ANALYSIS OF SEISMIC RESPONSE IN IRREGULAR RC STRUCTURES USING ETABS

A PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

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IN

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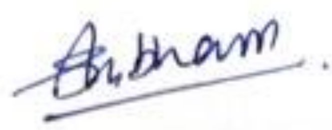
CANDIDATE’S DECLARATION

I **Shubham Rawat**, 2K19/STE/11 student of M. TECH Structural Engineering, hereby declare that the project Dissertation titled **“Analysis of Seismic Response in Irregular RC Structures Using E-TABS”,** which is submitted by me to Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, in original and not copied for any source without proper Citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or similar recognition.



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This is to certify that project report entitles "ANALYSIS OF SEISMIC RESPONSE IN IRREGULAR RC STRUCTURES USING E-TABS", is the bonafide work of **Mr. Shubham Rawat** for awarding Master of Technology in Structural Engineering from Department of Civil Engineering, Delhi Technological University. This work has been carried out fully under my supervision. Content and results of this report, in parts or in full has not been submitted to any other institute or university for awarding of a degree.

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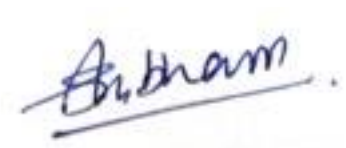

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ABSTRACT

Behavior of structure is dominated by structural configuration under earthquake motion. This presence of irregularity in structure either in plan or in vertical is a matter of concern. Structure is weakened by sudden change in vertical or plan configuration. In general, structures possess combination of different irregularities. So accurate predictions can't be made based on consideration of single irregularity. In order to reduce the hazardous potential of these irregular structures, a detailed study has to be done for the responses of these structures towards lateral loads. Present study is carried out for the seismic responses of reinforced concrete [RC] structure which are analyzed for different combination of irregularities. A ten storied building is modified to obtain irregular configuration. 30 irregular as well as regular configuration frames are to be analyzed for studying their effect. The analytical tool package used in this project is ETABS version-17 software. Result obtained is for parameters i.e. drift, storey displacement and base shear which are then compared for regular structure.

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Chapter 1

INTRODUCTION

1.1 General

India is one of the countries where most of the structures are low rise, but thanks to migration towards cities leads to population increment in most of the cities. So as to accommodate these people in cities height of buildings should be increased to medium or high. Large portion of urban infrastructures is contributed by irregular structures. Design and analysis of these structures is very complicated, when these structures are present in a region of very high seismic activity. Improper design and construction of every type of residential buildings leads to great destruction of structure across the globe. Hence we've to contemplate the structure safety instead of economy.

Designing of structure should be carried out while keeping in mind both safety and economy. Both earthquake and wind force contribute for dynamic action on a structure but analysis and design for these force follows very different process. Prominent force affecting a structure due to increase in height are lateral forces hence to eliminate the effect of those forces and to reduce the impact of the forces on structure certain measures are mandatory. Similarly the soil conditions within which the building is present also encompasses a greater effect on the structure.

Earthquake is among the most catastrophic natural hazards which claims very high losses, collapse of structures is being most significant of them which results in both livelihood and life loss. During an event of earthquake, weakness at various locations in a structure leads to its failure. These weakness may appears due to existing discontinuities in stiffness, mass and structural geometry or their combinations. The irregular structure are structures with these discontinuities present in them. Structural elements and their arrangement present in a building determine its behavior. Presence of irregularities leads to flow force interruption and concentration of stress within structure.

Structural configuration depends upon various aspects which are geometry, size and shape of the building. Due to development of inertial forces at structural center of mass and its concentration during event of earthquake when dynamic loading is acting on a structure. Inertial forces in horizontal direction are resisted by vertical members of structures. Point of concentration of resultant forces is stiffness center. Without overlapping of mass and stiffness center, eccentricity is developed in the structure. Torsion is induced in a structure due to eccentricity which is developed due to irregular arrangement of structure. Size and location directly impact torsional coupling which is responsible for structural damages. Changing height, mass and stiffness of regular arrangement helps in obtaining different dynamic characteristics for analysis. Regular structures are those structures which are independent of plan and vertical discontinuities in their arrangement. Structural performance of an irregular structure is affected when subjected to lateral loads as dis continuities present in both plan and vertical or individually. Vertical irregularities comprises of variation of mass, stiffness and dimensions along vertical direction leading arrangement change. Presence of discontinuities in plan can be attributed as Horizontal irregularities. Seismic response of structure is affected by different structural irregularities in several ways. Response magnitude variates depending upon location, degree and type of irregularity, so to overcome it structural performance is improved by judiciously choosing designing parameters as irregularities are unavoidable in real life due to utility and aesthetic limitation.

Multiple irregularities in various combinations are present in real life structure. However, there are scarce number of studies done on irregularities combined effect. To cater this issue, present study is made in effort to know behavior of irregularities combination on structures under impact of ground motion using a multi storied RC model for regular and irregular arrangements. 10 storied RC structural model with column fixed at footing, without basement, shear wall and beams at plinth.

In current study, irregularities in plan and elevation for structures are considered. Vertical irregularities comprises of vertical geometrical, stiffness and mass irregularity whereas re-entrant corner and torsional irregularities comprises horizontal irregularity. For analysis, thirty different irregular models are opted. Among the cases to be analyzed, seventeen cases includes configuration of single irregularities whereas thirteen included are combinations of irregularities. Identification of critical combinations of irregularities is the main purpose of this study.

1.2 Earthquake:

Earthquake can be understood as “Earth surface shaking because of energy which is suddenly released by reason of Earth’s movement”. This Earth’s movement is consequence of plate movement these plates are termed as tectonic plates. The crust of the earth is surrounded by large number of very big size bodies called tectonic plates, they are constantly under motion with respect to one another, due to their unexpected collision with one another leading to release of energy which travels towards the earth surface in the form of waves.

1.2.1 Earthquake Zones Of India:

Division of India on the basis of earthquake zones is mentioned below:

Zone 2: it attracts very less seismic forces having low seismic intensity causing zone factor to be very low.

Zone 3: having medium seismic intensities of earthquakes since it attracts medium seismic forces, the zone factor is above zone 2 lying in medium range.

Zone 4: attracts moderate seismic forces having moderate intensities of earthquake and the zone factor is moderate.

Zone 5: it attracts very severe seismic forces having severe seismic intensity since the zone factor is high.

1.3 Irregularities:

A structure is irregular when limits specified by the standards are exceeded for structural parameters.

Table 1.1: shows the limits of re entrant corner (RI) and torsional (THI), mass (MVI), stiffness (SVI), and vertical geometric (VIG) irregularities as per (IS: 1893:2016(part-1))

Table 1.1.limits for irregularities prescribed as per (IS: 1893:2016(part-1))

Classification Of Irregularity	Type Of Irregularity	Limit
A. Horizontal irregularity	a) Re Entrant corner(RI)	RI_X <=15%
	b) Torsional(THI)	$\Delta_{MAX} <= 1.5\Delta_{AVG}$
B. Vertical irregularity	a) Mass(MVI)	$MVI_X<1.5MVI_Y$
	b) Stiffness(SVI)	$SVI_X<SVI_{1+X}$
	c) Vertical geometry(VIG)	$VIG<1.25VIG_Y$

X= Number of the Storey, Y = Number of the Adjacent Storey, Δ_{MAX} = Maximum Deformation and Δ_{AVG} = Average Deformation

Perfect regularity of a structure is an ideal condition but in real life structures are usually irregular. Original forces which act on structures are always more than design forces. Overall seismic performance of the irregular structure is significantly reduced due to seismic forces, extra shear, displacement and torsion are induced. A model structure should pass all the design checks in order to get a safe design.

Structures with irregularities are bound to be constructed by engineers due to the growing demands of aesthetic for buildings. Sometimes, irregularities are provided due to different functionality of the building i.e. for buildings with an unusual purposes. However, it is undeniable that vulnerability of such types of irregular structures is increased in earthquake or any dynamic event. The response of the building is considerably affected by torsion in addition to stiffness and stiffness of structure. Decrement in structural stiffness makes structure more susceptible to the large displacement as structures reduced geometrically to provide provision for setbacks which might turn destructive in nature. Mass of structure plays important role in affecting building response, large torsional moment will be developed if mass of building is concentrated at particular portion which is not recommended in designing. For overcoming these irregular configuration building defects, effective analysis methodology is to be followed which is adept in investigating these weak zones in the structures.

1.3.1 Types of Irregularities

The basis classification of Structural irregularities is of two types:

i) Plan irregularities

ii) Vertical irregularities

Table 1.2.Plan irregularities as per IS 1893(part-1):2016

Plan irregularities as per IS 1893(part-1):2016		
SNo.	***Type Of Irregularity***	***Description***
1.	Torsion Irregularity	It is considered when floor diaphragms are rigid in plan when compared with lateral force resisting vertical structural members. Condition of torsional irregularity arises when eccentricity is used to compute the max. storey drift of one side is 1.2 times avg. storey drift of two sides
2.	Re – entrant corners	Re-entrant corner on lateral force resisting system and plan, with fifteen percent projection beyond re-entrant in a direction

3.	Diaphragm Discontinuity	Abrupt discontinuous diaphragm or varied stiffness with open or cutout of greater than fifty percent for one storey to another
4.	Out of plane offsets	Out of plane offsets leading to discontinuity in lateral force resisting path
5.	Non parallel Systems	Non parallel or symmetrical along major axis of vertical lateral force resisting members

Table 1.3.Vertical irregularities as per IS 1893(part 1):2016

Vertical Irregularities (IS 1893 (Part 1): 2016)		
SNo.	***Irregularity Type***	***Description***
1.	Stiffness Irregularity	Soft storey: lateral stiffness less than eighty percent for three stories above or seventy percent of single storey Extreme Soft storey: lateral stiffness less than seventy percent for three stories above or sixty percent of single storey For example: STILTS in buildings
2.	Mass Irregularity	Seismic weight of a floor more than two hundred times of adjacent floor this doesn't include roofs
3.	Vertical Geometrical Irregularity	Horizontal dimension is one fifty times of adjacent storey for lateral resisting force
4.	In Plane Discontinuity	Greater length of in plane offset of members than vertical lateral force resisting elements

5.	Discontinuity in Capacity–Weak Storey	Lateral strength less than eighty percent of above storey is a weak storey. Total strength of all the elements which are resisting seismic forces in a direction is termed as lateral strength. It also shares storey shear for that direction

1.4 Different seismic zones in India

Indian plate is responsible for earthquakes of high intensities and frequency leading Indian subcontinent to catastrophic earthquakes. Around 53% Indian land mass is vulnerable to earthquakes, based on Indian geographical statistics. According to estimation based on report of World Bank and United Nations, around 200 million Indian population to be affected from storms and earthquakes around 2050. According to latest design practice code (IS: 1893: part-1; 2016), India is divided into four zones based on seismicity observed of Indian landmass. These zones are namely zone 2,3,4,5 which covers entire country. Before the present code these divisions of zones is of five to six types for entire country which is now reduced to only four ranging between zone five to zone two associated with highest to lowest seismicity respectively.

Various activities are performed nodal agencies under ministry of earth sciences for government of India. Agencies responsible for seismology and other allied discipline are center for seismology and IMD.

Centre of seismology pursued various activities among which majorly includes:

a) 24*7 monitoring of seismic activities, real time monitoring of earthquakes for early warning system of tsunamis

b) Local and nationwide operation and maintenance of seismological networks.

c) Setup of center and services for seismological data

d) Studies regarding risks and hazards due to seismic activities

e) Studies for site response, aftershock at the field

f) Modelling and processes for earthquakes etc.

Philosophy of dual designing as per IS code:

i. Minor to moderate damage to structure for frequently occurring events of earthquake
ii. No structural damage resulting in total failure for events of extreme earthquake with low probability i.e. MCE

Zone 5

Attracts earthquake of high intensity with highest risks involved attributed with very high risk damage. Zone factor indicates effective level of earthquake i.e. for zero period which is used for designing of earthquakes resistant structures by structural engineers. Earthquake prone areas generally consists of trap and basalt rocks, regions under this zones are Kashmir and Himalayan region, north east states, northern areas of Bihar and region of Gujarat state mainly Kutch.

Zone 4

Attributed with high risk damage with factor of .24 as per is code. The zone encompasses gangetic plains, national capital Delhi, state of Jammu and Kashmir, Faltan area of Maharashtra, (Koyananager), northern regions of Bihar and border of Nepal and India.

Zone 3

Classified as moderate damage risk zone with factor of 0.16 as per code. Regions included are some parts of Himalayas and Kashmir; Andaman and Nicobar

Zone 2

Attracts less intensities of earthquakes and classified under low damage risk zone, as per IS code assigned factor of 0.10 as only 10% of gravitational acceleration is experienced by structure as maximum horizontal acceleration.

Chapter 2

LITERATURE SURVEY

2.1 Research Study

[1] Mohammed Affan, Md. Imtiyaz Qureshi, Syed Farooq Anwar (Nov 2018):

"Comparative study of Static and dynamic analysis of high rise building in different seismic zones and different soil types by E Tabs" In this paper static and dynamic analysis of multi storey building in different seismic zones of India with different soil types starting from medium or sof soil to hard or rocky soils is studied. They used E Tabs software for their analysis. The seismic and wind loading on the building is as per IS codes. After analyzing the building design parameters such as Storey drift, Storey torsion are compared for different zones. It has been concluded that Static analysis gives higher value of all the parameters such as displacement, torsion, drift than dynamic analysis.

[2] RaviKumar, P Raghava, Dr.T.Suresh Babu (April 2017):

"Seismic analysis of tall buildings for different earthquake zones" In this paper Response Theory is analyzed for G+20 Building in FEM Software that is E Tabs. The method of analysis they used is the dynamic method that is Response Spectrum analysis has been carried out on a 90m tall building in various seismic zones and with different wind speed and varying the value of zone factor for each zone. After the analysis of the structure it has been concluded that the behavior of the building in Zone 2 is good when compared to other zones. Stability indices value of zone 3 is 170% more than zone 5.

[3] Siva Naveen E, Nimmy Mariam Abraham et al (2018):

"Analysis of irregular structures under earthquake loads" In this paper the structural behavior of a multi storey frame with single irregularity and with multiple irregularities has been studied.

The irregularities considered are: Mass Irregularity, Vertical Irregularity, Tensional Irregularity and Stiffness Irregularity

It has been observed that frames with single irregularity or with multiple irregularities change their response. The combination of stiffness and vertical irregularity has shown maximum displacement response and the combination of Re entrant corners and vertical irregularity has shown maximum displacement.

[4] Rakshith G.M, Panender Naik G, et al (2019):

"Analysis of G+20 RCC tall building uses E Tabs" In this paper the action of lateral loads on a tall building has been studies in different zones. The wind loads on the structure is considered as per IS 1875 Part 3 and seismic loads considered as per IS 1893 2016. Software used for modelling of the structure is E Tabs. After the analysis of the building the following results have been concluded.

- Base shear of the building increases with increase in Zone factor.
- Storey displacement increases with increase in Zone factor.
- Storey drift increases with increase in Zone.

[5] MV Naveen, KJ Brahma Chari (2016):

"Study on Static and Dynamic analysis of multi storey building" This paper presents the behavior of a multi storey RCC residential building (G+10) in seismic zone 2. In the seismic zone 2 they used importance factor as 0.10, 0.16, 0.21, 0.36 and response reduction factor as 3. The analysis is carried out by using two methods that is equivalent Static and Dynamic methods using E Tabs. The analysis is done for different zones and the design parameters are studied. It has been concluded that

- Static analysis gives higher displacement values than dynamic analysis
- As the storeys increases, base shear also increases.
- For tall buildings Static analysis is not enough Dynamic analysis also required.

[6] A. Fathima, Shashi Kumar N V

"Behavior of Vertical Irregular Building in Different Seismic Zones" In this paper a RCC building with 15 storey is analyzed for irregularity of re-entrant corner using equivalent static analysis and push over method of analysis for all the seismic zone, soil condition and wind speeds. Analysis is carried out using ETABS. Analysis is done for irregularity and a comparison between equivalent static method and pushover analysis is carried out and result obtained can be concluded as:

- Zone-5 gives maximum response for all the cases under consideration.
- Push over analysis gives less response when compared with equivalent method responses.

[7] P A Krishnan, N Thasleen

"Seismic analysis of plan irregular RC building frames" In this paper a RCC building with 15 storey is analyzed for irregularity of re-entrant corner using push over method of analysis for seismic zone-V. Analysis is carried out using ETABS. Analysis is done for irregularity and strengthening technique and result obtained can be concluded as:

- With an increase in dimension of projection, an increase in storey displacement is observed.
- At re-entrant corners, high level of stress concentration are observed.

Chapter 3

BASIC DESIGN ASPECTS OF SEISMIC ANALYSIS

To design the earthquake resistance structure Bureau Indian standards recommended IS Code: 1893: part-1; 2016 “criteria for earthquake resistant design of structures”. Which involves the evaluation of seismic loads of various structures and the design of earthquake resistant buildings. These provision are applicable in stacked, elevated and industrial structures, embankments, bridges, earthen dams, concrete masonry, retaining walls and some other buildings

3.1 Importance and Response Reduction Factor I and R)

Table 3.1 and Table 3.2 shows minimum values of importance and response reduction factors for different types of structural systems

Table 3.1.Importance Factors, I

Sno.	Structure	Importance Factor(I)
i)	Buildings of important services or for community purposes, Emergency uses.	1.50
ii)	Other types of buildings	1.0

Points to be noted:

1) Selection of importance factor is dependent on judgement of design engineer to choose a value greater than those mentioned above.

