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Analysis of Highrise Building (G+15) with Vertical Irregularities Using ETABS

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ABSTRACT: Seismic forces can cause significant structural damage or destruction. Multi-story RC buildings have been subjected to the most dangerous earthquakes, as we all know. The existence of irregularity in RC constructions was discovered to be the primary cause of failure. The vertical irregularity of the building stands it apart from other structures. These structures are substantially more sensitive to earthquakes. For irregular buildings, 3D analytical models of highrise buildings were created in this work. The influence of numerous vertical irregularities on the building is studied using the structural analysis tool "ETABS." The seismic analysis will be performed in accordance with IS 1893-part-1:2016, seismic zone – IV, and soil type – medium soil in all cases.
KEYWORDS: Vertical irregularity, Irregular building, high impact of irregularity.

I. INTRODUCTION

At present time it is necessary to build multi-storied irregular structures due to shortage of space and non-accessibility of uniform ground conditions. During an earthquake, the structure's failure begins at the weakest areas.

These structures are referred to as irregular structures since they have this discontinuity. Urban infrastructure is full with irregular structures. Irregularities in a structure are key variables that reduce the seismic performance of any structure, as earthquake loads inject additional shear and twisting in irregular structures

As absolute regularity is an idealisation that rarely occurs in practice, it is recognised that existing buildings are usually irregular. Due to a lack of space and the inaccessibility of uniform ground conditions, it is currently required to construct multi-story irregular constructions.

Irregularities in a structure are very critical characteristics that severely reduce the seismic performance of any structure, as earthquake loads add extra shear and twisting in irregular structures. Those abnormal structural alignments in an elevation or plan were usually identified as one of the key actions of the collapse caused by a previous seismic motion.

Although structural imperfections are a mix of plan and vertical irregularities, many seismic regulations distinguish between the two.
Horizontal irregularity (plan irregularity) can be classified using the following criteria:

- ❖ Torsional irregularity
- ❖ Re-entrant corner
- ❖ Floor slabs having excessive cut-out and openings
- ❖ Out of plane offset in vertical element
- ❖ Non-parallel lateral force system

The vertical irregularity can be classified based on the following factors.

- ❖ Stiffness irregularity
- ❖ Mass irregularity
- ❖ Vertical geometric irregularity
- ❖ In plane discontinuity in vertical elements resisting lateral force
- ❖ Strength irregularity
- ❖ Floating or stub column
- ❖ Irregular modes of oscillation in two principal plan direction

The massive loss of high-rise and low-rise buildings in recent severe earthquakes demonstrates why such investigations are critical in emerging countries like India. As a result, the seismic behaviour of asymmetric building systems has become a hot area for research around the world. Many investigations into the elastic and inelastic seismic behaviour of asymmetric systems have been conducted in order to determine the origin of such structures' seismic vulnerability.

The ELF technique, on the other hand, is predicated on a number of assumptions. These assumptions hold true for regular structures, i.e., structures with uniform stiffness, strength, and mass distributions across their height. In real building constructions, there is an irregular distribution of these properties. As a result, it's critical to create criteria that would allow the ELF approach to be used in the study of irregular structures. "It is true that additional research is required to confirm these restrictions. However, there can be no unambiguous enforceable terms without such constraints."

In the current context, many buildings have irregular design and elevation arrangements. In the future, they may be subjected to disastrous earthquakes. As a result, it is vital to assess the performance of both new and old structures in terms of earthquake resistance.

II. OBJECTIVE

Objectives of the present study are as follows:

1. To describe the philosophy of structuralbehaviour.
2. To present various aspects of structural behaviour that alter with irregularity.
3. To investigate and analyse the high-rise structure using Response spectrum analysis.
4. To compare the results of the Parent model and other created models with irregularity combinations in Etabs.

III. LITERATURE REVIEW

[1] The seismic analysis of all eight regular and irregular RC structures was carried out in this study.

There are two sorts of vertical anomalies to consider: stiffness and setback.

The failure of a multistory building owing to seismic loading usually begins at the area where the building has a weakness. This flaw causes the building to deteriorate, eventually leading to structural collapse. The story displacement is higher in rigidity uneven structures than in regular structures. In severely irregular constructions, story drift is strongest for irregular storylines.

The overturning moment and story shear force of rigidity irregular constructions are slightly higher than those of regular buildings. The slope of the shear force curve increased moderately at the uneven story's. In stiffness irregular buildings, a drastic drop in the stiffness of the building has been seen at the uneven stories. These anomalies should be avoided wherever possible, but if they must be included, they must be developed well.

[2]. The special moment-resisting frame is the primary LFRS intended for structures (SMRF). The constructions are typically cast-in-place reinforced concrete structures with monolithic beams supported by columns and monolithic slabs.

In the direction of the earthquake, all structures have three bays. The bay sizes are modified within practical bounds in order to investigate their impact on seismic response. Buildings of three various height categories, including 5-, 10-, and 20-story systems, are also evaluated. Normal-weight concrete with a 28-day cylinder strength of 5 KSI and A615 Grade 60 reinforcing is used for the beams and columns.

[3]. An analogous static approach was used to investigate the seismic response of regular and vertically uneven multi-story building frames in this paper. The paper's G+2, G+5, and G+11 story frames were examined with ETABS 16.1.0. (2016).

A total of nine models were examined, with zone 5 being utilised to assess the effects on building story displacement, story drift, and story shear. It contains a comparison of the results acquired from the examination of all of the building frames.

[4]. The following is the methodology that will be used to attain the objectives: -

1. Various Indian Design Codes for earthquake resistant analysis and design will be examined, as well as various code provisions for irregular structures.
2. A thorough investigation will be conducted into all aspects of a structure, including floating a column, types of imperfections in a structure, the effects of pounding on a structure, and the impacts of an earthquake on RC structures.
3. All general parameters of a building will be decided, such as frame a material, material constants, types, and intensities of a loading, and loading combinations.
4. The seismic coefficient approach will be used to perform the manual calculation for a base shear.
5. The modelling and analysis will be completed using a dependable programme (STAAD PRO). The required results will be reviewed and compared after assessing all of the selected models using selected materials.

[5]. In terms of cost and performance, steel-concrete composite structures outperform traditional RCC constructions. As a result,

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imperfections must be considered while analysing composite constructions, and performance must be compared to RCC buildings.

The subject of this article is a ten-story RCC and composite building with various vertical imperfections. Individual models with irregularities at the bottom, middle, and top of the structure are modelled for study, with irregularities at the 2nd, 5th, and 9th floors. Each model has an irregularity at a different level of the structure. Irregularities are not allowed to be placed at the roof level, according to the code.

To investigate the impact of irregularities, Etabs was used to do a response spectrum analysis on the building model. The effects of various vertical irregularities on the RCC and composite constructions are compared and studied.

[6]. The goal of this work is to do a non-linear static pushover analysis of medium-height RC buildings and look at how structural behaviour varies when shear walls are taken into account. In this work, multi-story buildings (eight stories) located in zone III of medium soil sites were studied using the Indian code's Linear Static and Linear Dynamic methods and evaluated utilising pushover analysis as required in ATC-40 and FEMA-356. The Etabs analysis package is used for the analysis.

