	13.427	11.489	76.67%	75.82%
C-3C	16.032	13.771	72.15%	71.02%

C-4A	14.395	12.411	74.99%	73.88%
C-4B	16.525	14.228	71.29%	70.06%
C-4C	15.611	13.415	72.88%	71.77%

Table G: 6 Top Storey Displacement Reduction due to ESA and RSA, G+9 Storey

Building Type	Displacement Due to ESA(mm)	Displacement Due to RSA(mm)	Reduction (ESA)	Reduction (RSA)
FSWD-B	69.682	56.314	-	-
C-1A	20.869	17.933	70.05%	68.16%
C-1B	20.221	17.226	70.98%	69.41%
C-1C	25.154	21.459	63.90%	61.89%
C-2A	20.175	17.191	71.05%	69.47%
C-2B	22.058	18.946	68.34%	66.36%
<b>C-2C</b>	26.734	22.772	<b>61.63%</b>	<b>59.56%</b>
<b>C-3A</b>	19.799	16.866	<b>71.59%</b>	<b>70.05%</b>
C-3B	22.245	19.169	68.08%	65.96%
C-3C	26.171	22.355	62.44%	60.30%
C-4A	23.886	20.673	65.72%	63.29%
C-4B	26.49	22.636	61.98%	59.80%
C-4C	25.782	21.907	63.00%	61.10%

## APPENDIX H

Base shear values for different braced and unbraced models with their increments are presented here.

Table H: 1 Base Shear (KN) and Increment due to applications of bracings, G+5 Storey

Building Type	Base Shear(KN)	Increment
CB-B	2168.739	-
FSWD-B	1736.2695	-
DG-CB	2741.6000	158%
X-CB	3483.4184	201%
V-CB	2895.9559	167%
CH-CB	3463.2462	199%
DG-MB	3058.5788	176%
X-MB	3646.5051	210%
V-MB	3326.7155	192%
CH-MB	3551.3398	205%
DG-AB	2793.2742	161%
X-AB	3174.4084	183%
V-AB	2933.9015	169%
CH-AB	3178.2187	183%
DG-PB	4390.0381	253%
X-PB	4946.7114	285%
V-PB	4889.1055	282%
CH-PB	4889.1055	282%

Table H: 2 Base Shear (KN) and Increment due to applications of bracings, G+7 Storey

Building Type	Base Shear(KN)	Increment
CB-B	2300.254	-
FSWD-B	1949.1151	-
DG-CB	3255.0954	174%
X-CB	3801.4565	204%
V-CB	3454.2275	185%
CH-CB	3810.1804	204%
DG-MB	3605.4262	193%
X-MB	4380.7962	235%
V-MB	3949.5643	211%
CH-MB	4265.9167	228%
DG-AB	3303.2135	177%
X-AB	3813.9478	204%
V-AB	3474.5463	186%
CH-AB	3837.8088	205%
DG-PB	4573.0905	245%
X-PB	4656.377	249%
V-PB	4601.3618	246%
CH-PB	4601.3618	246%

Table H: 3 Base Shear (KN) and Increment due to applications of bracings, G+9 Storey

<b>Building Type</b>	<b>Base Shear(KN)</b>	<b>Increment</b>
CB-B	2742.5109	-
FSWD-B	21127737	-
DG-CB	3316.5152	164%
X-CB	3801.4211	188%
V-CB	3503.2396	173%
CH-CB	3797.584	188%
DG-MB	3699.9646	183%
X-MB	4411.1794	218%
V-MB	4024.3298	199%
CH-MB	4296.0579	213%
DG-AB	3379.0255	167%
X-AB	3840.0838	190%
V-AB	3549.1425	176%
CH-AB	3844.6931	190%
DG-PB	5310.6318	263%
X-PB	5984.0398	296%
V-PB	5914.3539	293%
CH-PB	5914.3539	293%

Table H: 4 Base Shear (KN) and Increment due to applications of different configurations of bracings, G+5 Storey

<b>Building Type</b>	<b>Base Shear(KN)</b>	<b>Increment</b>
FSWD-B	1670.03	-
C-1A	3381.9265	203%
C-1B	3381.9265	203%
C-1C	3371.5604	202%
C-2A	3381.9265	203%
C-2B	3361.7543	201%
C-2C	3351.3881	201%
C-3A	3381.9265	203%
C-3B	3361.7543	201%
C-3C	3351.3881	201%
C-4A	3371.5604	202%
C-4B	3351.3881	201%
C-4C	3351.3881	201%

Table H: 5 Base Shear (KN) and Increment due to applications of different configurations of bracings, G+7 Storey

<b>Building Type</b>	<b>Base Shear(KN)</b>	<b>Increment</b>
FSWD-B	1868.0358	-
C-1A	4628.8694	248%
C-1B	4628.8694	248%
C-1C	4614.7337	247%
C-2A	4628.8694	248%
C-2B	4601.3618	246%
C-2C	4587.2262	246%
C-3A	4628.8694	248%
C-3B	4601.3618	246%
C-3C	4587.2262	246%
C-4A	4614.7337	247%
C-4B	4587.2262	246%
C-4C	4587.2262	246%

Table H: 6 Base Shear (KN) and Increment due to applications of different configurations of bracings, G+9 Storey

<b>Building Type</b>	<b>Base Shear(KN)</b>	<b>Increment</b>
FSWD-B	2020.2363	-
C-1A	5949.1969	294%
C-1B	5949.1969	294%
C-1C	5931.2917	294%
C-2A	5949.1969	294%
C-2B	5914.3539	293%
C-2C	5896.4488	292%
C-3A	5949.1969	294%
C-3B	5914.3539	293%
C-3C	5896.4488	292%
C-4A	5931.2917	294%
C-4B	5896.4488	292%
C-4C	5896.4488	292%

## APPENDIX I

Fundamental natural time period (sec) value for different types of braced as well as unbraced models are presented below.