2) Based on parameters of design and economy a building with higher importance factor than mentioned in Table 3.1can be designed excluding the above mentioned building types ; for example combined residential units
3) For temporary structures of short durations i.e. scaffolding, excavations etc. doesn't comply with above parameters
4) Importance of industrial structures included structures that contain hazardous materials, according to IS: 1893 (Part 4).

3.2 Redundancy

Buildings should have high redundancy resistance to lateral load. Increased redundancy in the fabric will result in increased power dissipation level and excessive current. Assuming that adequate redundancy level is achieved in a structure, table 3.2 gives values for response reduction factor. For buildings with low redundancy, for example, for a given direction resistance is offered by two or three shear wall against lateral loading. The design engineer can use 0.75 of the value given in Table 3.2. R value in the range 0.90 times, used for Low Redundancy Buildings across a bay frame, etc.

Table 3.2.Response Reduction Factor, R,

SNo.	Lateral Load Resisting System	Reduction Factor (R)
	Building with Framing Systems	
1.	Ordinary RC moment resisting frame (OMRF)	3.0
2.	Intermediate RC moment resisting frame	4.0
3.	Special RC moment resisting frame (SMRF)	5.0
	Buildings with Shear Walls	
	Load bearing masonry wall buildings:	
4.	a) Unreinforced masonry without special seismic strengthening	1.5

		2.25
	b) Unreinforced masonry with strengthening	
	c) Ordinary reinforced masonry shear wall	3.0
	d) Special reinforced masonry shear wall	4.0
5.	Shear walls of ordinary RC	3.0
6.	Shear walls with ductility	4.0
	Buildings with Dual Systems	
7.	Shear wall of ordinary type with OMRF	3.0
8.	Shear wall of ordinary type with SMRF	4.0
9.	Shear wall with ductility for OMRF	4.5
10.	Shear wall for ductility for SMRF	5.0

Lateral displacement between two consecutive stories is termed **as *Storey Drift***

3.3 Zone Factor (Z)

Refer to intensity of earthquake of vibration or shaking, notation refer to Z for zone V .36 means .36g.

Table 3.4.Zone Factor (Z)

SEISMIC ZONES IN INDIA	ZONE II	ZONE III	ZONE IV	ZONE V
Z	.10	.16	.24	.36

LIMITATION

Due to the minimum design lateral force specified by, the floor drift of any floor, the load-factor of part is 1.0, which must not exceed 0.004 times the height of the floor.

Only for the purpose of displacement requirements, it is allowed to use the calculated basic period of seismic force (T) building .There is no lower limit of design seismic force. A single story building designed to accommodate floor drifts will have no drift limit.

3.4 Different Methods Analysis of the Structures in Earthquake:

A. Linear Static Procedure
B. Linear dynamic Procedure
C. Response Spectrum method
D. Time history method
E. Nonlinear Static Procedure (Pushover analysis)
F. Nonlinear dynamic procedure.

3.4.1 Linear dynamic Procedure:

When the high mode effect is not significant, a static procedure is appropriate. This generally applies to short conventional structures. Dynamic programs are needed for systems with torsional irregularities or non-orthogonal systems in a high rise structures. Using linear elastic stiffness matrix and equivalent viscous damping matrix, a multiple degree of freedom (MDoF) structural modal is prepared in linear dynamic process whereas when modal spectrum or time history inputs are used as seismic modal, linear elastic analysis is used to get internal forces and displacement which corresponds to it. Even though linear dynamic programs uses superior modes, their applicability decreases when compared with linear static program because of its increased non-linear behaviour which is compensated by overall force reduction factor.

3.4.2 Nonlinear Static Procedure (Pushover analysis):

Application linear procedure is opted for cases where elastic behaviour of structure is assumed at ground motion level or where nonlinear response of entire structure is a uniform distribution for design results. For real structures to cater high inelastic demand and doubt regarding linear methods safety and limits a new process is required. Inelastic analysis procedure can reduce these ambiguities. Also known as push over analysis. On linear properties models are applied with force method which is used to define capacity curve when total force is plotted with respect to displacement. By combining it with demand curve it reduces problem to SDoF problem

In Push over analysis vertical load and lateral load gradually increase on a structure to be considered to study the displacement and damage of the structure. Cyclic behavior and reversal of load is also observed in this method.

As the name indicates Push – over, the structure is pushed until it achieves its most extreme ability to twist. This method very much helpful in understanding the miss happening and splitting of a structure, if there should arises an occurrence of quake and grants a reasonable comprehension for the distortion in structure and plastic hinges arrangements in structures

Pushover analysis is of two types:

- Force controlled
- Displacement controlled.

3.4.3 Model super position method:

The basic stages involved in modal superposition method are as follows:

i. Choosing a suitable design spectrum selection.
ii. Determine time period and mode shapes.
iii. After determining the time period, determine the response for each mode period using spectral data of design.
iv. Participation of every node contributing to SDoF response are to calculated.
v. Addition of the effects of modes in order obtains combined maximum response.
vi. Converting combined maximum response obtained into shears and moments.

3.4.4 Nonlinear dynamic procedure:

Nonlinear is regarded as domain of time. In this surface records and structural details are combined to acquire a result with less ambiguities to accomplish it, component strain estimated value is generated based on ground motion for each degree of freedom of model using square root sum scheme to combine model response. This method is rigorous, and some codes practiced require this method to be used for special configurations or constructions of exceptional concerns. Different analysis for multiple ground motion is to be carried out for reliable distribution of response as calculated response for single ground motion is sensitive to this seismic input. Intensity and severity establish seismic response of model for the earthquake, the inclusive evaluation requires a large number of non linear dynamic analysis at different intensity levels to symbolize different probable scenarios of earthquake event. Therefore increment dynamic analysis is arises from it

Dynamic analysis will remain completed either by Response spectrum method or site explicit Time history technique. Following techniques can be opted for analysis based on requirement.

3.4.5 Equivalent Static Analysis/ Pseudo Static Analysis/ Linear Static Analysis:

Assuming building response in basis mode, ground motion effect during earthquake are represented using series of forces affecting a structure which are defined by spectrum of design response. This analysis is performed for low rise structure which doesn’t gets distorted significantly for ground motion using a spectrum to read response for given natural frequency.

Design of structures against lateral forces must use dynamic force effect. But, for linear method analysis of simple structures i.e. (Static) equivalent linear static methods is satisfied. Equivalent linear static method is allowed for irregular, regular, low to medium rise as per codal provisions. It Static equivalent method first step is determination of base shear load and its distribution for each floor using codal formulas. The viability of this method for tall structures is questionable as it offers inconvenience in usage because there are multiple number of mode shapes for tall structures, so this method can't be used.

STEPS:

Step 1: Find the lump mass and seismic weight (W):

Step 2: Calculation of basic natural period:

Ta=fundamental natural period of vibration (sec)

$= 0.075 * h^{0.75}$, for RC frame structure

h = building height (m).

Step 3: Determination of horizontal earthquake coefficient. DetermineA_n:

Step 4: Determination of base shear by design:

The total seismic base shear (V_{BS}) by design along principle directions;

$$V_{BS}=A_l W$$

A_l= Use the basic natural period of the considered vibration direction to design the value of the acceleration spectrum (horizontal)

Step 5: determination of vertical distribution

Using expression in code distribution of design base shear along height

$$Q_x=V_{BS}\frac{W_x h_i^2}{\sum_{i=1}^{n} W_i h_i^2}$$

Where,

Q_x= lateral forces by design at xth floor

W_x=seismic weight for xth floor

h_i= floor height of xth floor from base.

n = nos. for stories present in structure

Step 6: lateral forces are distributed among elements which are resisting lateral force

3.4.6 Time history analysis

It is the study of structural behavior under past earthquake or wind acceleration data. The structure does not need to be an SDoF system. Time history is a graph of the relationship between amplitude or acceleration and time.

In time history analysis, with a delay of few moments' structural response is calculated. In other words, for a certain input of time history structural response is acquired as result. In response spectrum analysis, the time course of the response cannot be calculated.

3.4.7 Response spectrum analysis

When behavior of structure is greatly impacted by modes other than fundamental modes, then response spectrum method is most suitable. In this method, the response of MDOF system can be illustrated as superposition of model responses. Total response is obtained combining the response of each modal case which is determined using spectral analysis performed for SDOF systems.

For this method, amid earthquake maximum responses are directly acquired from either design spectrum or seismic response spectrum. Under earthquake, response of multiple modes is considered.

In each mode, for reading of a design spectrum response we are dependent on modal period. Different modes response is culminated for evaluation of total reaction of structures using a complete secondary combination (CQC), a square root (SRSS), or a mode combinatorial method, such as a total method (ABS). Provide a value.

Prerequisite for performing response spectrum analysis is having a method for designing spectrum or using site specific design spectra that are obtained specifically for the structure of a particular project site.

3.5 Tools for Analysis

Many software's are available on which analysis can be carried out, they are

- STAAD PRO
- ETABS
- SAP2000
- ADINA
- SC PUSH3D

ETABS is the tool used for carrying out analysis in the presented work, as it can provide most productive solution from a 2D frame to a complex 3D model for non linear analysis. Step by step deformation is provided in advanced analytical techniques; stiffness of non linear cases is based upon Eigen and Ritz analysis. It is finite element software which works with complex geometry. It also has by default all material properties and codes like ATC 40, FEMA 356, FEMA 440, IS 1893 (part 1) : 2002 so as to facilitate easy and quick solution for a set of boundary conditions.

ETABS is an FEM based software product used for engineering problems. In civil engineering it can useful for the purpose of analyzing or designing of multi storied structures. With unique grid–like geometry, modeling tool and templates, code based regulations for loads, different analysis procedures and techniques for solutions are synchronized with type of structure. ETABS can be used for static and dynamic conditions for evaluation of different systems ranging between basic to advance. For complex situations such as evaluation of seismic performance then either direct method or modal integration time history analysis will be combined with P-Delta and large displacement effects.

Non linear links and concentrated PMMs or fiber hinges used for capturing materials, Non-linarites which exhibits monotonous or hysterical behavior. Built in and intuitive functions allow for many complex uses. Linking between multiple types of platforms brands ETABS as efficient and well coordinated designing application suitable for various designing regimes ranging between 2 D frames to modern complex high rise buildings.

Chapter 4

SCOPE AND OBJECTIVES OF STUDY

4.1 Objectives of Study:-

The current study focuses on the investigation of the following:

[1] To know more about different irregularities present in a structure and their possible combinations which affect the structure

[2] How to perform seismic assessment on these types of structures.

[3] Analyzing the effect of lateral loads on structures with these irregularities.

[4] To know the structural behavior under the application of lateral loads i.e. on irregular structures.

4.2 Scope of Study:

[1] Determination of potential damages which may occur in a RC Residential structure under effect of lateral loads due to earthquake for zone-V.

[2] The work is done by using Symmetrical bay frame and the means for carrying out analysis is using linear Static method of Analysis

[3] In this study seventeen different models of single irregularities and thirteen different models for the combinations of irregularities are used and their behavior is studied for seismic zone V.

[4] Main scope of present study is to obtain seismic responses for different models of irregularities and compare their results to understand vulnerable cases of irregularities which may arise.

Chapter 5

METHODOLOGY

For carrying out present study different models of irregular configuration are to be analyzed to get seismic responses. Numerically results are obtained using finite element package i.e. in present study ETABS is used. After modelling the frames, they are analyzed using equivalent static analysis. Input used for introducing irregularities are frame geometry which includes columns and storey dimensions as well as total mass of storey is considered as input. When lad is applied on model, it is assumed that model is presently a rest. Responses obtained after analysis are base shear, drift and lateral displacement. Lastly comparison, interpretation & validation of the results is done. For validation purpose of results, responses for regular configuration models are compared with results obtained in literatures.

5.1 Steps Involved

The steps undertaken to accomplish the objective are in order as discussed below:

1) Selection of exhaustive sets for regular and different irregular framed structure models where height remain same for all these models along with their equal width of bays of 3m in horizontal.
2) Performing linear static analysis for every model of structure which are opted in this study.
3) After analyzing seismic responses for structures, a comparison is made with regular model.
4) Presenting analysis results into a understandable format of tabular or graphical forms.
5) Detailed observations and discussions are made using Tables and graphs obtained.

5.2 Model Description

Details for the structure of regular configuration model are tabulated in Table-5.1. From Table-5.2, details regarding earthquake and loading parameters are shown.

Table 5.1-Structure Details for Regular Configuration

Parameters	**Data**
Types of building modelled	Residential
Height of structure	30m
No. of Stories	G+9
Frame spacing along X-direction (in m)	3
Frame spacing along Y-direction (in m)	3
Bays along X-direction (in m)	6
Bays along Y-direction (in m)	4
Beam dimension (in mm)	250 * 350
Column dimension (in mm)	450 *600
Slab thickness used (in mm)	150
Height of each floor (in mm)	3
Support condition	Fixed
Grade of concreate used	M-30
Steel Grade	Fe 415
Concrete density	25 KN/M^3
Density of Steel	78.5KN/M^3

Table 5.2-Loading and Earthquake Details

Seismic Parameters	**Data**
Zone factor	.36
Live Load (KN/m2)	2.5
Earthquake Zone	V
Importance Factor	1
Type of Soil	Medium

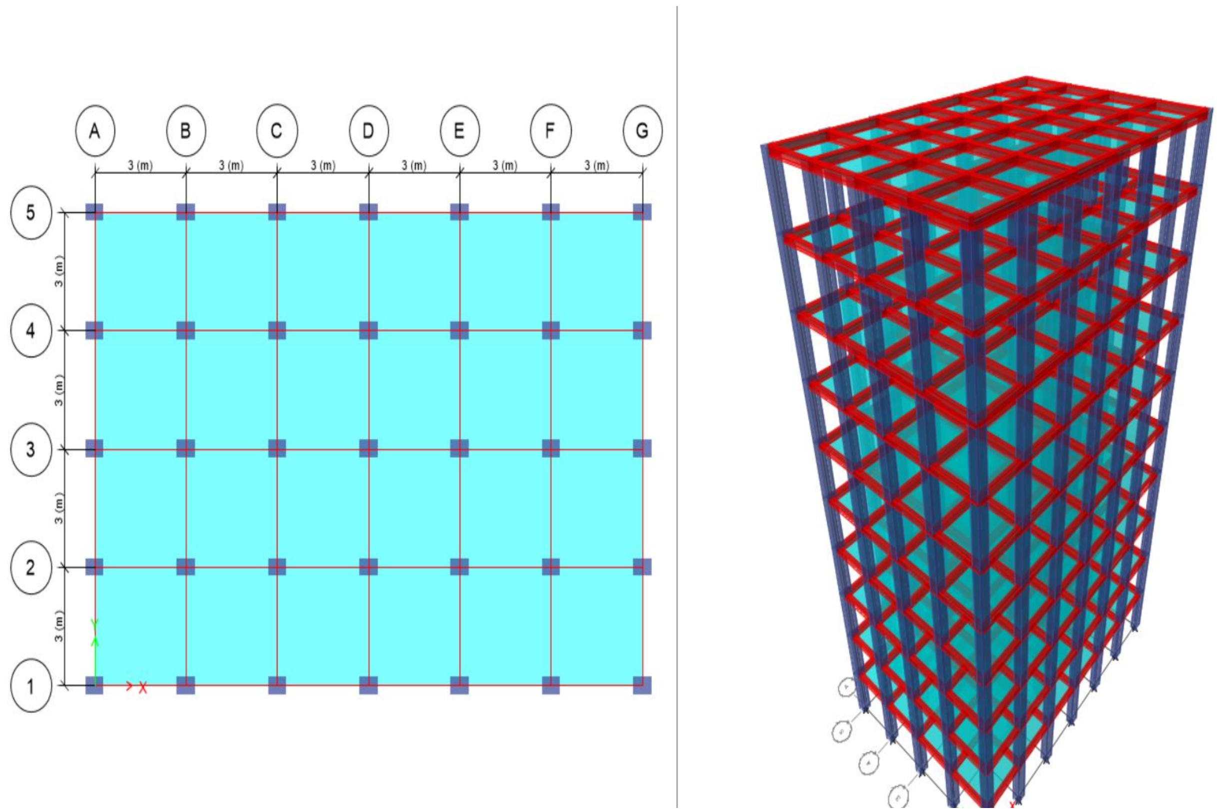

Figure 5.1.Model RS (Regular Symmetrical Model)

5.3 Configurations of frames with Single Irregularity

Single irregularities consists of horizontal and vertical irregularities. Geometrical irregularity in vertical, stiffness and mass irregularities comes under domain of vertical irregularities whereas torsional and re-entrant corner irregularities comes under domain of horizontal or plan irregularities. Following twelve cases depicts regular configuration as well as vertical models of irregularities considered of study in figures 5.1 to 5.8. From figures 5.9 to 5.14, represents single irregularities present in the plan configuration. for the purpose of uniformity in comparison number of stories and length of bay are meant to be constant . given below is the details of irregularities which are being analyzed in present study:

A. Mass irregularity (MVI)

In this analysis, three mass irregularity model (MVI-1 to MVI-3) cases are opted out. By increasing mass of selected storey, incorporation of irregularity is carried out.

In case of model MVI-1, mass increase is carried out for fourth storey by a multiple of 1.5 times. For model MVI-2, mass increase is carried out for seventh storey by a multiple of 1.5 times. For model MVI-3, mass increase is carried out for fourth and seventh storey simultaneously by a multiple of 1.5 times

B. Stiffness Irregularity (SVI)

In this analysis, six stiffness irregularity model (SVI-1 to SVI-6) cases are opted out. By increasing column length, changing number of columns or their cross sectional area for a selected storey, incorporation of irregularity is carried out.