Three-dimensional frame elements are used to model columns and beams. Rigid diaphragms are used to model slabs. The joints between the beam and the column are believed to be rigid. ETABS provides default hinge properties. Various construction components are modelled using software as explained.

On eight story building models on flat ground and sloping ground, three distinct assessments are carried out, as follows:

1. Equivalent Static Analysis
2. Response Spectrum Analysis
3. Pushover analysis

In this research, numerous models are constructed and tested in order to determine the parameters.

IV. METHODOLOGY

For the purpose of structural analysis. The ETABS software is used to model the building, and the Response spectrum analysis method is used to analyze the multi-story building. The seismic zone is V, and the soil type is Medium.
Vertical irregularity is added in building models, and a combination of it also added in the models. These forms of irregularities introduce different aspects for analysis in models.

In the models, we incorporate vertical irregularities at three levels
Base
Middle (7th story)
Terrace,
Vertical irregularities are created by altering the model's parameters.

Table-1: Changes to be made to the parameters for vertical irregularity

Types of irregularity	**Changes**	**Parameter**
Stiffness irregularity	Height of that floor	4.5 m
Mass irregularity	SDL of that floor	20 KN/m^2
Vertical geometric irregularity	Setback in building	after every 4 story
In-plane discontinuity	Displace the column of one side throughout from that floor	200 mm
Stub column	column supported on beam on that floor	pin supported

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4.1 MODEL DESCRIPTION
4.1.1 data of parent model

Table-2: Model data in ETABS for parent model

Description	Data values
Material property	
Concrete grade	M30
Steel grade	Fe500
Building data	
Story	G+15
Story height (m)	3.2 (at all levels)
Beam size (mm)	300 x 600
Column size (mm)	525 x 525
Slab thickness (mm)	150
Soli type	II
Seismic zone	V
Wind speed (m/s)	39
Importance factor	1.5
Response reduction factor	5
Loading data	
Floor finish (SDL) (KN/m2)	1.5
Live load at typical floor (KN/m2)	2
Roof live load (KN/m2)	1.5
Roof dead load (SDL) (KN/m2)	2.5
Type of support (KN/m2)	Fix

Table-3: Story displacement of parent model in EQx dir.

STORY	ELEVATION (m)	X-Dir. (mm)	Y - Dir. (mm)
TERRACE	54.4	104.741	0
14th F.S.	51.2	103.05	0
13th F.S.	48	100.36	0
12th F.S.	44.8	96.702	0
11th F.S.	41.6	92.181	0
10th F.S.	38.4	86.908	0
9th F.S.	35.2	80.988	0
8th F.S.	32	74.521	0
7th F.S.	28.8	67.599	0
6th F.S.	25.6	60.307	0
5th F.S.	22.4	52.723	0

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4th F.S.	19.2	44.917	0
3rd F.S.	16	36.951	0
2nd F.S.	12.8	28.881	0
1st F.S.	9.6	20.76	0
GF SLAB	6.4	12.668	0
PLT. LVL.	3.2	4.911	0.002
Base	0	0	0

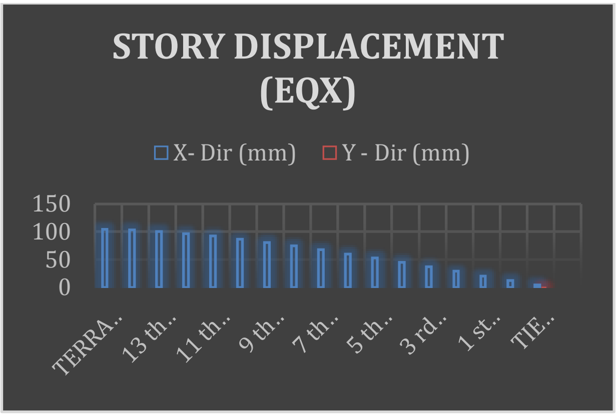

Fig-1: Story displacement of parent model in EQxdir.

Table-4: Story displacement of parent model in EQy dir.

STORY	ELEVATION (m)	X- Dir. (mm)	Y - Dir. (mm)
TERRACE	54.4	0	104.741
14th F.S.	51.2	0	103.05
13th F.S.	48	0	100.36
12th F.S.	44.8	0	96.702
11th F.S.	41.6	0	92.181
10th F.S.	38.4	0	86.908
9th F.S.	35.2	0	80.988
8th F.S.	32	0	74.521
7th F.S.	28.8	0	67.599
6th F.S.	25.6	0	60.307
5th F.S.	22.4	0	52.723

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4th F.S.	19.2	0	44.917
3rd F.S.	16	0	36.951
2nd F.S.	12.8	0	28.881
1st F.S.	9.6	0	20.76
GF SLAB	6.4	0	12.668
PLT. LVL.	3.2	0.002	4.911
Base	0	0	0

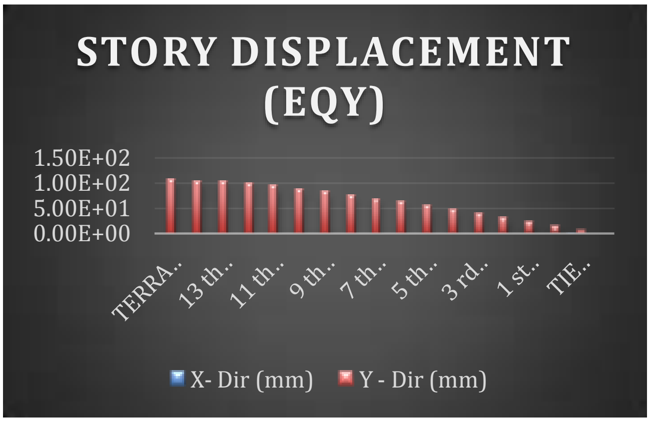

Fig-2: Story displacement of parent model in EQy dir.

Table-5: Story drift of parent model in EQx dir.

STORY	ELEVATION (m)	X-Dir. (mm)	Y - Dir. (mm)
TERRACE	54.4	0.000528	0
14th F.S.	51.2	0.000841	0
13th F.S.	48	0.001143	0
12th F.S.	44.8	0.001413	0
11th F.S.	41.6	0.001648	0
10th F.S.	38.4	0.00185	0
9th F.S.	35.2	0.002021	0
8th F.S.	32	0.002163	0
7th F.S.	28.8	0.002279	0
6th F.S.	25.6	0.00237	0
5th F.S.	22.4	0.00244	0

4th F.S.	19.2	0.002489	0
3rd F.S.	16	0.002522	0
2nd F.S.	12.8	0.002538	0
1st F.S.	9.6	0.002529	0
GF SLAB	6.4	0.002444	1.00*10^06
PLT. LVL.	3.2	0.001535	1.00*10^06
Base	0	0	0

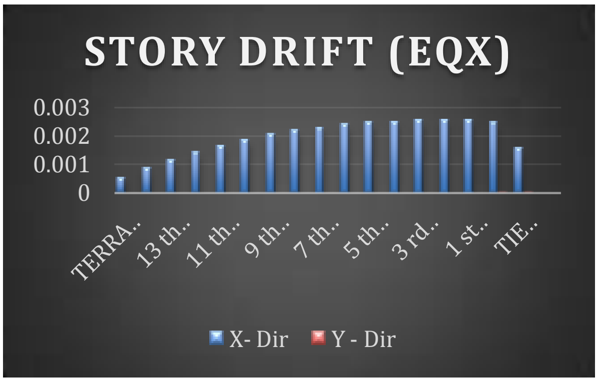

Fig-3: Story drift of parent model in EQx dir.