Table I: 1 Fundamental Natural Time Period (Sec) and Reduction Calculation, G+5 Storey

Building Type	Time Period(Sec)	Reduction
CB-B	0.904	-
FSWD-B	1.072	-
DG-CB	0.567	47.11%
X-CB	0.474	55.04%
V-CB	0.529	50.65%
CH-CB	0.469	55.97%
DG-MB	0.516	51.87%
X-MB	0.416	61.19%
V-MB	0.467	56.44%
CH-MB	0.426	60.26%
DG-AB	0.561	47.67%
X-AB	0.478	55.41%
V-AB	0.532	50.37%
CH-AB	0.468	56.34%
DG-PB	0.365	65.95%
X-PB	0.266	75.19%
V-PB	0.301	71.92%
CH-PB	0.291	72.85%

Table I: 2 Fundamental Natural Time Period (Sec) and Reduction Calculation, G+7 Storey

Building Type	Time Period(Sec)	Reduction
CB-B	1.107	-
FSWD-B	1.305	-
DG-CB	0.761	41.69%
X-CB	0.654	49.35%
V-CB	0.716	45.13%
CH-CB	0.649	50.04%
DG-MB	0.684	47.59%
X-MB	0.568	56.48%
V-MB	0.626	52.03%
CH-MB	0.58	55.56%
DG-AB	0.749	42.61%
X-AB	0.652	50.04%
V-AB	0.712	45.44%
CH-AB	0.644	50.65%
DG-PB	0.485	62.84%
X-PB	0.359	72.49%
V-PB	0.405	68.97%
CH-PB	0.392	69.96%

Table I: 3 Fundamental Natural Time Period (Sec) and Reduction Calculation, G+9 Storey

Building Type	Time Period(Sec)	Reduction
CB-B	1.195	
FSWD-B	1.546	
DG-CB	0.961	37.84%
X-CB	0.841	45.21%
V-CB	0.907	41.33%
CH-CB	0.837	45.80%
DG-MB	0.857	44.57%
X-MB	0.725	53.10%
V-MB	0.79	48.90%
CH-MB	0.74	52.13%
DG-AB	0.941	39.13%
X-AB	0.833	46.12%
V-AB	0.896	42.04%
CH-AB	0.827	46.51%
DG-PB	0.61	60.54%
X-PB	0.458	70.38%
V-PB	0.515	66.69%
CH-PB	0.499	67.72%

Table I: 4 Fundamental Natural Time Period (Sec) and Reduction Calculation, G+5 Storey

Building Type	Time Period(Sec)	Reduction
FSWD-B	1.068	-
C-1A	0.284	73.41%
C-1B	0.28	73.78%
C-1C	0.314	70.60%
C-2A	0.279	73.88%
C-2B	0.295	72.38%
<b>C-2C</b>	<b>0.336</b>	<b>68.54%</b>
<b>C-3A</b>	<b>0.276</b>	<b>74.16%</b>
C-3B	0.295	72.38%
C-3C	0.324	69.66%
C-4A	0.306	71.35%
C-4B	0.331	69.01%
C-4C	0.321	69.94%

Table I: 5 Fundamental Natural Time Period (Sec) and Reduction Calculation, G+7 Storey

Building Type	Time Period(Sec)	Reduction
FSWD-B	1.307	-
C-1A	0.383	70.70%
C-1B	0.378	71.08%
C-1C	0.423	67.64%
C-2A	0.377	71.16%
C-2B	0.397	69.63%
<b>C-2C</b>	<b>0.448</b>	<b>65.72%</b>
<b>C-3A</b>	<b>0.373</b>	<b>71.46%</b>
C-3B	0.397	69.63%
C-3C	0.436	66.64%
C-4A	0.412	68.48%
C-4B	0.443	66.11%
C-4C	0.431	67.02%

Table I: 6 Fundamental Natural Time Period (Sec) and Reduction Calculation, G+9 Storey

<b>Building Type</b>	<b>Time Period(Sec)</b>	<b>Reduction</b>
FSWD-B	1.555	-
C-1A	0.488	68.62%
C-1B	0.481	69.07%
C-1C	0.536	65.53%
C-2A	0.48	69.13%
C-2B	0.504	67.59%
<b>C-2C</b>	<b>0.567</b>	<b>63.54%</b>
<b>C-3A</b>	<b>0.475</b>	<b>69.45%</b>
C-3B	0.505	67.52%
C-3C	0.553	64.44%
C-4A	0.523	66.37%
C-4B	0.56	63.99%
C-4C	0.547	64.82%