In case of model SVI-1 and SVI-2, column length is increased at first and seventh storey respectively. In case of model SVI-3 and SVI-4, column numbers are reduced from thirty five to twenty at first and seventh storey respectively. In case of model SVI-5, area of cross section is increased for first two floors. The increase in column area is from 450mm x 600mm to 500mm x 600mm

In case of model SVI-6, replacement of column from rectangular to circular is carried out for first two stories. This change is done only in shape without changing cross sectional area. From Figure 5.2 to Figure 5.6, it is clearly visible how these model cases from SVI-1, SVI-2, SVI-3, SVI-4 and SVI-6 respectively are inputted for analysis.

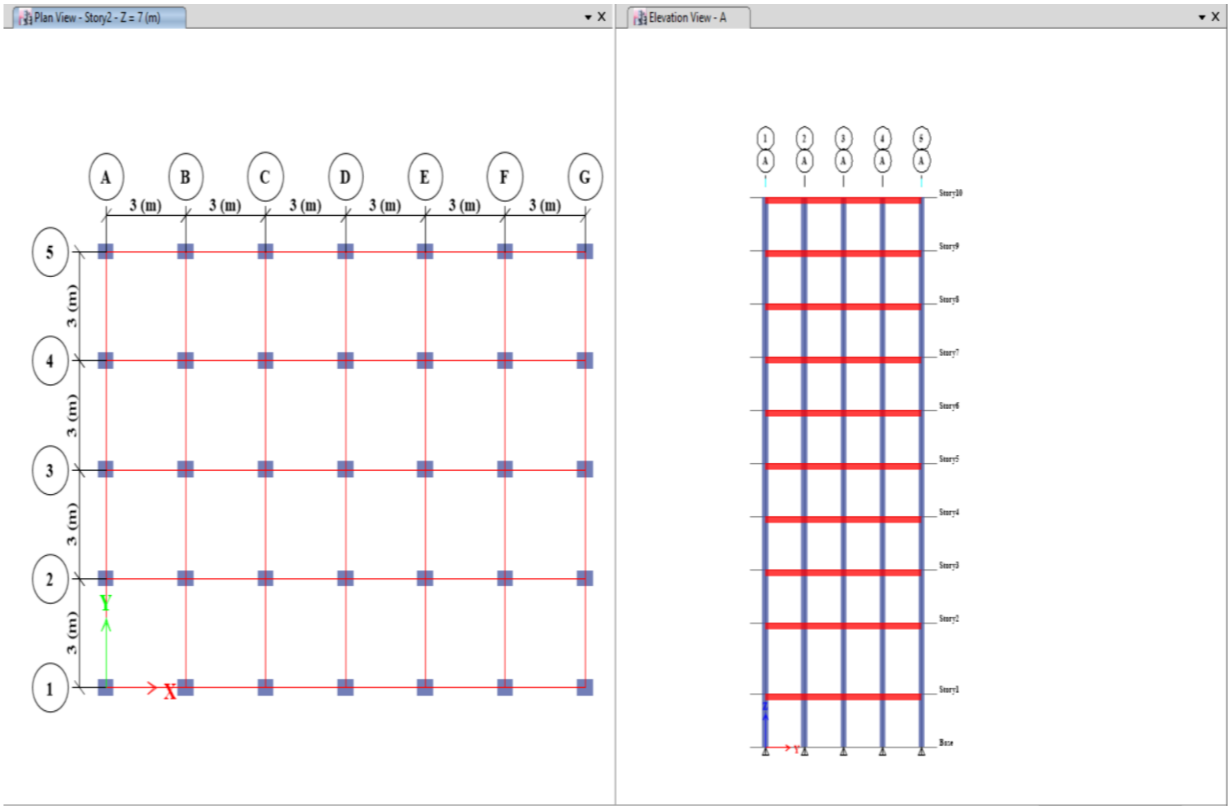

Figure 5.2.Model SVI-1: Column Length Increased on Storey 1

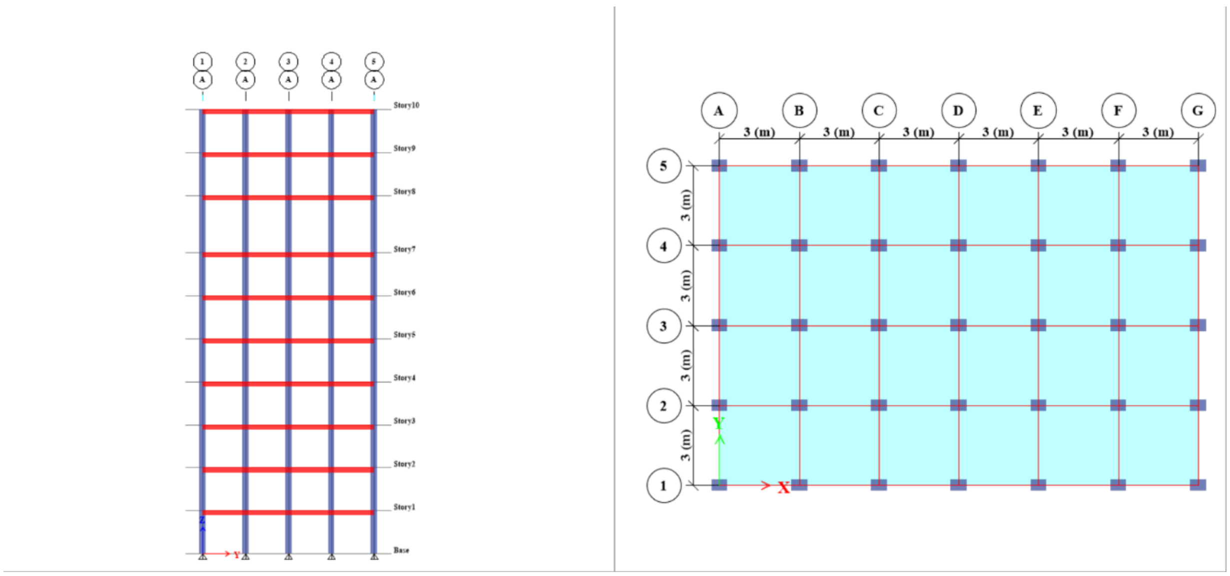

Figure 5.3.Model SVI-2: Column Length Increased on Storey 7

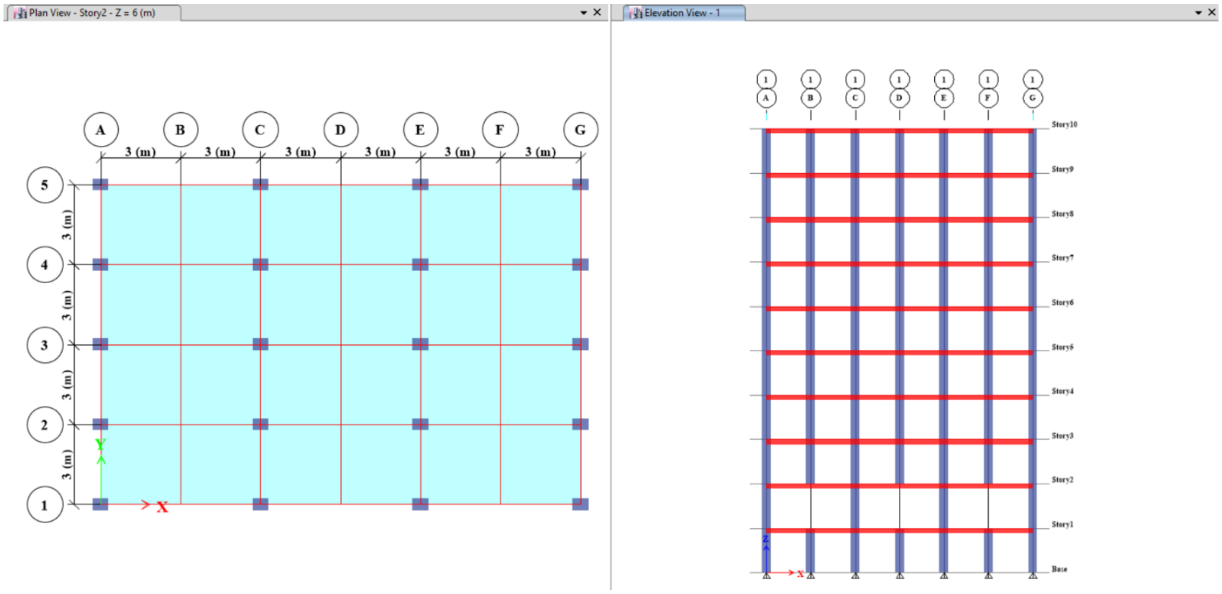

Figure 5.4.Model SVI-3: Number of Column Decreased from 35 to 20 on Storey 1

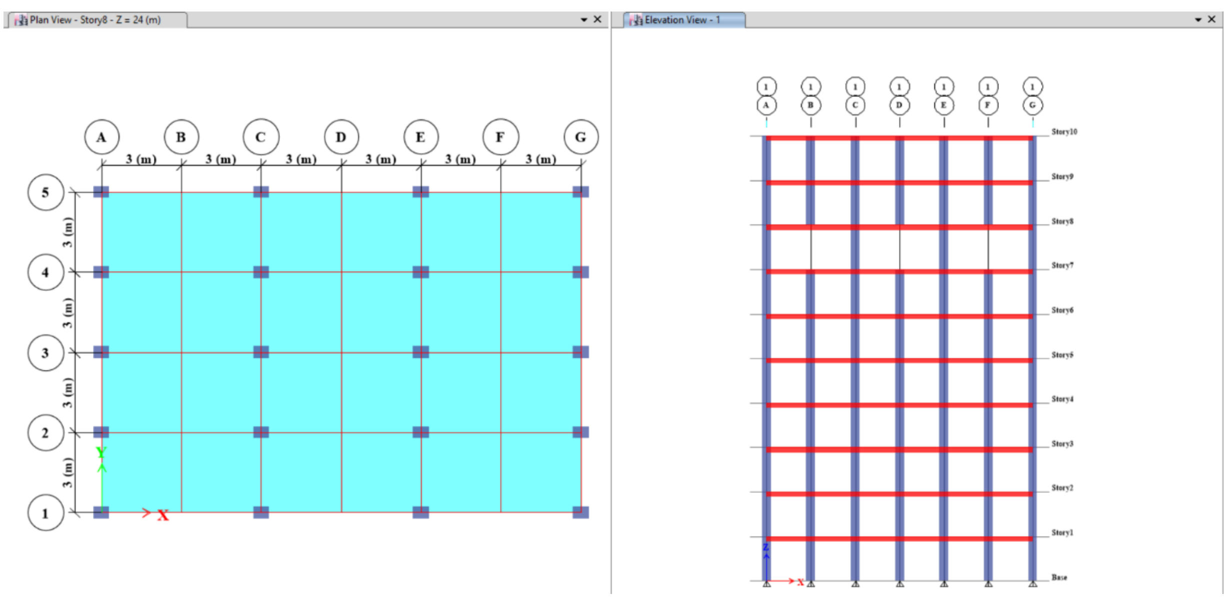

Figure 5.5.Model SVI-4: Number of Column Decreased from 35 to 20 on Storey 7

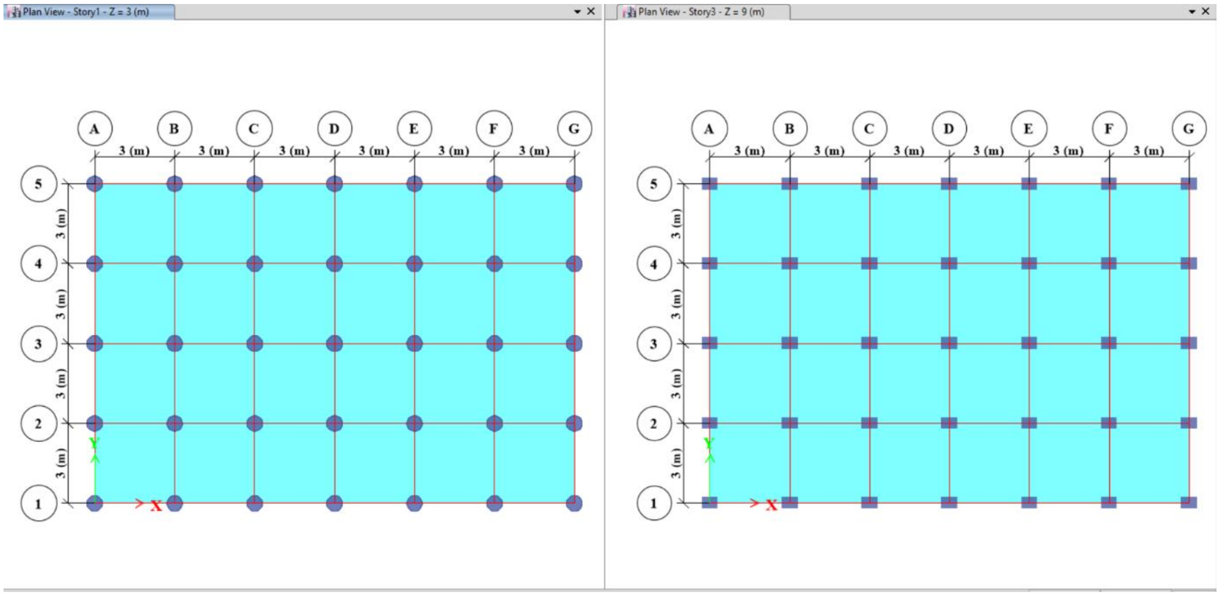

Figure 5.6.Model SVI-6: Rectangular Columns Are Replaced with Circular Column of Same Cross Section

C. Vertical Geometric Irregularity (VIG)

Only two cases of vertical geometrical irregularities are opted out in this study which are VIG-1 and VIG-2. Variation in vertical configuration to introduce irregularity is carried out over the height of building. For these models given below, said irregularities are introduced by variation in dimension for elements resisting lateral forces along horizontal. Following Figures 5.7 and 5.8 shows these cases.

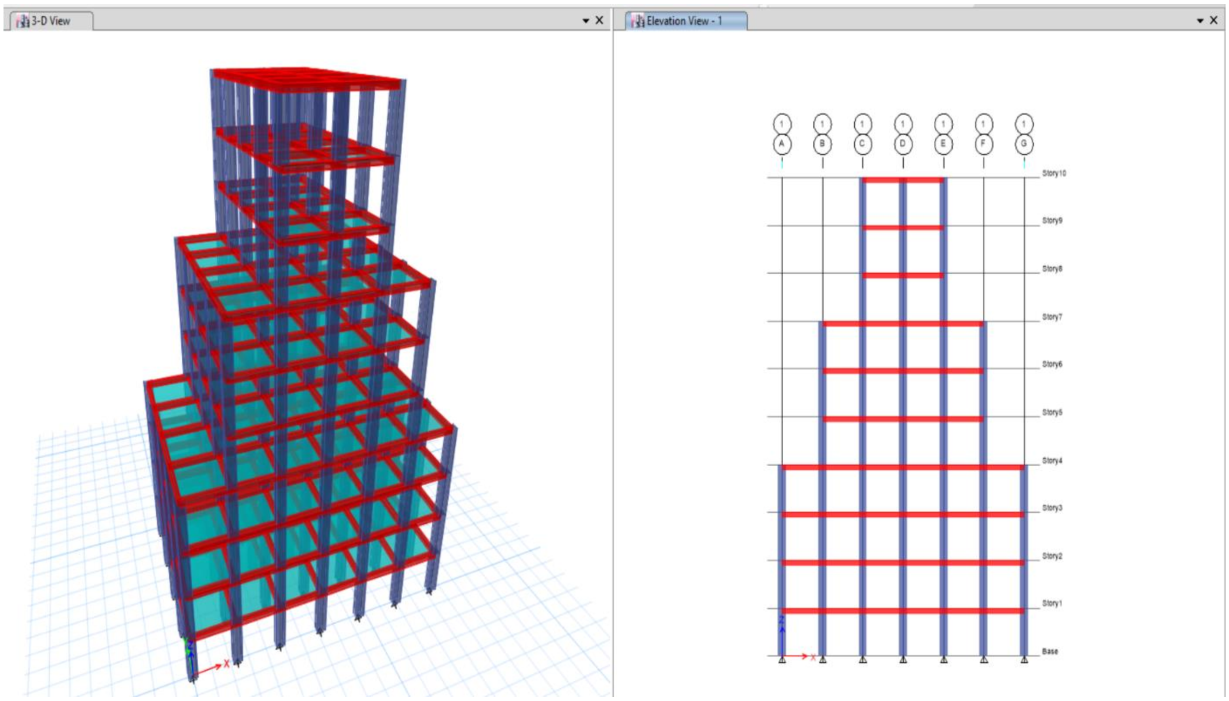

Figure 5.7.Model VIG-1: Horizontal Dimension of Lateral Resisting Force is Reduced Equally about Center