Table-6: Story drift of parent model in EQy dir.

STORY	ELEVATION (m)	X- Dir. (mm)	Y - Dir. (mm)
TERRACE	54.4	0	0.000528
14th F.S.	51.2	0	0.000841
13th F.S.	48	0	0.001143
12th F.S.	44.8	0	0.001413
11th F.S.	41.6	0	0.001648
10th F.S.	38.4	0	0.00185
9th F.S.	35.2	0	0.002021
8th F.S.	32	0	0.002163
7th F.S.	28.8	0	0.002279
6th F.S.	25.6	0	0.00237
5th F.S.	22.4	0	0.00244
4th F.S.	19.2	0	0.002489

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Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

3rd F.S.	16	0	0.002522
2nd F.S.	12.8	0	0.002538
1st F.S.	9.6	0	0.002529
GF SLAB	6.4	1.00*10^06	0.002444
PLT. LVL.	3.2	1.00*10^06	0.001535
Base	0	0	0

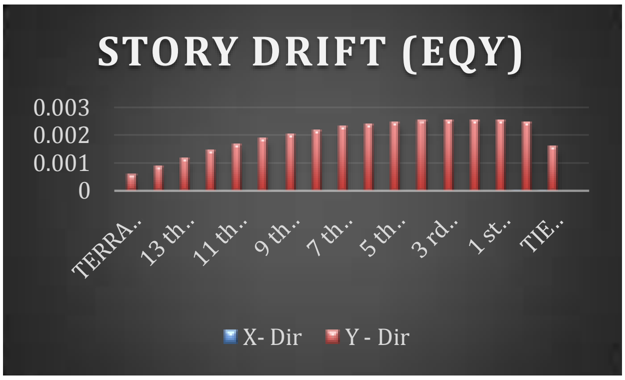

Fig-4: Story drift of parent model in EQy dir.

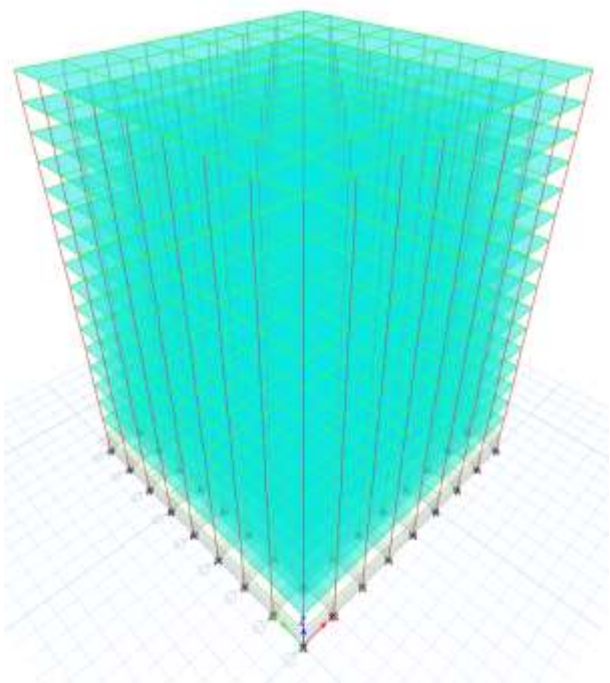
Fig-5: 3-D view of parent model

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4.1.2 List and description of models which is prepared

Case 1 - Model having Stiffness irregularity

Comb. 1 - Height of ground floor is 4.5 m
Comb. 2 - Height of 7th floor is 4.5 m
Comb. 3 - Height of terrace floor is 4.5 m
Comb. 4 - Height of ground & 7th floor is 4.5 m
Comb. 5 - Height of ground & terrace floor is 4.5 m
Comb. 6 - Height of 7th& terrace floor is 4.5 m
Comb. 7 - Height of ground, 7th& terrace floor is 4.5 m

Case 2 - Model having Mass irregularity

Comb. 8 -Load on ground floor is 20 KN/m^2
Comb. 9 - Load on 7th floor is 20 KN/m^2
Comb. 10 - Load on terrace floor is 20 KN/m^2
Comb. 11 - Load on ground & 7th floor is 20 KN/m^2
Comb. 12 - Load on ground & terrace floor is 20 KN/m^2
Comb. 13 - Load on 7th& terrace floor is 20 KN/m^2
Comb. 14 - Load on ground, 7th& terrace floor is 20 KN/m^2

Case 3 - Model having Vertical geometrical irregularity

Comb. 15 - a) Setback in Y-dir. after every 4 story from G.F.
Comb. 16 - a) Setback in X & Y-dir. after every 4 story from G.F.
Comb. 17 - a) Setback in Y-dir. after every 4 story from 7th floor
Comb. 18 - a) Setback in X & Y-dir. after every 4 story from 7th floor
Comb. 19 - b) Setback in Y-dir. after every 4 story from G.F. on both side
Comb. 20 - b) Setback in X & Y-dir. after every 4 story from G.F. on both side
Comb. 21 - b) Setback in Y-dir. after every 4 story from 7th floor on both side
Comb. 22 - b) Setback in X & Y-dir. after every 4 story from 7th floor on both side
Comb. 23 - c) Setback in Y-dir. from 1ST F. on both side
Comb. 24 - c) Setback in X & Y-dir. from 1ST F. on both side

Case 4 - Model having In-plane discontinuity

Comb. 25 - Shift the column of one side to 200 mm from 7th floor
Comb. 26 - Shift the column of one side to 200 mm from terrace floor
Comb. 27 - Shift the column of one side to 200 mm from 7th & terrace floor

Case 5 - Model having Stub column

Comb. 28 - Stub column from G.F.
Comb. 29 - Stub column from 7th floor
Comb. 30 - Stub column from G.F. & 7th floor

Case 6 - Model having Stiffness & Mass irregularity [Description + (Height of floor – 4.5m)]

Comb. 33 -Load on ground floor is 20 KN/m^2
Comb. 34 - Load on 7th floor is 20 KN/m^2
Comb. 35 - Load on terrace floor is 20 KN/m^2
Comb. 36 - Load on ground & 7th floor is 20 KN/m^2
Comb. 37 - Load on ground & terrace floor is 20 KN/m^2
Comb. 38 - Load on 7th& terrace floor is 20 KN/m^2
Comb. 39 - Load on ground, 7th& terrace floor is 20 KN/m^2

Case 7 - Model having Stiffness & Vertical geometric irregularity [Description + (Height of floor – 4.5m)]

Comb. 40 - a) Setback in Y-dir. after every 4 story from G.F.
Comb. 41 - a) Setback in X & Y-dir. after every 4 story from G.F.
Comb. 42 - a) Setback in Y-dir. after every 4 story from 7th floor
Comb. 43 - a) Setback in X & Y-dir. after every 4 story from 7th floor
Comb. 44 - b) Setback in Y-dir. after every 4 story from G.F. on both side
Comb. 45 - b) Setback in X & Y-dir. after every 4 story from G.F. on both side
Comb. 46 - b) Setback in Y-dir. after every 4 story from 7th floor on both side
Comb. 47 - b) Setback in X & Y-dir. after every 4 story from 7th floor on both side
Comb. 48 - c) Setback in Y-dir. from 1ST F. on both side
Comb. 49 - c) Setback in X & Y-dir. from 1ST F. on both side

Case 8 - Model having Stiffness & In-plane discontinuity irregularity [Description + (Height of floor – 4.5m)]

Comb. 50 - Shift the column of one side to 200 mm from 7th floor
Comb. 51 - Shift the column of one side to 200 mm from terrace floor
Comb. 52 - Shift the column of one side to 200 mm from 7th & terrace floor

Case 9 - Model having Stiffness & stub column irregularity [Description + (Height of floor – 4.5m)]
Comb. 53 - Stub column from G.F.
Comb. 54 - Stub column from 7th floor
Comb. 55 - Stub column from G.F. & 7th floor

Case 10 - Model having Mass & Vertical geometry irregularity [Description + (Mass on that floor – 20KN/m^2)]
Comb. 56 - a) Setback in Y-dir. after every 4 story from G.F.
Comb. 57 - a) Setback in X & Y-dir. after every 4 story from G.F.
Comb. 58 - a) Setback in Y-dir. after every 4 story from 7th floor
Comb. 59 - a) Setback in X & Y-dir. after every 4 story from 7th floor
Comb. 60 - b) Setback in Y-dir. after every 4 story from G.F. on both side
Comb. 61 - b) Setback in X & Y-dir. after every 4 story from G.F. on both side
Comb. 62 - b) Setback in Y-dir. after every 4 story from 7th floor on both side
Comb. 63 - b) Setback in X & Y-dir. after every 4 story from 7th floor on both side
Comb. 64 - c) Setback in Y-dir. from 1ST F. on both side
Comb. 65 - c) Setback in X & Y-dir. from 1ST F. on both side

Case 11 - Model having Mass & In-plane discontinuity irregularity [Description + (Mass on that floor – 20KN/m^2)]
Comb. 66 - Shift the column of one side to 200 mm from 7th floor
Comb. 67 - Shift the column of one side to 200 mm from terrace floor
Comb. 68 - Shift the column of one side to 200 mm from 7th & terrace floor

Case 12 - Model having Mass & Stub column irregularity [Description + (Mass on that floor – 20KN/m^2)]
Comb. 69 - Stub column from G.F.
Comb. 70 - Stub column from 7th floor
Comb. 71 - Stub column from G.F. & 7th floor

Case 13 – Model having Vertical geometric & In-plane discontinuity irregularity [Description + (Shift the column of one side 200 mm)]
Comb. 72 - a) Setback in Y-dir. after every 4 story from G.F.
Comb. 73 - a) Setback in X & Y-dir. after every 4 story from G.F.
Comb. 74 - a) Setback in Y-dir. after every 4 story from 7th floor
Comb. 75 - a) Setback in X & Y-dir. after every 4 story from 7th floor
Comb. 76 - b) Setback in Y-dir. after every 4 story from G.F. on both side
Comb. 77 - b) Setback in X & Y-dir. after every 4 story from G.F. on both side
Comb. 78 - b) Setback in Y-dir. after every 4 story from 7th floor on both side
Comb. 79 - b) Setback in X & Y-dir. after every 4 story from 7th floor on both side
Comb. 80 - c) Setback in Y-dir. from 1ST F. on both side
Comb. 81 - c) Setback in X & Y-dir. from 1ST F. on both side

Case 14 - Model having Vertical geometric & Stub column irregularity [Description + (Stub column from that floor)]
Comb. 82 - a) Setback in Y-dir. after every 4 story from G.F.
Comb. 83 - a) Setback in X & Y-dir. after every 4 story from G.F.
Comb. 84 - a) Setback in Y-dir. after every 4 story from 7th floor
Comb. 85 - a) Setback in X & Y-dir. after every 4 story from 7th floor
Comb. 86 - b) Setback in Y-dir. after every 4 story from G.F. on both side
Comb. 87 - b) Setback in X & Y-dir. after every 4 story from G.F. on both side
Comb. 88 - b) Setback in Y-dir. after every 4 story from 7th floor on both side
Comb. 89 - b) Setback in X & Y-dir. after every 4 story from 7th floor on both side
Comb. 90 - c) Setback in Y-dir. from 1ST F. on both side
Comb. 91 - c) Setback in X & Y-dir. from 1ST F. on both side

4.1.3 Following load combinations are used in models

DL + LL
DL ± EQx/y
DL + LL ± EQx/y
1.5DL
1.5(DL + LL)
1.2(DL + LL ± Wx/y)
1.5(DL ± Wx/y)
0.9DL ± 1.5Wx/y
1.2(DL + LL ± EQx/y)
1.5(DL ± EQx/y)
0.9DL ± 1.5 EQx/y
1.2(DL + LL + RSx/y)
1.5(DL + RSx/y)
0.9DL + 1.5RSx/y

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V. RESULTS

All the indicating values are the Maximum value obtained from the analysis

Case 1 - Model having Stiffness irregularity

Table 7:Maximum parameters for case 1

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa.Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 1	EQx	112.095176	0.003465
	EQy	112.095176	0.003465
comb 2	EQx	111.750503	0.003145
	EQy	111.750503	0.003145
comb 3	EQx	105.284182	0.002502
	EQy	105.284182	0.002502
comb 4	EQx	118.903488	0.003417
	EQy	118.903488	0.003417
comb 5	EQx	112.535175	0.003416
	EQy	112.535175	0.003416
comb 6	EQx	112.228104	0.003109
	EQy	112.228104	0.003109
comb 7	EQx	119.290022	0.003371
	EQy	119.290022	0.003371