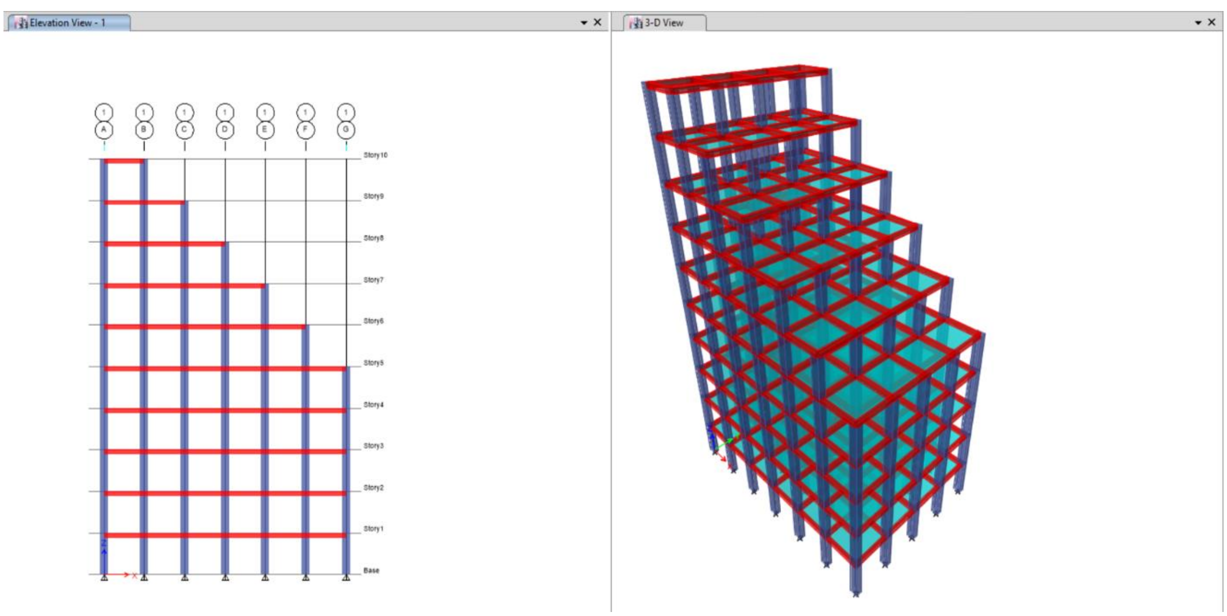

Figure 5.8.Model VIG-2: Horizontal Dimension of Lateral Resisting Force Is Reduced along One Side Only

D. Re-entrant Corner Irregularity (RI)

Introduction of re-entrant corner irregularity is accomplished by changing plan dimension in the configuration of regular frame. Four cases ranging between (RI-1 to RI-4) are opted out in this analysis and Model of RI-1 to RI-4 are represented from Figures 5.9 to 5.12

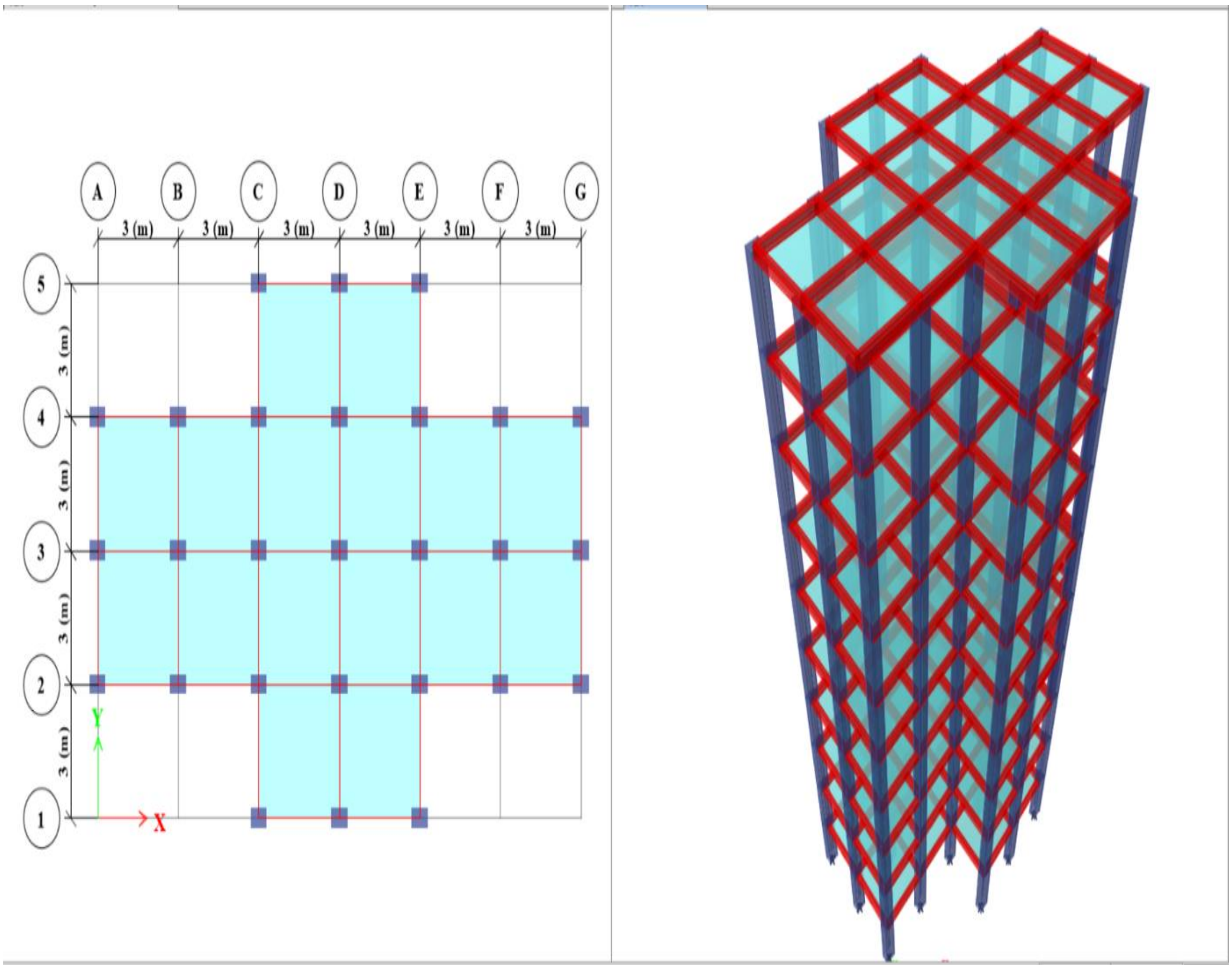

Figure 5.9.Model RI-1: Projections provided is 50% in X direction and 25% in Y direction

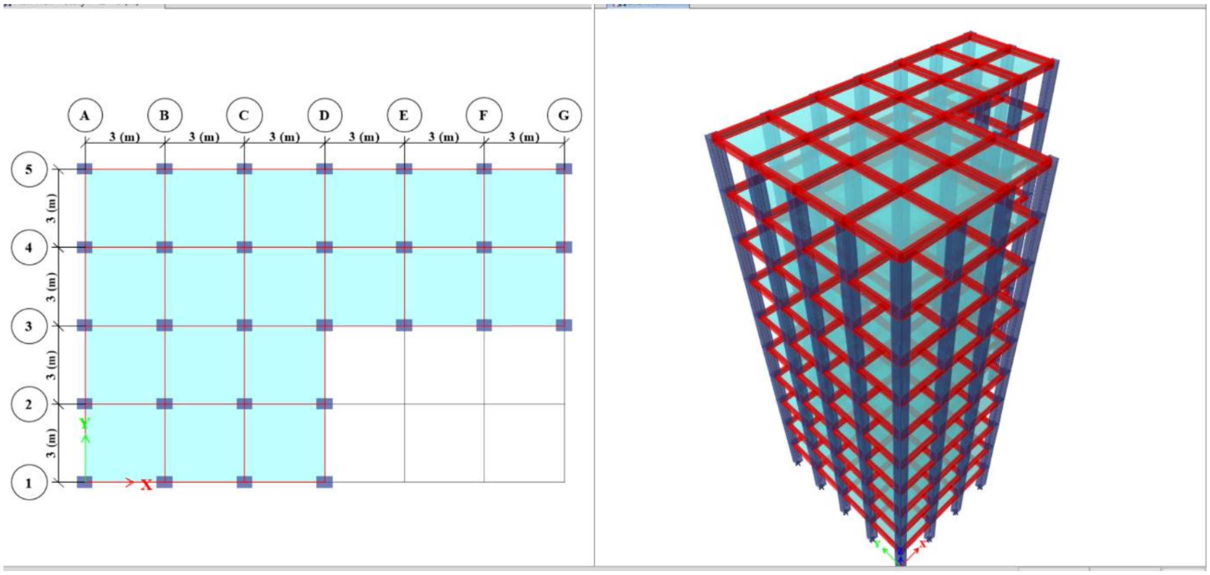

Figure 5.10.Model RI-2: Projections provided is 30% in X direction and 30% in Y direction

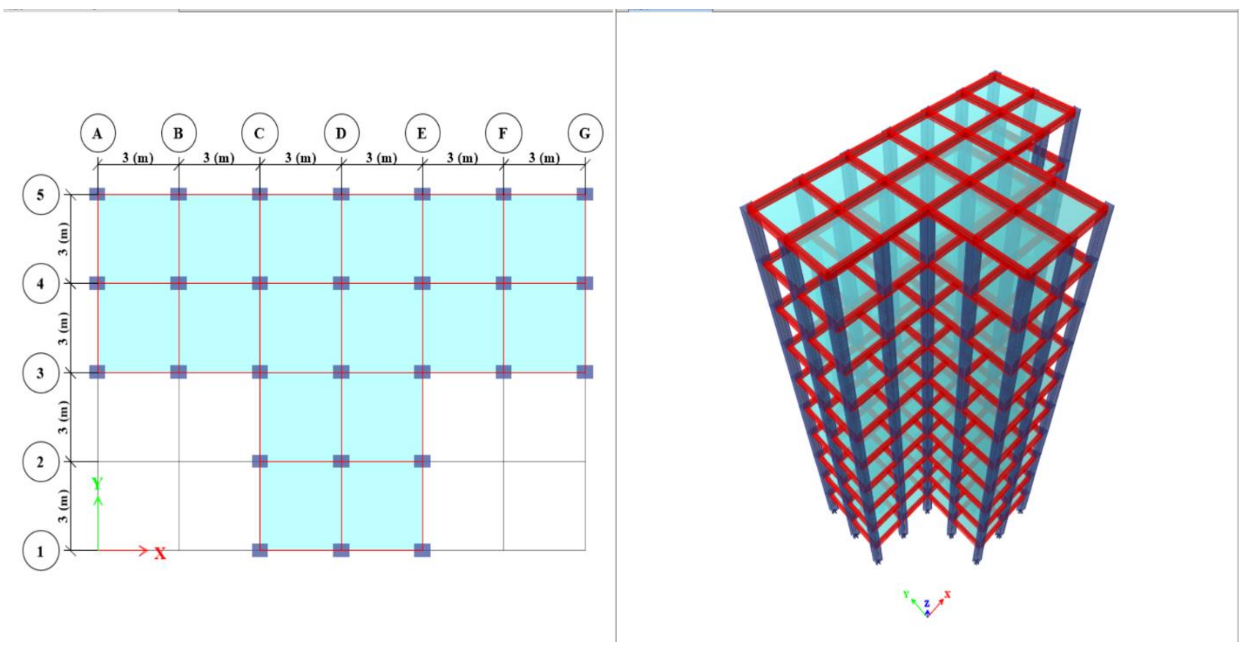

Figure 5.11.Model RI-3: Projections provided is 50% in the X direction whereas 25% in Y direction

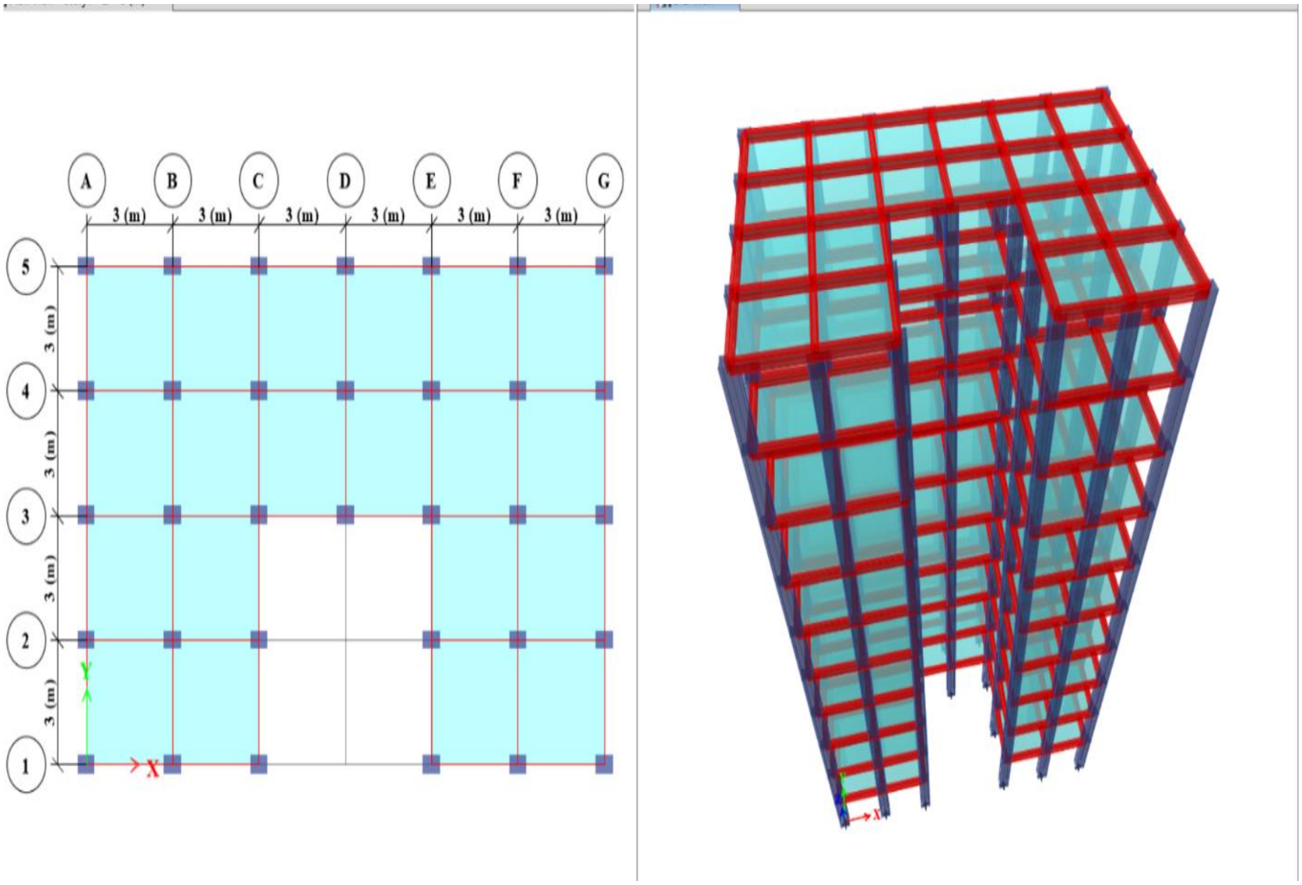

Figure 5.12.Model RI-4: Projection provided is 30% in the Y direction

E. *Torsional Irregularity (THI)*

Vertical structural elements are changed to introduce torsional irregularity. Two different cases of torsional irregularity (THI-1 and THI-2) are opted out for the analysis. For Model THI-2, incorporation of irregularity is carried out using circular cross sectional columns of dimension 600mm. For Model THI-1, incorporation of irregularity is done by introducing shear walls of dimension 150mm on corners of section 4 and 5 in the building. Above irregularities are mentioned in Figure 5.13 and figure 5.14

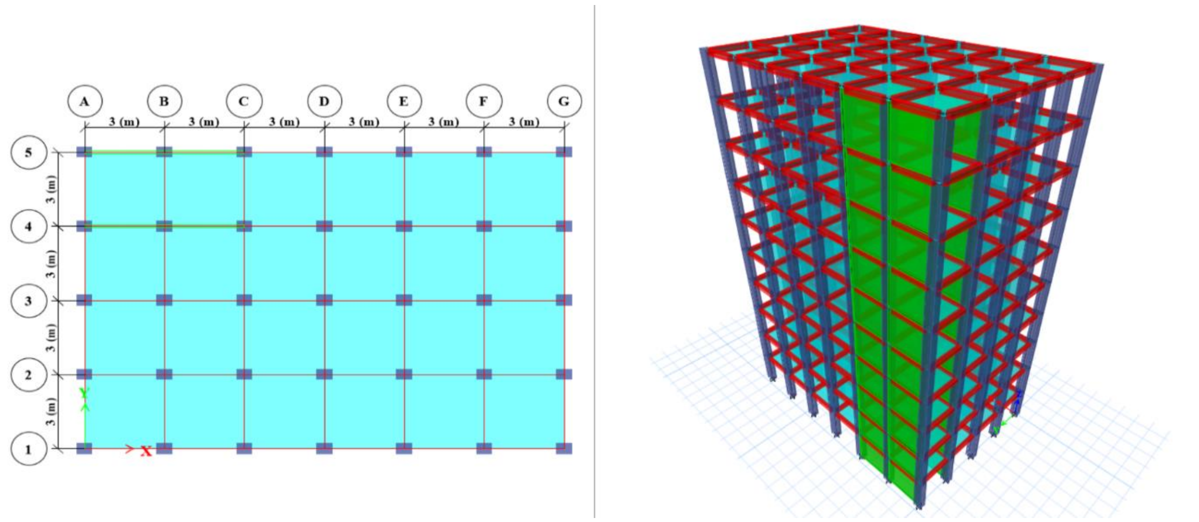

Figure 5.13.Model THI-1: shear wall of thickness 150mm at corner of building

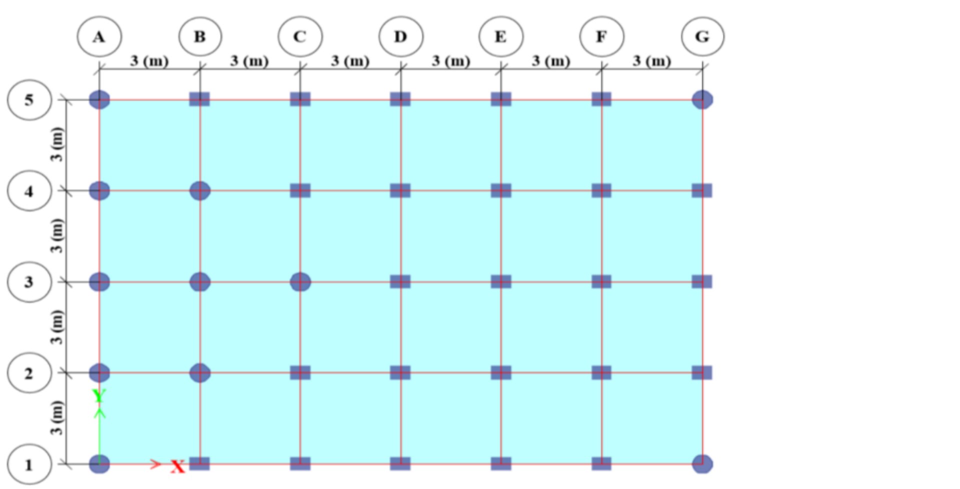

Figure 5.14.Model THI-2: Circular column of 600mm are introduced at few places to introduce torsional irregularity