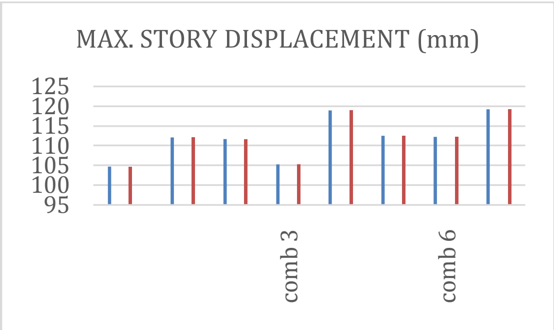

Fig-6: Maximum story displacement for case 1

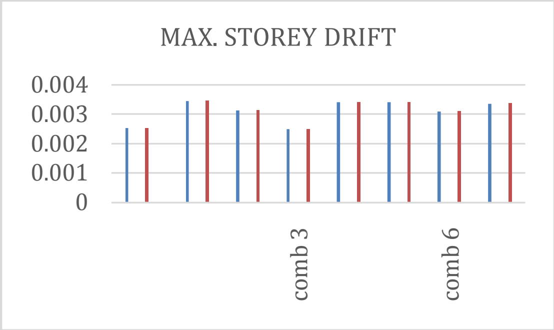

Fig-7: Maximum story displacement for case 1

Case 2 - Model having Mass irregularity

Table 8: Maximum parameters for case 2

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa.Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 8	EQx	104.843931	0.002538
	EQy	104.843931	0.002538
comb 9	EQx	105.387414	0.002562
	EQy	105.387414	0.002562
comb 10	EQx	105.698935	0.002561
	EQy	105.698935	0.002561
comb 11	EQx	105.492523	0.002563
	EQy	105.492523	0.002563
comb 12	EQx	105.803959	0.002562
	EQy	105.803959	0.002562
comb 13	EQx	106.357609	0.002586
	EQy	106.357609	0.002586
comb 14	EQx	106.464429	0.002587
	EQy	106.464429	0.002587

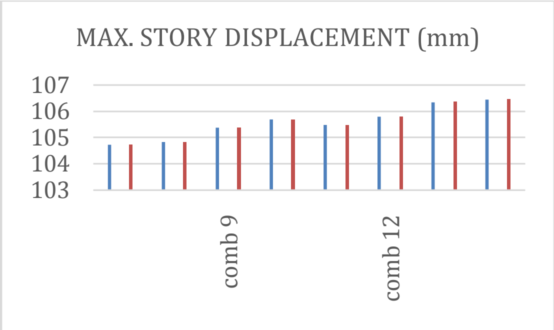

Fig-8: Maximum story displacement for case 2

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Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

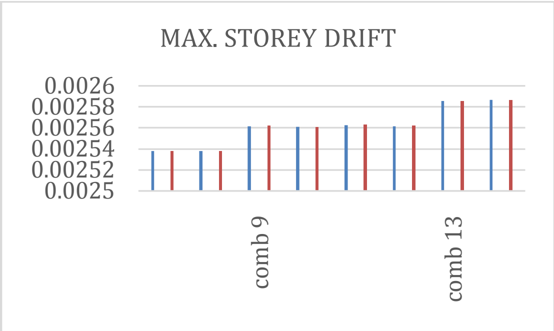

Fig-9: Maximum story displacement for case 2

Case 3 - Model having Vertical geometrical irregularity

Table 9: Maximum parameters for case 3

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 15	EQx	113.396709	0.002761
	EQy	94.994199	0.002189
comb 16	EQx	105.504471	0.002448
	EQy	105.504471	0.002448
comb 17	EQx	112.617525	0.00275
	EQy	96.697897	0.002284
comb 18	EQx	104.465741	0.00248
	EQy	104.465741	0.00248
comb 19	EQx	81.28044	0.001897
	EQy	84.477763	0.001944
comb 20	EQx	76.890193	0.001925
	EQy	76.890193	0.001925
comb 21	EQx	89.346767	0.002046
	EQy	88.223122	0.002036
comb 22	EQx	79.664568	0.001755
	EQy	79.664568	0.001755
comb 23	EQx	101.222975	0.002516
	EQy	105.182037	0.002609
comb 24	EQx	103.277224	0.002623
	EQy	103.277224	0.002623

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

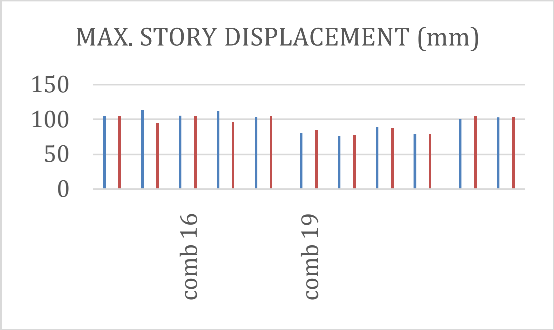

Fig-10: Maximum story displacement for case 3

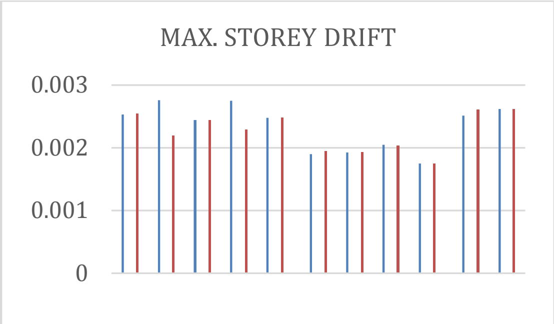

Fig-11: Maximum story displacement for case 3

Case 4 - Model having In-plane discontinuity

Table 10: Maximum parameters for case 4

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 25	EQx	105.412258	0.002543
	EQy	105.390577	0.002555
comb 26	EQx	104.815743	0.002539
	EQy	104.983171	0.002542
comb 27	EQx	105.487411	0.002544
	EQy	105.639341	0.00256

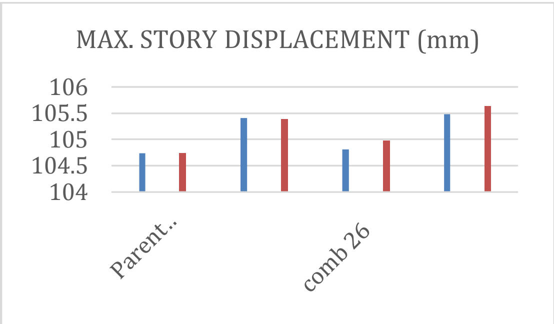

Fig-12: Maximum story displacement for case 4

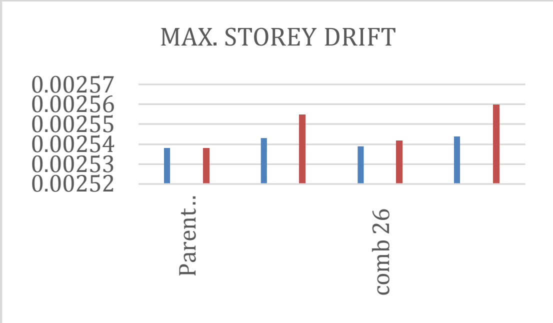

Fig-13: Maximum story displacement for case 4

Case 5 - Model having Stub column

Table 11: Maximum parameters for case 5

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 28	EQx	106.837335	0.002793
	EQy	108.067914	0.00275
comb 29	EQx	106.647064	0.002562
	EQy	106.220592	0.002535
comb 30	EQx	108.758624	0.002793
	EQy	109.026577	0.002748

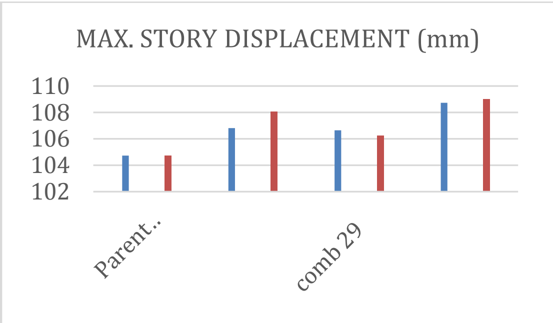

Fig-14: Maximum story displacement for case 5

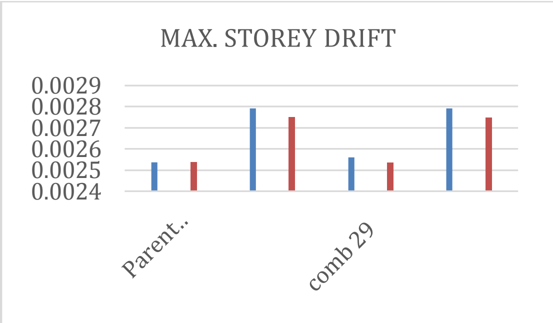

Fig-15: Maximum story displacement for case 5

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

Case 6 - Model having Stiffness & Mass irregularity

Table 12: Maximum parameters for case 6

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 33	EQx	112.347485	0.003502
	EQy	112.347485	0.003502
comb 34	EQx	112.531127	0.00318
	EQy	112.531127	0.00318
comb 35	EQx	106.262012	0.002525
	EQy	106.262012	0.002525
comb 36	EQx	120.096224	0.003498
	EQy	120.096224	0.003498
comb 37	EQx	113.911409	0.003495
	EQy	113.911409	0.003495
comb 38	EQx	114.128711	0.003183
	EQy	114.128711	0.003183
comb 39	EQx	121.74362	0.003493
	EQy	121.74362	0.003493

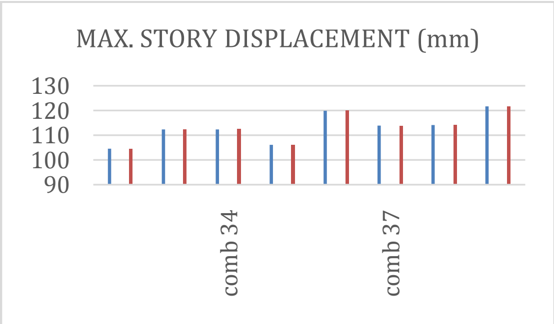

Fig-16: Maximum story displacement for case 6

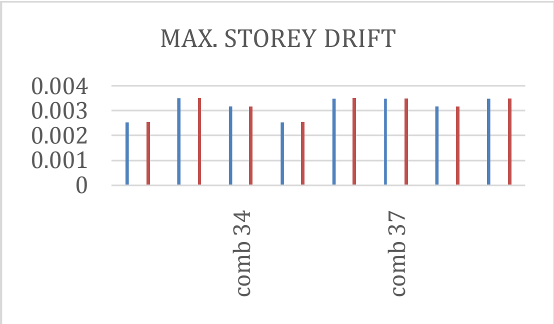

Fig-17: Maximum story displacement for case 6

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

Case 7 - Model having Stiffness & Vertical geometric irregularity

Table 13: Maximum parameters for case 7

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 40	EQx	121.434722	0.003802
	EQy	100.715104	0.002803
comb 41	EQx	111.578736	0.003087
	EQy	111.578736	0.003087
comb 42	EQx	120.218944	0.003397
	EQy	102.781568	0.002761
comb 43	EQx	111.092227	0.002989
	EQy	111.092227	0.002989
comb 44	EQx	85.389219	0.002149
	EQy	88.251899	0.002109
comb 45	EQx	79.031405	0.001868
	EQy	79.031405	0.001868
comb 46	EQx	94.689888	0.002402
	EQy	93.346766	0.00236
comb 47	EQx	83.768879	0.001882
	EQy	83.768879	0.001882
comb 48	EQx	106.496056	0.002692
	EQy	110.293044	0.002634
comb 49	EQx	106.929616	0.002593
	EQy	106.929616	0.002593

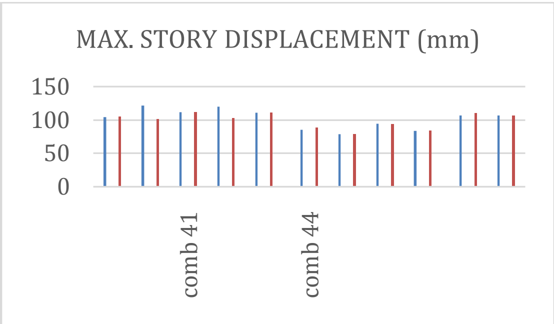

Fig-18: Maximum story displacement for case 7

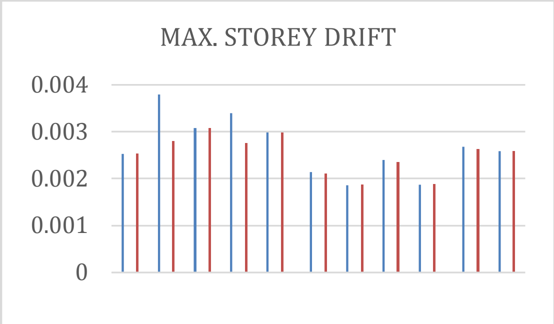

Fig-19: Maximum story displacement for case 7

Case 8 - Model having Stiffness & In-plane discontinuity irregularity

Table 14: Maximum parameters for case 8

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 50	EQx	112.608803	0.003194
	EQy	112.431435	0.003157
comb 51	EQx	105.370439	0.002503
	EQy	105.545503	0.002506
comb 52	EQx	113.18822	0.00316
	EQy	113.182111	0.003127

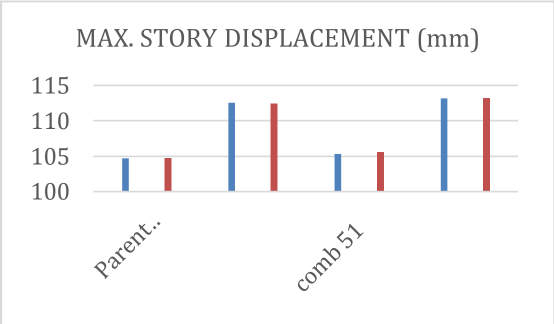

Fig-20: Maximum story displacement for case 8

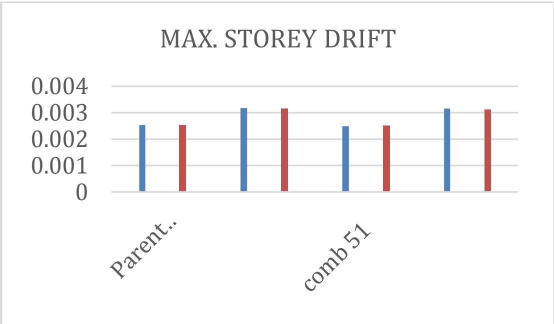

Fig-20: Maximum story displacement for case 8

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

Case 9 - Model having Stiffness & stub column irregularity

Table 15: Maximum parameters for case 9

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 53	EQx	115.490466	0.003972
	EQy	116.545723	0.003928
comb 54	EQx	114.721575	0.003558
	EQy	113.984025	0.003435
comb 55	EQx	125.176998	0.003915
	EQy	124.986428	0.003869