5.4 Configurations with Combinations of Irregularities

In the following analysis, thirteen different cases of combination of irregularities (CMI) are considered. In Table 5.3, details of all the cases of combination are mentioned. Combination considered comprises of cases of single irregularities resulting in maximum response for further analysis of frames. Figure-5.15 shows the case of combinations of five irregularities:-

Table 5.3.Cases of Combination of Irregularities

Combination No.	Irregularity involved	Combination No.	Irregularity involved
CMI-1	MVI-3+SVI-1	CMI-8	MVI-2+SVI-5+VIG-1
CMI-2	MVI-2+SVI-5	CMI-9	RI-4+VIG-1
CMI-3	MVI-2+VIG-1	CMI-10	VIG-2+RI-2
CMI-4	MVI-3+VIG-2	CMI-11	MVI-2+SVI-5+VIG-1+RI-4
CMI-5	SVI-5+VIG-1	CMI-12	MVI-2+SVI-5+VIG-1+RI-4+THI-2
CMI-6	VIG-2+SVI-1	CMI-13	MVI-2+SVI-5+VIG-1+RI-4+THI-1
CMI-7	MVI-3+SVI-1+VIG-2		

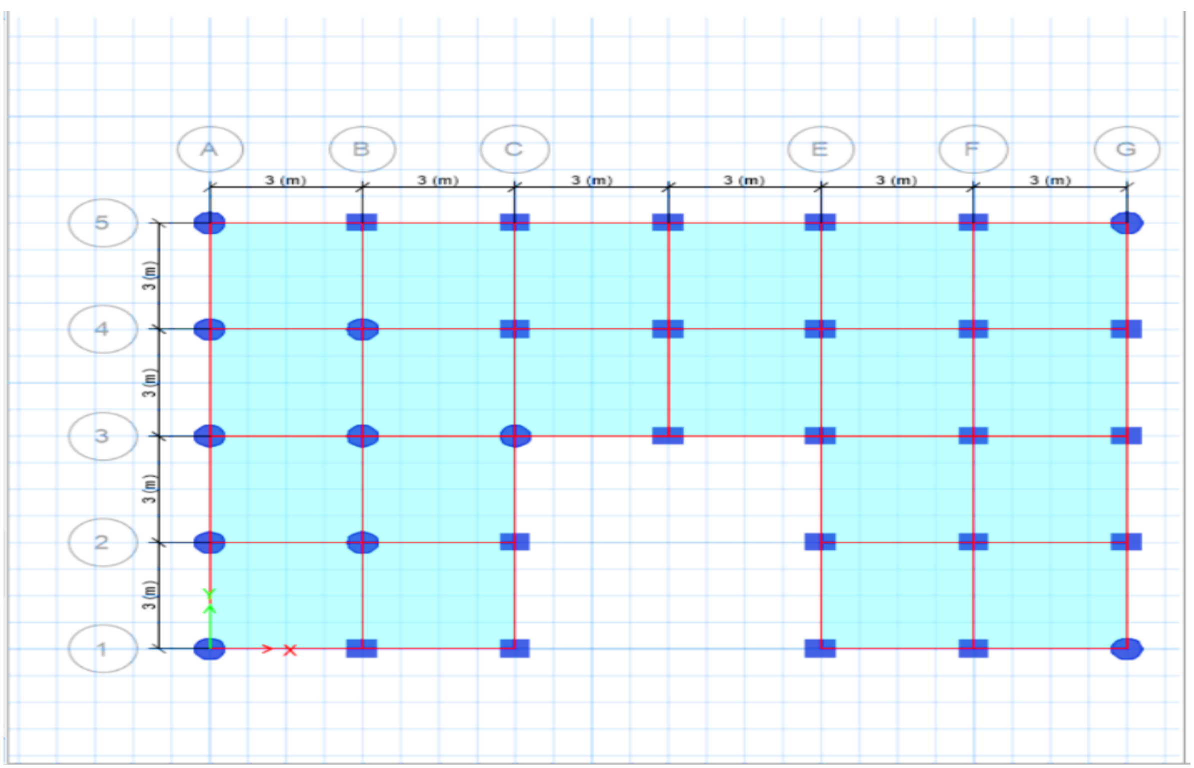

Figure 5.15.Model CMI-12: an example of combination of irregularities

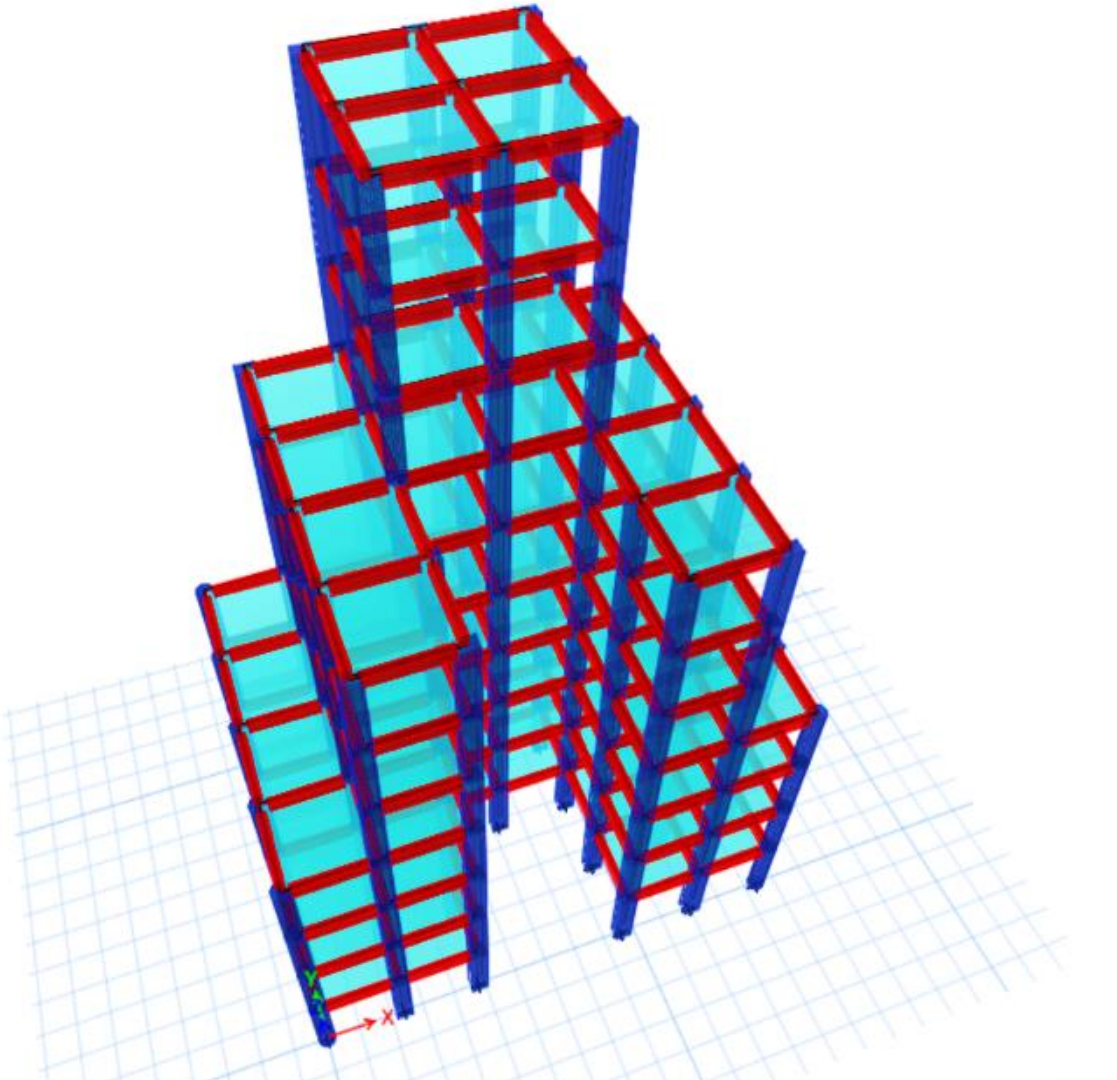

Figure 5.16.Model CMI-12: in 3-D view

Chapter 6

RESULT AND DISCUSSION

After analysis, the results are obtained for cases of single and combination of irregularities which are plotted and compared with the case of regular configuration.

6.1 Frames having single irregularities:

Results are in the form of following:

6.1.1 Storey Displacement:

Magnitude of storey displacement for regular and other cases of irregularities (MVI, VIG, SVI, RI and THI) are shown below in Table 6.1(a), (b) and (c).

Table 6.1(a).Displacement Response for MI and VI Cases Compared with Regular Configuration

STOREY	STOREY DISPLACEMENT(in mm)					
	RS	MVI-1	MVI-2	MVI-3	VIG-1	VIG-2
0	0	0	0	0	0	0
1	5.541	7.35	7.315	7.365	5.515	7.286
2	16.318	20.607	20.508	20.65	15.282	20.429
3	28.329	34.704	34.538	34.781	25.406	34.355
4	40.051	48.128	47.91	48.242	34.839	47.506
5	50.85	60.343	60.106	60.499	44.547	59.303
6	60.406	71.103	70.872	71.302	53.446	69.464
7	68.507	80.219	80.009	80.442	60.929	77.839
8	74.994	87.515	87.314	87.705	68.015	84.363
9	79.791	92.86	92.614	93.005	73.66	89.069
10	83.052	96.354	96.063	96.469	77.382	92.14

Table 6.1(b).Displacement response for SVI cases compared with regular configuration

STOREY	STOREY DISPLACEMENT(in mm)						
	RS	SVI-1	SVI-2	SVI-3	SVI-4	SVI-5	SVI-6
0	0	0	0	0	0	0	0
1	5.541	7.868	7.275	7.089	7.286	6.062	6.266
2	16.318	29.287	20.395	23.568	20.422	17.751	18.21
3	28.329	44.165	34.351	38.407	34.386	31.439	31.958
4	40.051	57.577	47.663	52.466	47.684	44.775	45.286
5	50.85	69.581	59.841	65.322	59.806	57.008	57.495
6	60.406	80.088	70.709	76.746	70.521	67.814	68.275
7	68.507	88.961	80.339	86.562	79.744	76.973	77.413
8	74.994	96.051	91.93	94.604	88.54	84.296	84.723
9	79.791	101.249	97.667	100.756	94.035	89.648	90.072
10	83.052	104.665	101.289	105.123	97.797	93.126	93.557

Table 6.1(c) .Displacement Response for RI and TI Cases Compared with Regular Configuration

STOREY	STOREY DISPLACEMENT(in mm)						
	RS	RI-1	RI-2	RI-3	RI-4	THI-1	THI-2
0	0	0	0	0	0	0	0
1	5.541	6.757	6.938	6.757	6.698	7.945	7.143
2	16.318	19.149	19.784	19.152	18.83	22.271	20.184
3	28.329	32.481	33.69	32.487	31.775	37.483	34.142
4	40.051	45.285	47.105	45.297	44.143	51.939	47.479
5	50.85	57.032	59.453	57.05	55.446	65.069	59.647
6	60.406	67.452	70.439	67.478	65.435	76.597	70.377
7	68.507	76.34	79.846	76.376	73.92	86.318	79.469
8	74.994	83.518	87.482	83.563	80.725	94.05	86.743
9	79.791	88.857	93.22	88.914	85.725	99.669	92.078
10	83.052	92.46	97.172	92.529	89.009	103.302	95.588

For better understanding of lateral displacement of single irregular cases magnitude is plotted in the form of graph which is shown in figure 6.1(a), (b) and (c).

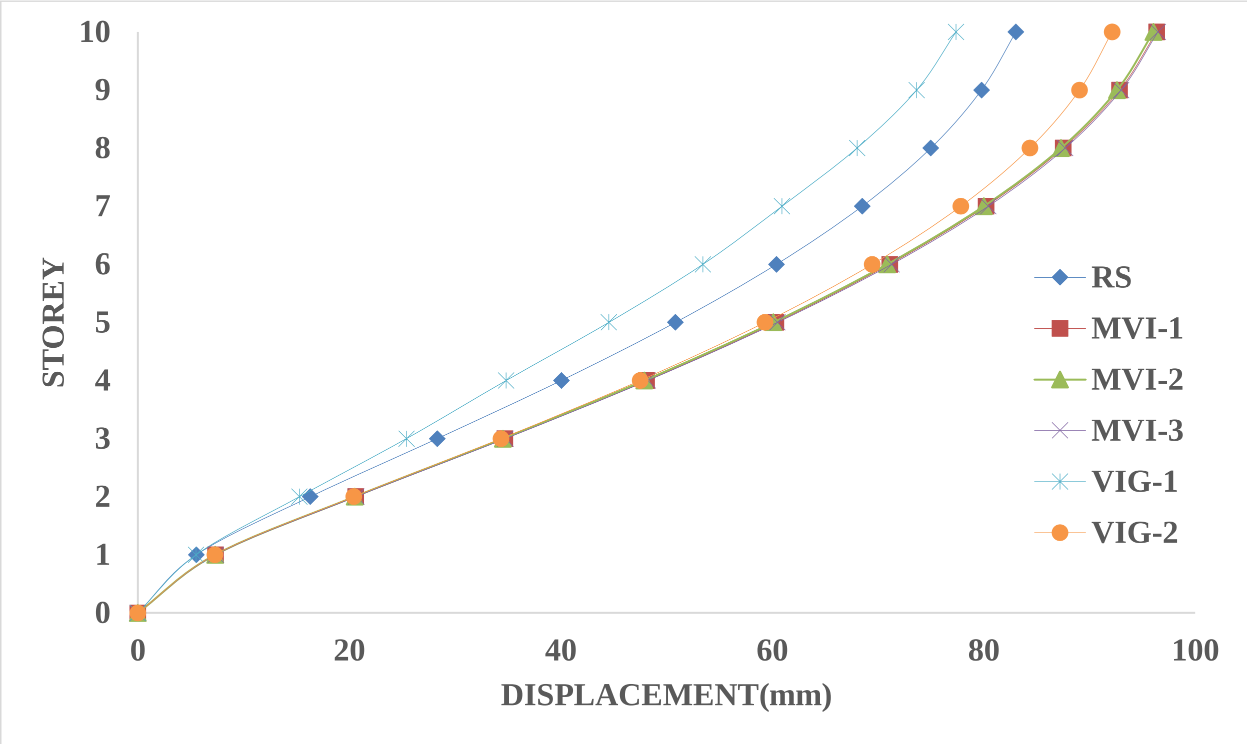

Figure 6.1(a). Displacement Response for MVI and VIG Cases

Following observations can be made from Figure 6.1(a):

- ❖ The cases of mass irregularities, vertical geometrical irregularities are compared with regular configuration.
- ❖ Least storey displacement is found in VIG-1 case whereas maximum displacement is observed for MVI-3 case.
- ❖ It is to be noted that no significant difference is observed in the case of MVI-1, MVI-2 and MVI-3.