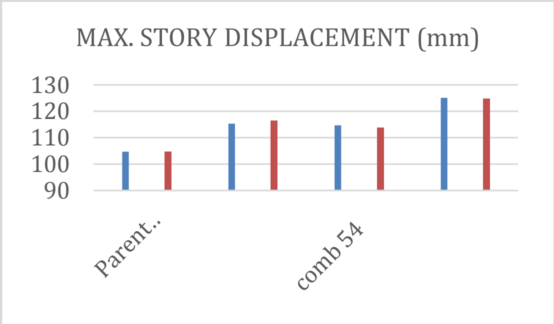

Fig-21: Maximum story displacement for case 9

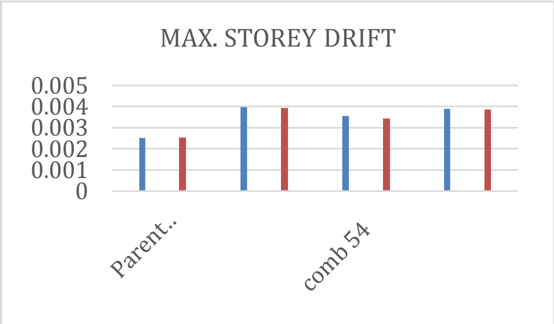

Fig-22: Maximum story displacement for case 9

Case 10 - Model having Mass & Vertical geometry irregularity

Table 16: Maximum parameters for case 10

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 56	EQx	113.750857	0.002785
	EQy	95.264119	0.00219
comb 57	EQx	105.788802	0.002449
	EQy	105.788802	0.002449
comb 58	EQx	113.295315	0.002776

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

	EQy	97.267703	0.002306
comb 59	EQx	105.064781	0.002503
	EQy	105.064781	0.002503
comb 60	EQx	81.48852	0.001897
	EQy	84.677928	0.001944
comb 61	EQx	77.03725	0.001925
	EQy	77.03725	0.001925
comb 62	EQx	89.855317	0.002066
	EQy	88.715048	0.002055
comb 63	EQx	80.076765	0.001772
	EQy	80.076765	0.001772
comb 64	EQx	101.302725	0.002516
	EQy	105.258702	0.002609
comb 65	EQx	103.336925	0.002623
	EQy	103.336925	0.002623

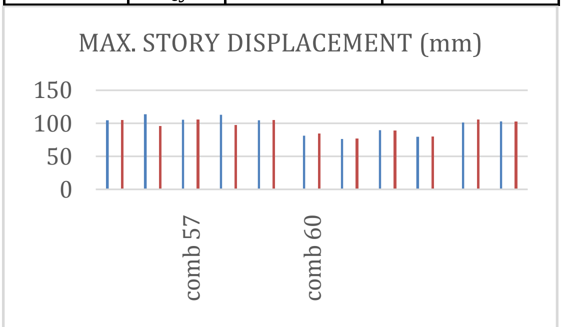

Fig-23: Maximum story displacement for case 10

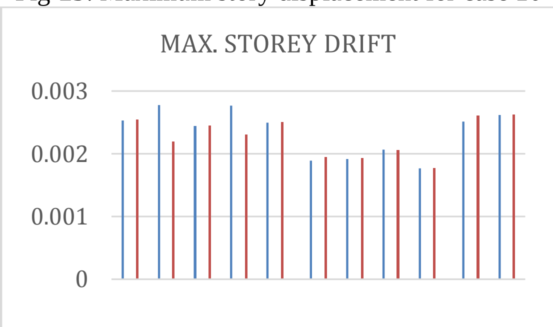

Fig-24: Maximum story displacement for case 10

Case 11 - Model having Mass & In-plane discontinuity irregularity

Table 17: Maximum parameters for case 11

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 66	EQx	106.066951	0.002567
	EQy	106.048987	0.00258
comb 67	EQx	105.779638	0.002562
	EQy	105.954204	0.002566
comb 68	EQx	107.13361	0.002593

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

	EQy	107.298292	0.002609

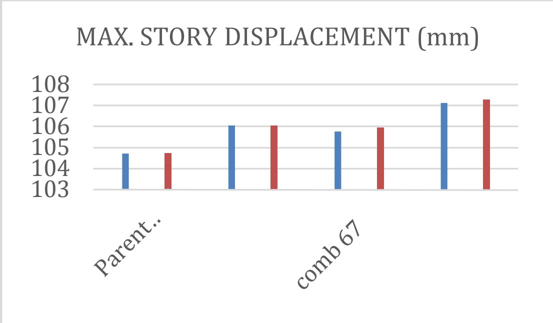

Fig-25: Maximum story displacement for case 11

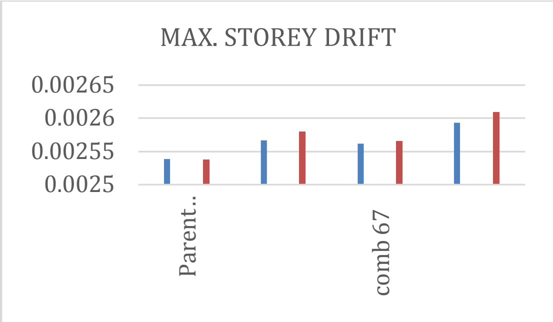

Fig-26: Maximum story displacement for case 11

Case 12 - Model having Mass & Stub column irregularity

Table 18: Maximum parameters for case 12

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 69	EQx	106.962454	0.002799
	EQy	108.196108	0.002772
comb 70	EQx	107.314904	0.002584
	EQy	106.879519	0.00256
comb 71	EQx	109.59702	0.002827
	EQy	109.866417	0.002798

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

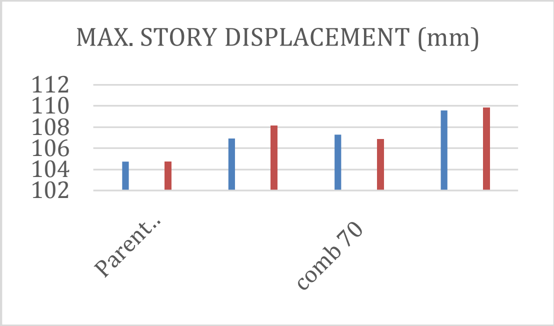

Fig-27: Maximum story displacement for case 12

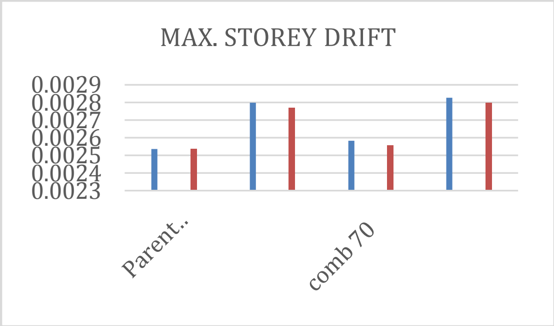

Fig-28: Maximum story displacement for case 12

Case 13 – Model having Vertical geometric & In-plane discontinuity irregularity

Table 19: Maximum parameters for case 13

MODEL	CASE	DISPLACEMENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 72	EQx	114.304571	0.002779
	EQy	96.164031	0.002215
comb 73	EQx	106.345721	0.002468
	EQy	106.625298	0.002473
comb 74	EQx	113.436904	0.002768
	EQy	97.394031	0.002289
comb 75	EQx	105.214692	0.002495
	EQy	105.153056	0.002485
comb 76	EQx	81.356099	0.001899
	EQy	84.482978	0.001945
comb 77	EQx	77.053739	0.001929
	EQy	76.911742	0.0019252
comb 78	EQx	89.408658	0.002048
	EQy	88.200287	0.002037
comb 79	EQx	79.744534	0.001757
	EQy	79.652071	0.001756
comb 80	EQx	101.458061	0.00252

	EQy	105.140062	0.002609
comb 81	EQx	103.539175	0.002629
	EQy	103.267757	0.002623

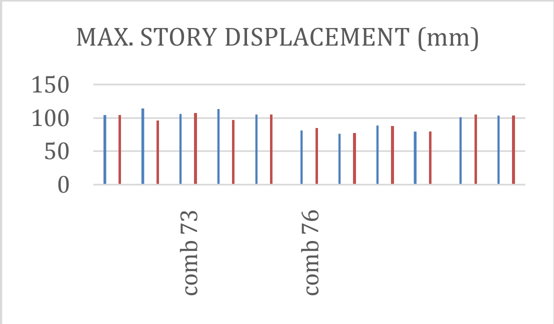

Fig-29: Maximum story displacement for case 13

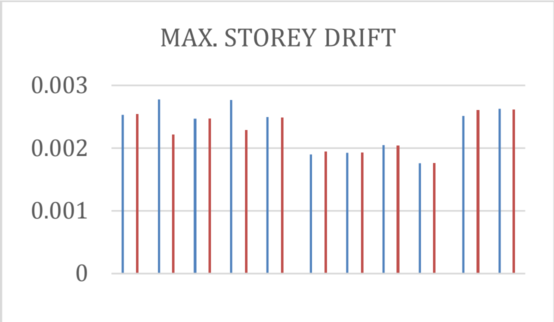

Fig-30: Maximum story displacement for case 13

Case 14 - Model having Vertical geometric & Stub column irregularity

Table 20: Maximum parameters for case 14

MODEL	CASE	DISPLACE MENT (mm)	MAX. STORY DRIFT
Pa. Mo.	EQx	104.74054	0.002538
	EQy	104.74054	0.002538
comb 82	EQx	115.392668	0.003037
	EQy	96.976801	0.002315
comb 83	EQx	107.168762	0.002641
	EQy	107.365592	0.002566
comb 84	EQx	114.500873	0.00275
	EQy	98.117803	0.002282
comb 85	EQx	106.19404	0.002479
	EQy	105.875879	0.002477
comb 86	EQx	83.678341	0.00197
	EQy	85.618941	0.001967
comb 87	EQx	79.400894	0.001967
	EQy	77.792751	0.001922
comb 88	EQx	90.890204	0.00208

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2814-2838 www.ijaem.net ISSN: 2395-5252

	EQy	89.741197	0.002075
comb 89	EQx	81.211554	0.001872
	EQy	80.97665	0.00192
comb 90	EQx	104.626167	0.002608
	EQy	107.045219	0.002637
comb 91	EQx	106.971002	0.002676
	EQy	104.868721	0.00263

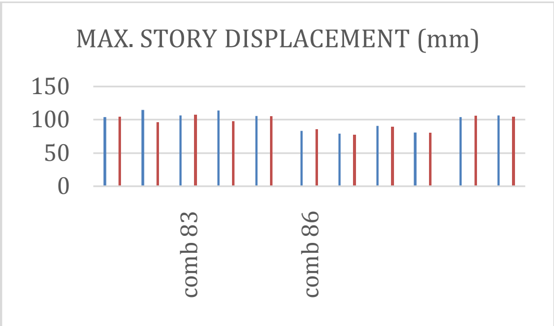

Fig-31: Maximum story displacement for case 14

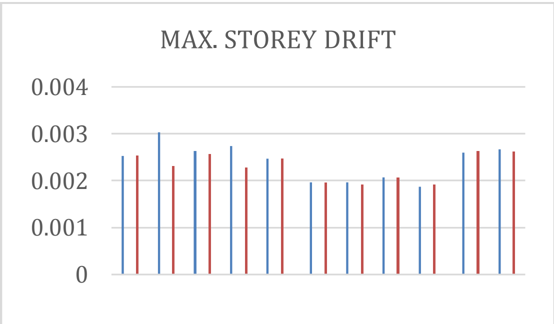

Fig-32: Maximum story displacement for case 14

VI. CONCLUSION

[1]. Stiffness irregularities in the lower half of the building have a significant impact on the building's earthquake behaviour.

[2]. Mass irregularity in the upper half of the building has a significant impact on the building's earthquake behaviour.

[3]. If a building only has a setback on one side in either direction, vertical geometrical irregularity has a significant impact on its behaviour.

[4]. In-plane discontinuity has an impact on the building's behaviour during an earthquake. If given in the bottom portion of the building.

[5]. Stub column irregularity has an impact on the building's behaviour during an earthquake. If given in the lower half of the building.

[6]. The stiffness irregularity is dominant nature over the mass irregularity.

[7]. The participation of stiffness irregularity and vertical geometric irregularity is the same.

[8]. Stiffness irregularity has a dominant nature over In-plane discontinuity.

[9]. Stiffness irregularity has more impact than stub column irregularity.

[10]. Vertical geometrical irregularity has a greater impact on structure behaviour than mass irregularity.

[11]. Mass irregularity has a greater impact on structure behaviour than In-plane discontinuity.

[12]. Stub column irregularity has a greater impact on building behaviour than mass irregularity.

[13]. Vertical geometrical irregularity has a greater impact on building behaviour than In-plane discontinuity.

[14]. Vertical geometrical irregularity has a greater impact on building behaviour than Stub column irregularity.

To begin with, the most serious irregularity is

Table 21: Most critical Vertical Irregularity

Name of irregularity	% Change in Displacement	% Change in Drift
Stiffness irregularity	13.89	36.52
Vertical geometrical irregularity	8.26	8.79
Stub column	4.09	10.05
Mass irregularity	1.65	1.93
In-plane discontinuity	0.86	0.87

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