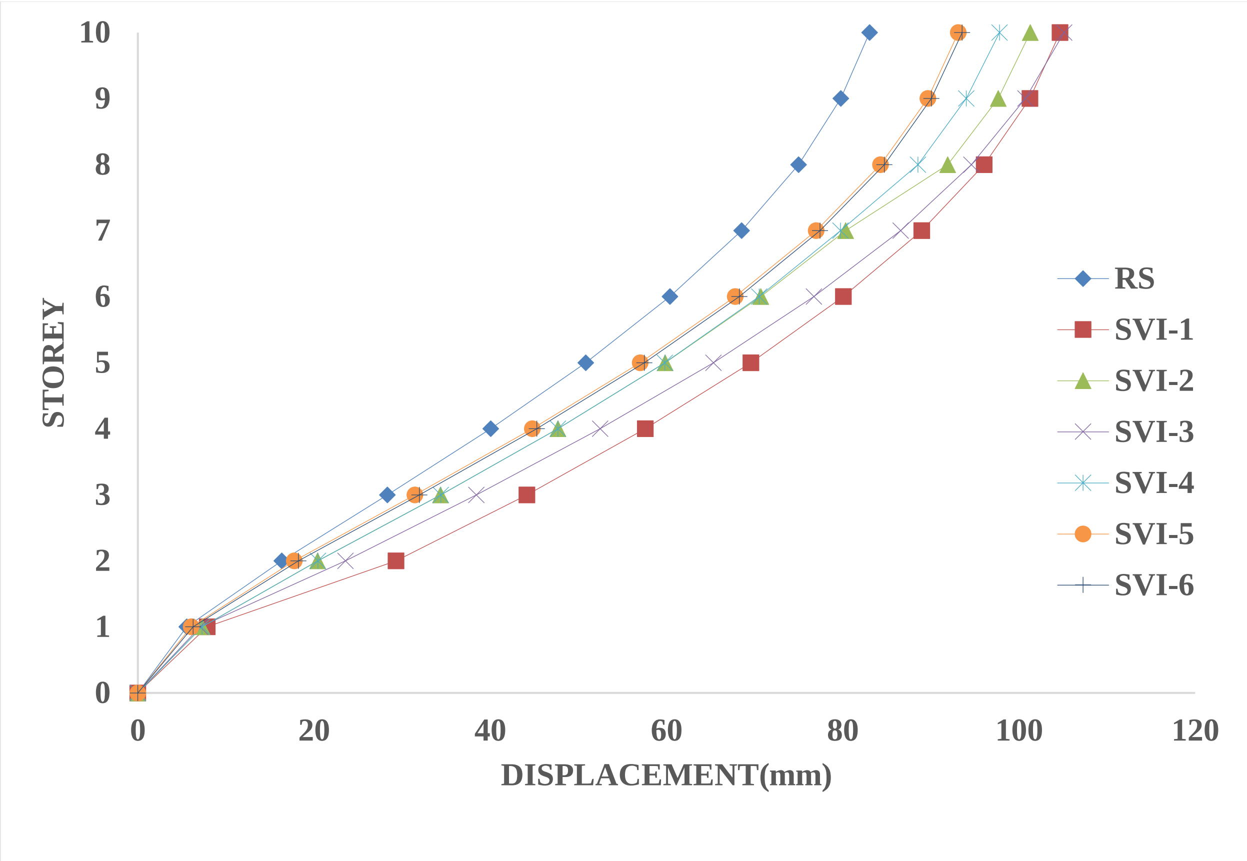

Figure 6.1(b).Displacement response for SVI cases compared with regular configuration

Following observations can be made from Figure 6.1(b):

- ❖ The cases of stiffness irregularities are compared with regular configuration.
- ❖ Least storey displacement is found in regular case whereas maximum displacement is observed for SVI-3 case.
- ❖ It is to be noted that no significant difference is observed in the case of SVI-5 and SVI-6.

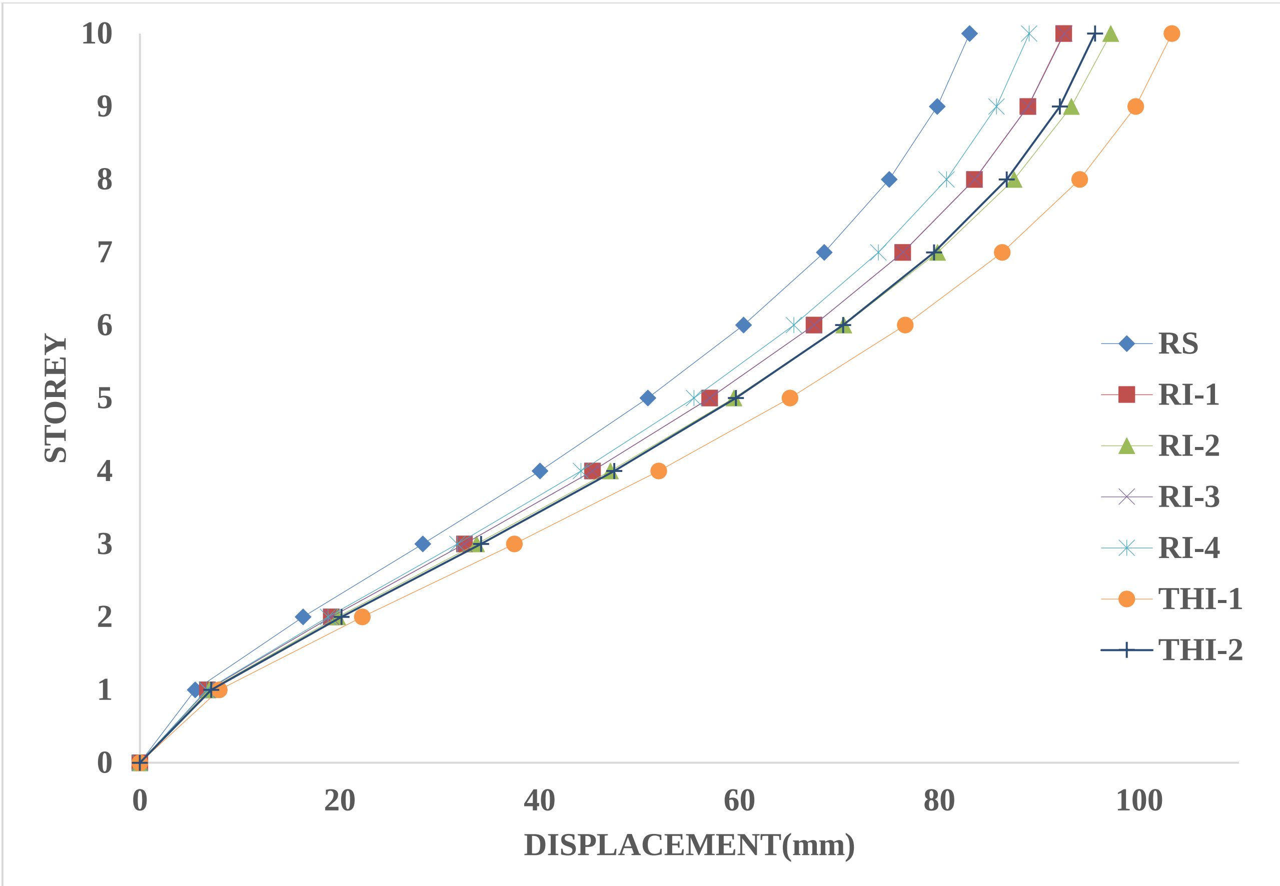

Figure 6.1(c).Displacement Response for THI and RI Cases Compared with Regular Configuration

Following observations can be made from Figure 6.1(c):

- ❖ The cases of re-entrant corner and torsional irregularities are compared with regular configuration.
- ❖ Least storey displacement is found in regular case whereas maximum displacement is observed for THI-1 case.
- ❖ It is to be noted that no significant difference is observed for cases of RI-1, RI-3 and THI-2

6.1.2 Drift:

Magnitude of drift for regular and other cases of irregularities (MVI, VIG, SVI, RI and THI) are shown below in Table 6.2(a), (b) and (c).

Table 6.2(a). Drift for MVI and VIG cases

STOREY	DRIFT					
	RS	MVI-1	MVI-2	MVI-3	VIG-1	VIG-2
10	0.0010869	0.001165	0.001149	0.001154	0.001241	0.001024
9	0.00159896	0.001782	0.001767	0.001767	0.001882	0.001569
8	0.00216246	0.002432	0.002435	0.002421	0.002362	0.002175
7	0.00270025	0.003039	0.003046	0.003047	0.002494	0.002792
6	0.00318522	0.003587	0.003589	0.003601	0.002966	0.003387
5	0.00359971	0.004072	0.004065	0.004086	0.003236	0.003933
4	0.00390738	0.004475	0.004457	0.004487	0.003145	0.004383
3	0.00400376	0.004699	0.004677	0.00471	0.003374	0.004642
2	0.00359221	0.004419	0.004398	0.004428	0.003256	0.004381
1	0.00184708	0.00245	0.002438	0.002455	0.001838	0.002429
0	0	0	0	0	0	0

Table 6.2(b).Drift for cases of SVI

STOREY	DRIFT						
	RS	SVI-1	SVI-2	SVI-3	SVI-4	SVI-5	SVI-6
10	0.0010869	0.00114	0.00121	0.001456	0.001254	0.001159	0.001162
9	0.00159896	0.00173	0.00191	0.002051	0.001832	0.001784	0.001783
8	0.00216246	0.00236	0.0029	0.002681	0.002932	0.002441	0.002437
7	0.00270025	0.00296	0.00321	0.003272	0.003074	0.003053	0.003046
6	0.00318522	0.0035	0.00362	0.003808	0.003572	0.003602	0.003593
5	0.00359971	0.004	0.00406	0.004285	0.004041	0.004078	0.00407
4	0.00390738	0.00447	0.00444	0.004686	0.004433	0.004445	0.004443
3	0.00400376	0.00496	0.00465	0.004946	0.004654	0.004563	0.004582
2	0.00359221	0.00536	0.00437	0.005493	0.004379	0.003896	0.003982
1	0.00184708	0.00262	0.00243	0.002363	0.002429	0.002021	0.002089
0	0	0	0	0	0	0	0

Table 6.2(c).Drift for cases of RI and THI

STOREY	DRIFT						
	RS	**RI-1**	**RI-2**	**RI-3**	**RI-4**	**THI-1**	**THI-2**
10	0.0010869	0.001131	0.001244	0.001205	0.001095	0.001211	0.001171
9	0.00159896	0.001669	0.001797	0.001783	0.001667	0.001873	0.001778
8	0.00216246	0.002242	0.00239	0.002396	0.002269	0.002577	0.002425
7	0.00270025	0.002783	0.00295	0.002966	0.002828	0.00324	0.003031
6	0.00318522	0.003279	0.003463	0.003476	0.00333	0.003843	0.003577
5	0.00359971	0.003739	0.003939	0.003918	0.003768	0.004377	0.004056
4	0.00390738	0.004197	0.004413	0.00427	0.004123	0.004819	0.004445
3	0.00400376	0.004756	0.00499	0.004445	0.004315	0.005071	0.004653
2	0.00359221	0.00576	0.006018	0.004132	0.004044	0.004775	0.004347
1	0.00184708	0.008315	0.008586	0.002252	0.002233	0.002648	0.002381
0	0	0	0	0	0	0	0

For better understanding of lateral drift of single irregular cases magnitude is plotted in the form of graph which is shown in figure 6.2(a), (b) and (c).

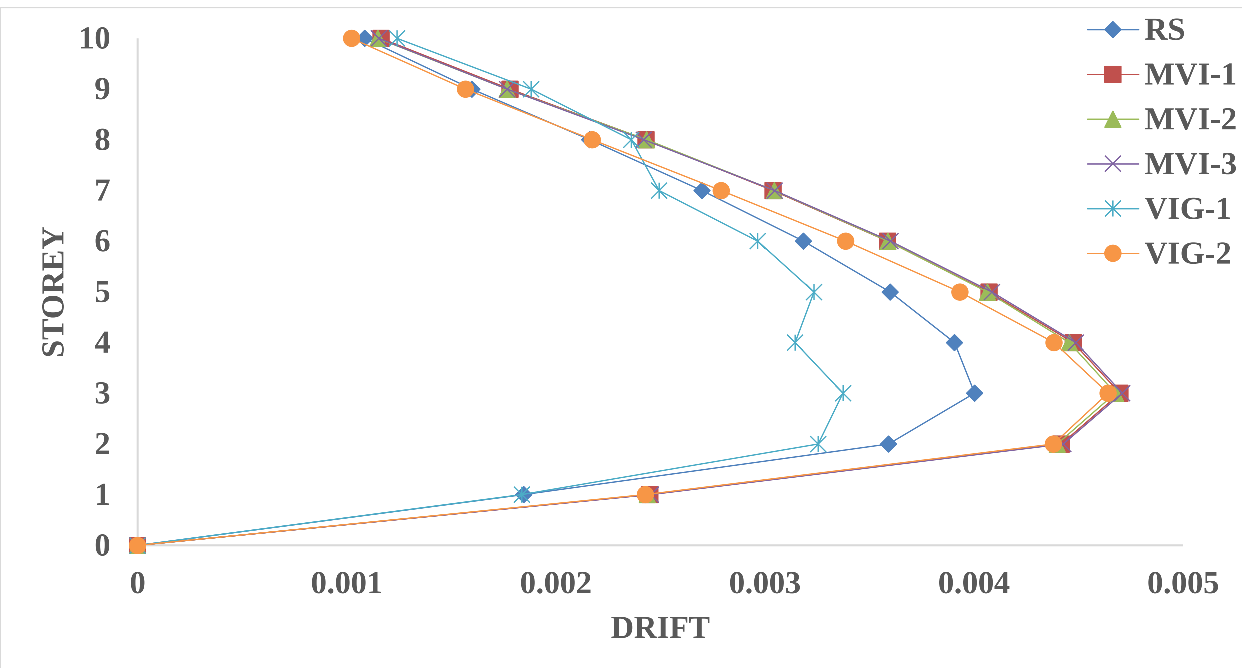

Figure 6.2(a).Drift for MVI and VIG cases

Following observations can be made from Figure 6.2(a):

- ❖ The cases of mass irregularities, vertical geometrical irregularities are compared with regular configuration.
- ❖ Least drift is found in VIG-1 case whereas maximum drift is observed for MVI-3 case.
- ❖ It is to be noted that no significant difference is observed in the case of MVI-1, MVI-2 ,MVI-3 and VIG-2

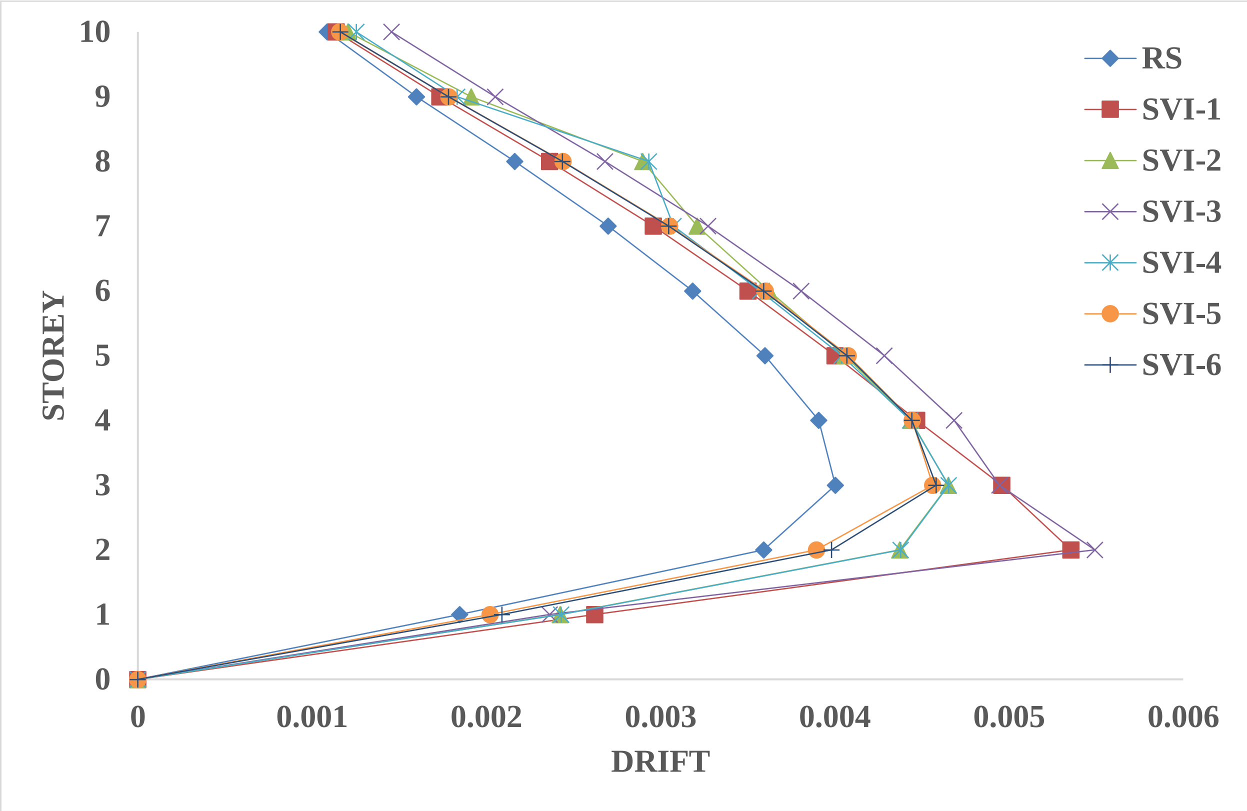

Figure 6.2(b) .Drift for cases of SVI

Following observations can be made from Figure 6.2(b):

- ❖ The cases of stiffness irregularities are compared with regular configuration.
- ❖ Least drift is found in regular case whereas maximum drift is observed for SVI-3 case.
- ❖ It is to be noted that no significant difference is observed in the case of SVI-5 and SVI-6

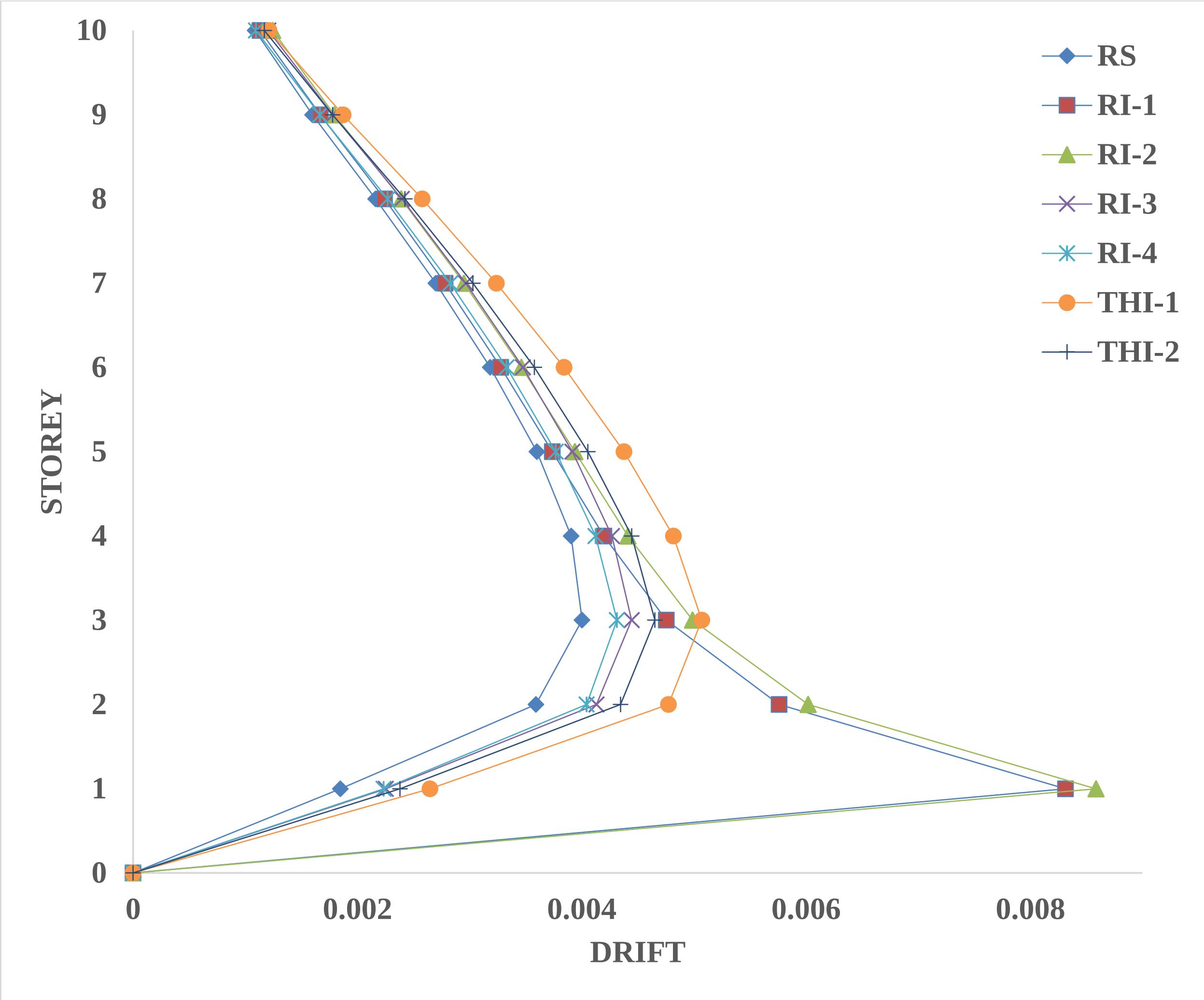

Figure 6.2(c).Drift for cases of RI and THI

Following observations can be made from Figure 6.2(c):

- The cases of re-entrant corner and torsional irregularities are compared with regular configuration.
- Least drift is found in case of RI-4 whereas maximum drift is observed for RI-2 case.
- It is to be noted that no significant difference is observed for cases of R, RI-3, RI-4 and THI-2.
- An abrupt change is observed in case of RI-1 and RI-2.

6.2 Frames having combination of irregularities-

Results are in the form of following:

6.2.1 Storey Displacement:

Magnitude of storey displacement for regular and combination of irregularities (CI-1 to CMI-13) are shown below in Table 6.3(a) and (b).

Table 6.3(a).Displacement Response for combination Cases CMI-1 to CMI-7 when compared with Regular Configuration

STOREY	**STOREY DISPLACEMENT(in mm)**							
	RS	**CMI-1**	**CMI-2**	**CMI-3**	**CMI-4**	**CMI-5**	**CMI-6**	**CMI-7**
0	0	0	0	0	0	0	0	0
1	5.541	7.924	6.067	5.51	7.341	4.581	7.761	7.813
2	16.318	29.502	17.768	15.269	20.588	13.277	28.823	29.025
3	28.329	44.496	31.474	25.386	34.63	23.221	43.435	43.749
4	40.051	58.015	44.833	34.82	47.891	32.699	56.486	56.899
5	50.85	70.103	57.099	44.543	59.77	42.533	67.966	68.449
6	60.406	80.681	67.949	53.475	69.998	51.571	77.765	78.304
7	68.507	89.602	77.161	61.007	78.409	59.177	85.798	86.367
8	74.994	96.681	84.521	68.146	84.884	66.386	92.037	92.556
9	79.791	101.854	89.845	73.765	89.523	72.124	96.535	96.989
10	83.052	105.251	93.289	77.449	92.546	75.891	99.481	99.89

Table 6.3(b) .Displacement Response for combination Cases CMI-8 to CMI-13 when compared with Regular Configuration

STOREY	STOREY DISPLACEMENT(in mm)						
	RS	CMI-8	CMI-9	CMI-10	CMI-11	CMI-12	CMI-13
0	0	0	0	0	0	0	0
1	5.541	4.576	4.809	6.964	4.001	3.828	4.199
2	16.318	13.262	13.323	19.553	11.595	11.313	12.134
3	28.329	23.198	22.106	32.928	20.24	19.76	21.096
4	40.051	32.674	30.209	45.605	28.408	28.01	29.49
5	50.85	42.522	38.495	57.027	36.846	36.655	37.88
6	60.406	51.591	45.989	66.872	44.517	45.006	45.596
7	68.507	59.245	52.211	74.957	50.911	52.36	52.013
8	74.994	66.508	59.586	81.195	58.524	59.413	59.498
9	79.791	72.217	66.258	85.662	65.325	65.515	66.318
10	83.052	75.943	70.968	88.571	70.081	69.99	71.074

For better understanding of lateral displacement of combination cases, magnitude is plotted in the form of graph which is shown in Figure 6.3(a) and (b).

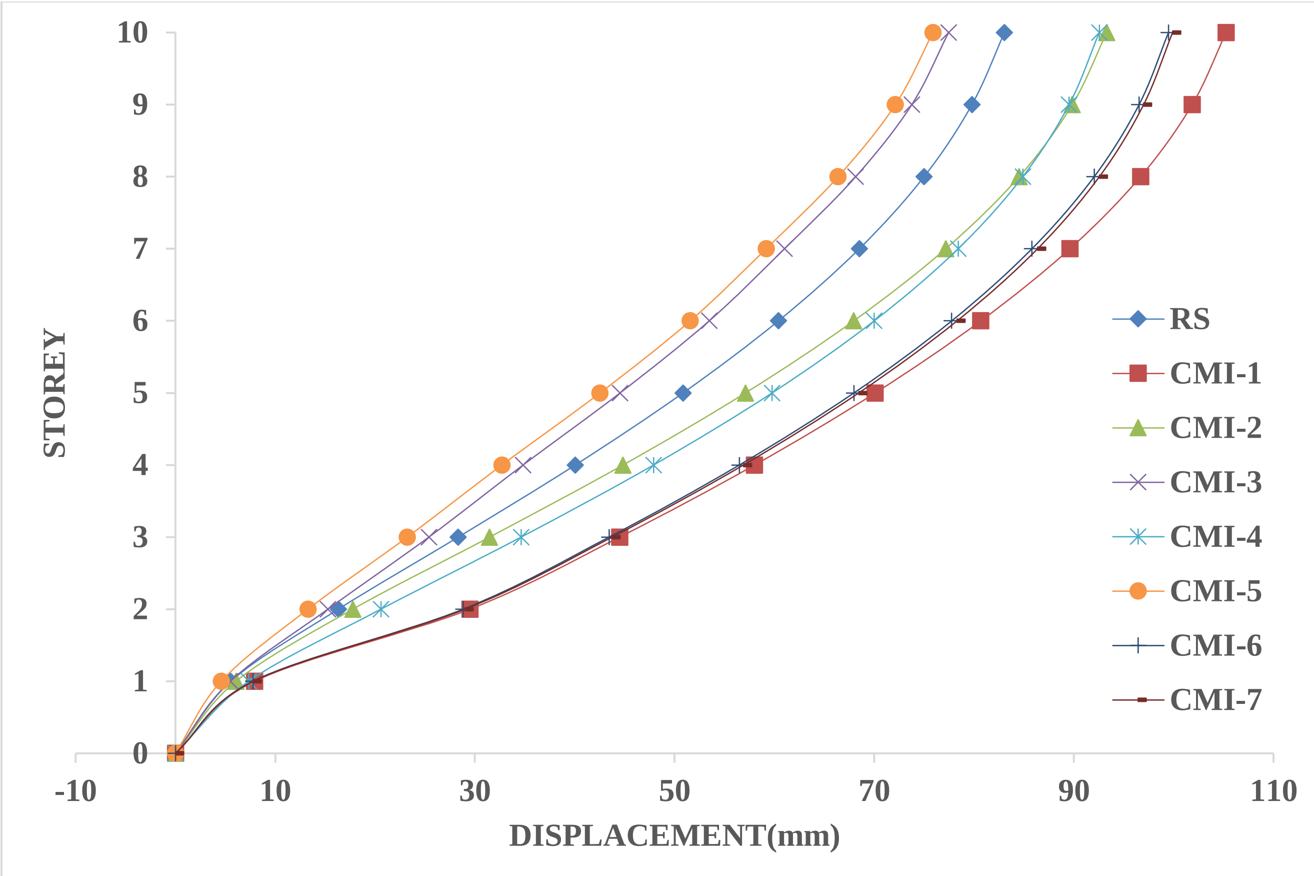

Figure 6.3(a).Displacement Response for CMI-1 to CMI-7 Case when compared with Regular Configuration

Following observations can be made from Figure 6.3(a):

- The cases of combination of irregularities ranging from CMI-1 to CMI-7 are compared with regular configuration.
- Least storey displacement is found in CMI-5 case whereas maximum displacement is observed for CMI-1 case.
- It is to be noted that no significant difference is observed in the case of CMI-6 and CMI-7.

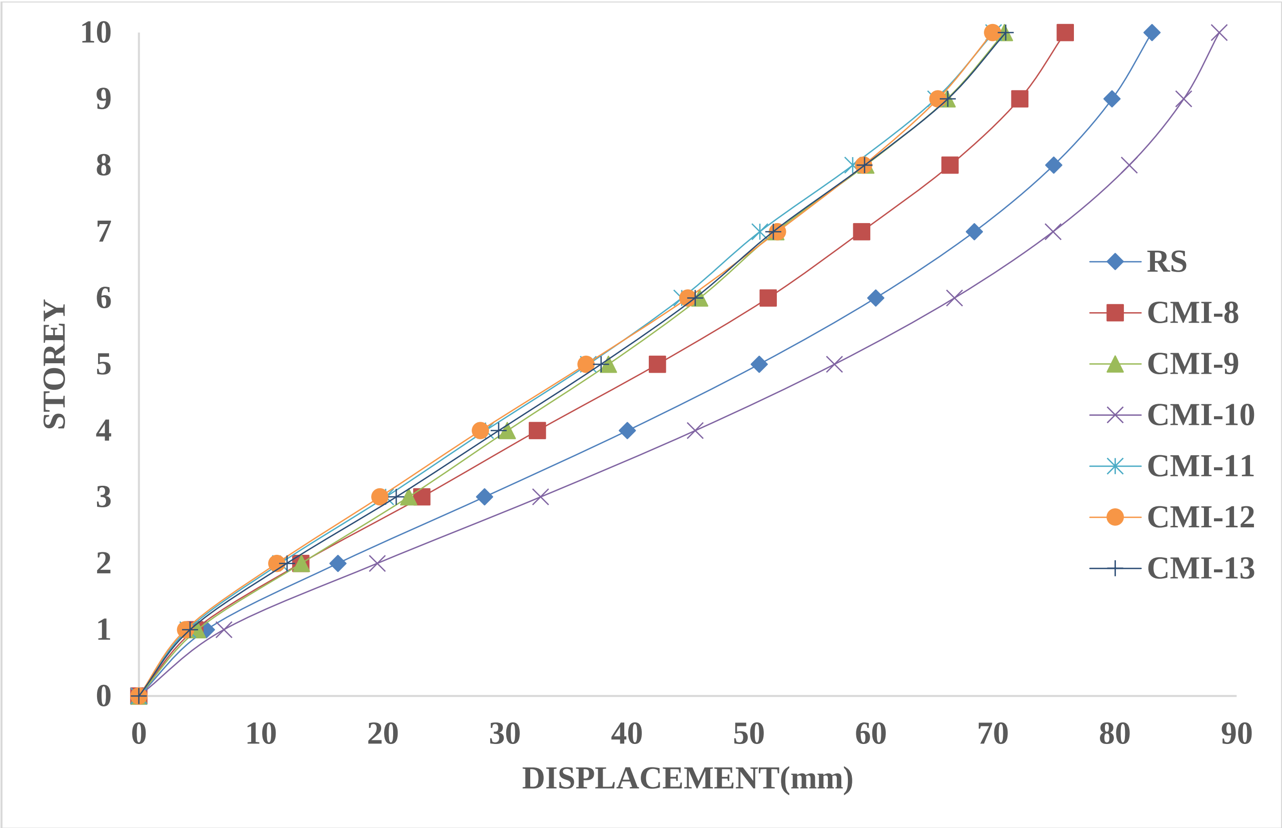

Figure 6.3(b).Displacement Response for combination Cases CMI-8 to CMI-13 when compared with Regular Configuration

Following observations can be made from Figure 6.3(b):

- The cases of combination of irregularities ranging from CMI-8 to CMI-13 are compared with regular configuration.
- Least storey displacement is found in CMI-12 case whereas maximum displacement is observed for CMI-10 case.
- It is to be noted that no significant difference is observed in the case of CMI-9, CMI-11, CMI-12 and CMI-13.

6.2.2 *Drift*:

Magnitude of drift for regular and combination of irregularities (CMI-1 to CMI-13) are shown below in Table 6.4(a) and (b).

Table 6.4(a).Drift for cases of combination of irregularities CMI-1 to CMI-7

	DRIFT							
STOREY	**RS**	**CMI-1**	**CMI-2**	**CMI-3**	**CMI-4**	**CMI-5**	**CMI-6**	**CMI-7**
10	0.001087	0.001133	0.001148	0.001228	0.001008	0.001256	0.000982	0.000967
9	0.001599	0.001724	0.001775	0.001873	0.001546	0.001912	0.001499	0.001478
8	0.002162	0.00236	0.002453	0.00238	0.002158	0.002403	0.00208	0.002063
7	0.0027	0.002973	0.003071	0.002511	0.002804	0.002535	0.002678	0.002688
6	0.003185	0.003526	0.003617	0.002977	0.003409	0.003013	0.003266	0.003285
5	0.0036	0.004029	0.004089	0.003241	0.00396	0.003278	0.003827	0.00385
4	0.003907	0.004506	0.004453	0.003145	0.00442	0.003159	0.00435	0.004383
3	0.004004	0.004998	0.004569	0.003372	0.004681	0.003315	0.004871	0.004908
2	0.003592	0.005395	0.0039	0.003253	0.004416	0.002899	0.005266	0.005303
1	0.001847	0.002641	0.002022	0.001837	0.002447	0.001527	0.002587	0.002604
0	0	0	0	0	0	0	0	0

Table 6.4(b).Drift for cases of combination of irregularities CMI-8 to CMI-13

	DRIFT						
STOREY	**RS**	**CMI-8**	**CMI-9**	**CMI-10**	**CMI-11**	**CMI-12**	**CMI-13**
10	0.001087	0.001242	0.00157	0.00097	0.001585	0.001597	0.001585
9	0.001599	0.001903	0.002224	0.001489	0.002267	0.002262	0.002273
8	0.002162	0.002421	0.002458	0.002079	0.002538	0.002528	0.002548
7	0.0027	0.002551	0.002074	0.002695	0.002131	0.002135	0.002141
6	0.003185	0.003023	0.002498	0.003282	0.002557	0.002554	0.002572
5	0.0036	0.003282	0.002762	0.003807	0.002813	0.002804	0.002845
4	0.003907	0.003159	0.002701	0.004226	0.002723	0.002723	0.002798
3	0.004004	0.003312	0.002928	0.004458	0.002882	0.002873	0.002987
2	0.003592	0.002895	0.002838	0.004196	0.002531	0.002537	0.002645
1	0.001847	0.001525	0.001603	0.002321	0.001334	0.001336	0.0014
0	0	0	0	0	0	0	0

For better understanding of lateral drift of combination cases, magnitude is plotted in the form of graph which is shown in figure 6.4(a), (b).

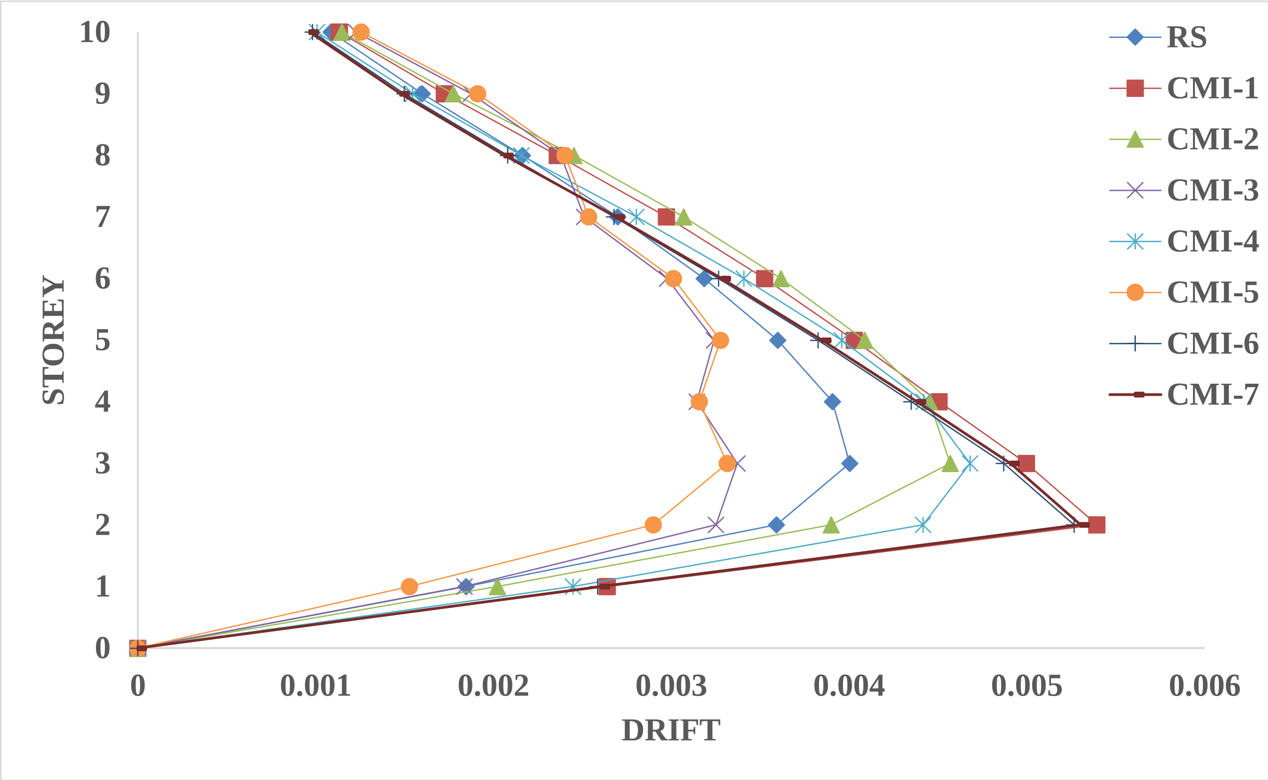

Figure 6.4(a) .Drift for cases of combination of irregularities CMI-1 to CMI-7 when compared with Regular Configuration

Following observations can be made from Figure 6.4(a):

- ❖ The cases of combination of irregularities ranging from CMI-1 to CMI-7 are compared with regular configuration.
- ❖ Least drift is found in CMI-5 case whereas maximum drift is observed for CMI-1 case.
- ❖ It is to be noted that large variation is observed in the case of CMI-1, CMI-6 and CMI-7.

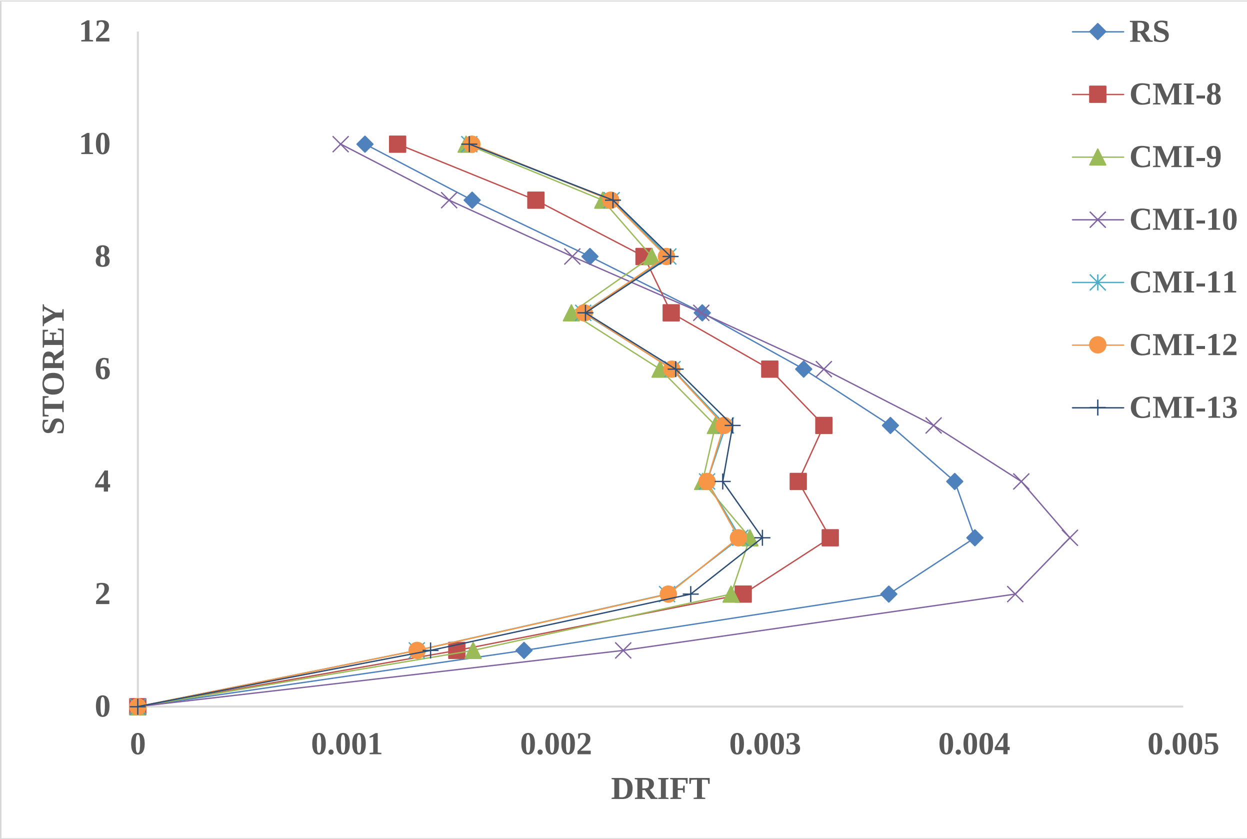

Figure 6.4(b).Drift for cases of combination of irregularities CMI-8 to CMI-13 when compared with Regular Configuration

Following observations can be made from Figure 6.4(b):

- ❖ The cases of combination of irregularities ranging from CMI-8 to CMI-13 are compared with regular configuration.
- ❖ Least drift is found in CMI-12 case whereas maximum drift is observed for CMI-10 case.
- ❖ It is to be noted that no significant difference is observed in the case of CMI-9, CMI-11, CMI-12 and CMI-13.

6.3 Base Shear:

Magnitude of maximum base shear for all the cases is shown in Table 6.5. From figure 6.5, it is observed that maximum magnitude is obtained for THI-1 case which consist a shear wall to introduce irregularities whereas least magnitude is for the case of combination of irregularity which is CMI-9.

Table 6.5.Maximum Base Shear in each cases analyzed

Model Type	Maximum Base Shear(KN)	Model Type	Maximum Base Shear(KN)
RS	3988.25	**THI-1**	5254.21
MVI-1	4012.37	**THI-2**	3992.77
MVI-2	3991.9	**CMI-1**	3954.66
MVI-3	4020.37	**CMI-2**	4021.84
SVI-1	3925.72	**CMI-3**	3062.51
SVI-2	3967.98	**CMI-4**	3315.35
SVI-3	3938.51	**CMI-5**	3097.9
SVI-4	3976.35	**CMI-6**	3219.3
SVI-5	4018.61	**CMI-7**	3243.66
SVI-6	3975.61	**CMI-8**	3093.76
RI-1	2585.65	**CMI-9**	2475.3
RI-2	2883.39	**CMI-10**	2617.96
RI-3	2727.893	**CMI-11**	2502.64
RI-4	3371.86	**CMI-12**	2497.17
VIG-1	3066.15	**CMI-13**	2850.51
VIG-2	3288.03		

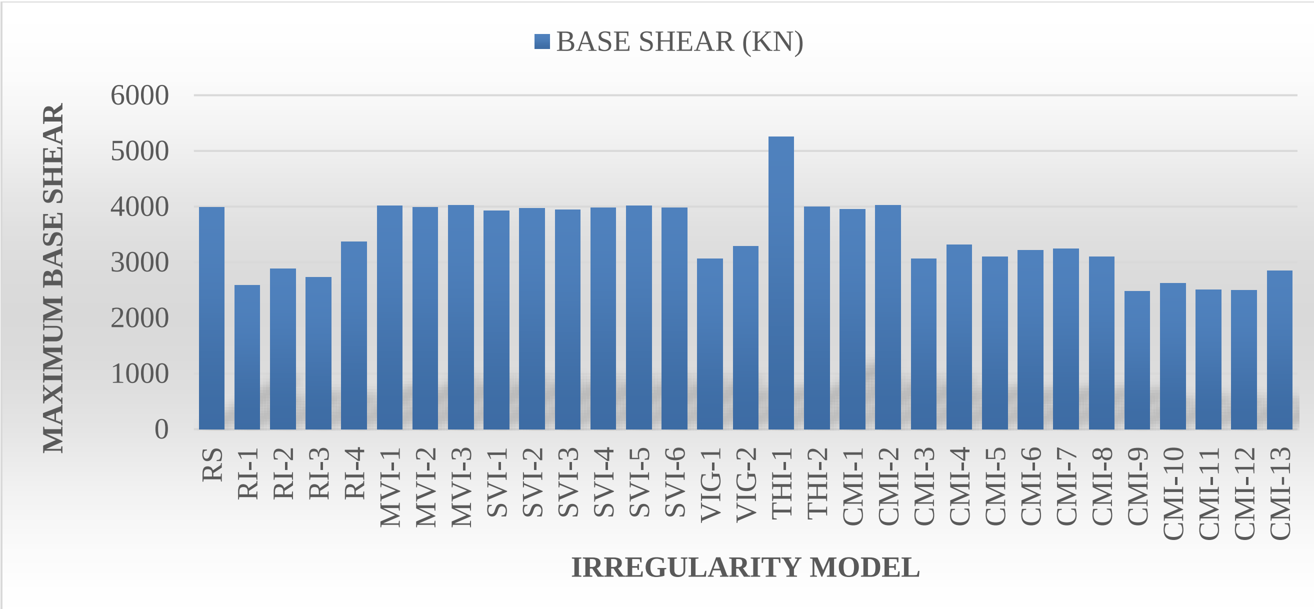

Figure 6.5.Maximum Magnitude of Base Shear in All the Cases

6.4 Percentage change in storey displacement:

Percentage change in storey displacement of irregular configuration with respect to regular configuration is depicted in Table 6.6. It can be noted from the graph of variation shown in Figure 6.6 that maximum positive variation from regular configuration is observed in SVI-1, SVI-3 and CMI-1 cases, whereas maximum negative variation is observed for CMI-12 and CMI-13 cases.

Table 6.6.Percentage change for response of maximum displacement in all the cases

Model Type	Percentage change for Displacement with Respect to Regular Configuration	Model Type	Percentage change for Displacement with Respect to Regular Configuration
MVI-1	16	***THI-1***	24
MVI-2	15	***THI-2***	15
MVI-3	16	***CMI-1***	26
SVI-1	26	***CMI-2***	12

SVI-2	21	***CMI-3***	-6
SVI-3	26	***CMI-4***	11
SVI-4	17	***CMI-5***	-8
SVI-5	12	***CMI-6***	19
SVI-6	12	***CMI-7***	20
RI-1	11	***CMI-8***	-8
RI-2	17	***CMI-9***	-14
RI-3	11	***CMI-10***	6
RI-4	7	***CMI-11***	-15
VIG-1	-6	***CMI-12***	*-15*
VIG-2	*10*	***CMI-13***	*-14*

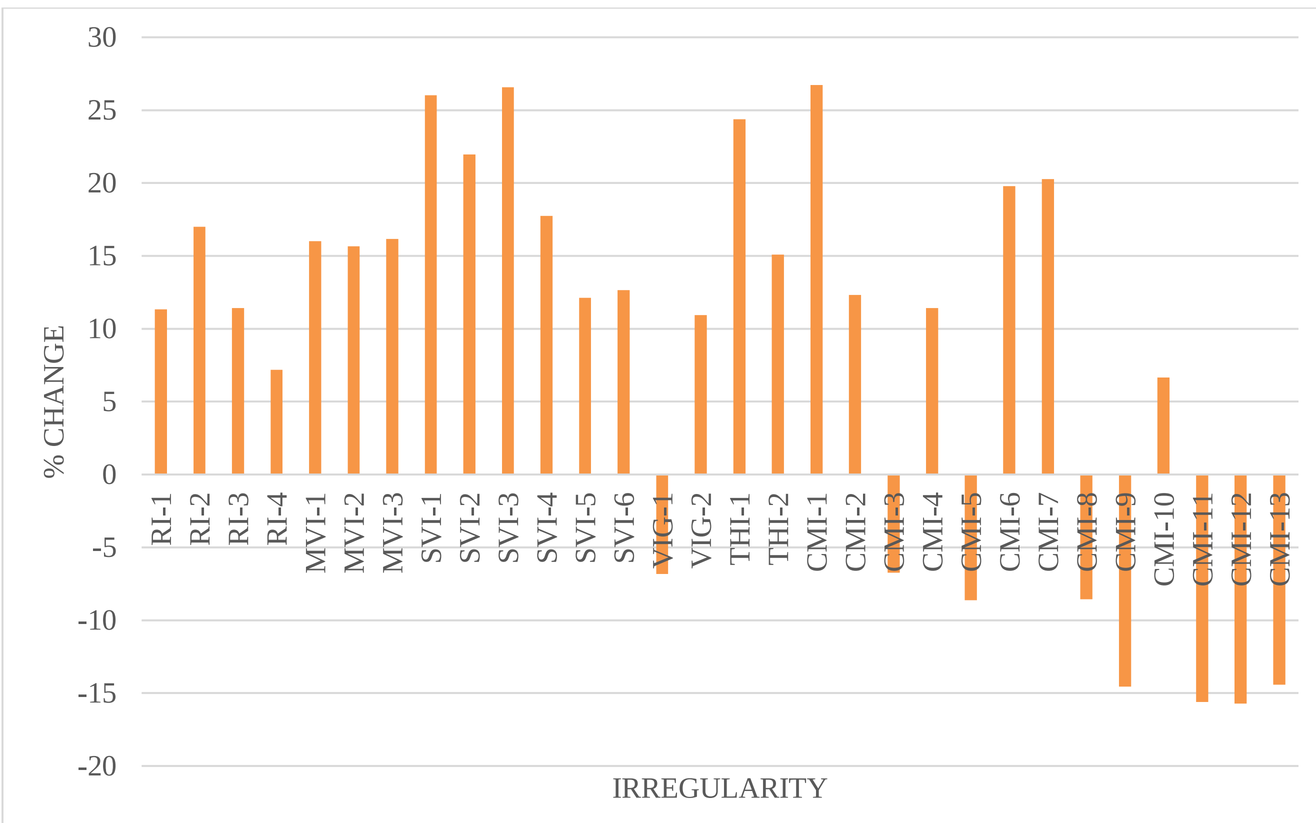

Figure 6.6.Percentage change for displacement response of all the cases

6.5 FINAL OBSERVATIONS

Lateral Displacement

- In a structure, maximum lateral displacement occur at top storey whereas minimum is observed at bottom storey.
- With increase in height of structure, lateral displacement increases along with it.
- From the analysis it has been noticed that minimum value of displacement is seen in vertical geometrical irregularity model (Model VIG-1) hence it can be concluded the presence of irregularity in a building may increase or decrease lateral displacement depending upon the case.

Base Shear

- It is observed that maximum magnitude of base shear is obtained for model THI-1 which consist a shear wall to introduce irregularities whereas least magnitude is for the case of combination of five different irregularity which is CMI-9.

Drift

- Model RI-2 shows maximum drift when compared to all the other cases of single or combination of irregularities.
- Drift is greatly impacted by the presence of irregularity
- Minimum drift is observed in Model CMI-12 when compared with other cases.

Chapter 7

CONCLUSION

All the irregular and regular frames are analyzed using equivalent static method of analysis and the study of responses when subjected to lateral loads is carried.

- Results obtained indicate that structural response of multi storied building frame for single irregularities and their combination is significantly affected when compared with regular frame.
- Irregularities may not necessarily amplify the response of structures, there are few irregularities or their combination present which can reduce the response of structures.
- A significant increase in structural response is observed in majority of cases of single irregularity with a few exceptions when compared with regular configuration for seismic loads.
- Maximum response is obtained for torsional irregularity case among all these single irregularity cases.
- For combination cases mass and stiffness combination bears the maximum response whereas vertical geometrical irregularity and re-entrant corner combination shows less displacement response.
- Location, degree and type of irregularity influences the structural response, so a special care is to be taken has to incorporate irregularities in buildings.

REFERENCES

[1] **Mohammed Affan, Md. Imtiyaz Qureshi, Syed Farooq Anwar** " Comparative study of static and dynamic analysis of high rise building in different seismic zones of India with different soil types using E Tabs" *IJMTER , Volume 8th, Issue 11*.

[2] **Siva Naveen E, Nimmy Mariam Abraham et al** "Analysis of irregular structures under earthquake loads" *Elsevier, Volume 14.*

[3] **Rakshith G. M, Panender Naik G, Swarna D et al "**Analysis of G+20 RC tall building in different zones using E Tabs" *IJIRSET, Volume 8, Issue 5.*

[4] **M. V Naveen, K J Brahma Chari** "Study on static and dynamic analysis of multi storey building in seismic zones" *IJRTE, Volume 7, Issue 6C2.*

[5] **A. Fathima, Shashi Kumar N V** "Behavior Of Vertical Irregular Building In Different Seismic Zones*" EJMCM, Volume 07, Issue 08*

[6] **E. RaviKumar, P Raghava, Dr.T.Suresh Babu** "Seismic analysis of tall buildings for different earthquake zones*" IJETER, Volume 5, Issue 4.*

[7] **P A Krishnan, N Thasleen** "Seismic analysis of plan irregular RC building frames"*5th ICMSCE,2010*

[8] **IS: 456, (2000)**, "Plain and reinforced concrete design"

[9] **Duggal, S.K**., Earthquake Resistant Design of Structures, *Oxford University Press, New Delhi 2010.*

[10] **ETABS 17***, "Documentation and Training Manuals"*.

[11] **IS 1893 (Part 1) 2016**. "Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1 General provisions and buildings", Bureau of Indian Standards, New Delhi.