A COMPARATIVE STUDY BETWEEN TALL BUILDINGS WITH CONVENTIONAL OUTRIGGER SYSTEMS, OFFSET OUTRIGGER SYSTEMS AND CONVENTIONAL RCC STRUCTURE

Gufran Safi Baig[1], Khalid Nayaz Khan[2], Dr. N S Kumar[3]

[1]*M. Tech, Structural Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India*
[2]*Associate Professor, Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India*
[3]*Prof. & HOD, former Director (R & D), Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara*

---***---

Abstract - *The aim of this project is to do comparative analysis of the two outrigger structural systems for tall building subjected to lateral loads. Today the development of structural system goes beyond the unexpected level. To overcome the problems persist in the structural behavior numerous studies has routed out. On this present have a look at is targeted at the performance of different outrigger structural systems for a multi storey is examined with the use of ETABS software program. The performance analysis of the tall building for distinctive fashions is performed to discover the surest function of outrigger gadget and belt truss with the aid of the usage of lateral loads. Time history analysis for floor movement statistics of the multi storey building version is carried out. The evaluation includes lateral displacement of the storeys go with the flow and base shear for static and dynamic loading. From the acquired results the effective performance of building with outriggers is evaluated. this project describes the structural layout of multi storey the use of overall performance based totally strategies for seismic and wind movements. The parameters of earthquake and wind load has been defined as per IS 1893 (Part-1): 2002 and IS 875 (Part-3): 1987 respectively*

1.INTRODUCTION

Tall Building has always been a vision of dreams and technical advancement leading to the progress of the world. Presently, with the rapidly increasing urbanization, tall building has become a more convenient option for office and residential housing. Tall buildings are usually designed for Residential, office or commercial use. There are many structural systems that can be used for the lateral resistance of tall buildings. Structural systems for tall buildings. The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method. The floor space is usually free of columns and is between the core and the external columns, thus increasing the functional efficiency of the building. Exterior columns restrained the core wall from free rotation through outrigger arms. Outrigger and belt trusses, connect planar vertical trusses and exterior frame columns. Outrigger system can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns. On the basis of connectivity of core to exterior columns, this system may be divided as in two types:

- Conventional Outrigger Concept
- Virtual Outrigger Concept

1.1 Conventional Outrigger Concept

In the conventional outrigger concept, the outrigger trusses or girders are connected directly to shear walls or braced frames at the core and to columns located outboard of the core. Typically (but not necessarily), the columns are at the outer edges of the building

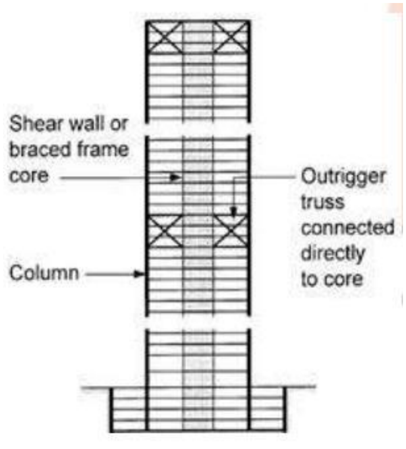


Fig-1 Conventional Outrigger System with Central Core

1.2 Virtual Outrigger Concept

In the "virtual" outrigger, the same transfer of overturning from the core to elements outboard of the core is achieved, but without a direct connection between the outrigger trusses and the core. The basic idea behind the virtual outrigger concept is to use floor diaphragms, which are typically very stiff and strong in their own plane.

The use of belt trusses as virtual outriggers avoids many of the problems associated with the use of conventional outriggers. The principle is the same as when belt trusses are used as virtual outriggers. Some fraction of the moment in the core is converted into a horizontal couple in the floors at the top and the bottom of the basement

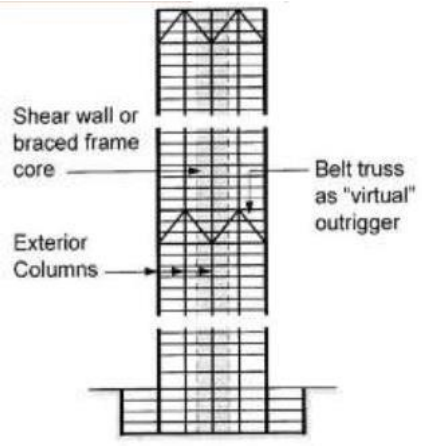


Fig-2 Virtual outrigger system with central core

1.3 OBJECTIVE OF THE PROJECT

The main objective of the study is to compare the response of the buildings with different structural forms to resist the lateral loads. The analysis is carried out by using ETABS software.

1. To understand the behaviour of the Outrigger and Offset Outrigger System in comparison with the RC framed Conventional system.
2. Analysis is carried out using equivalent static method, Response Spectrum method using IS 1893-2016 and dynamic time history analysis using ETABS for high seismic zone.
3. Efficiency of Outrigger and Offset Outrigger system with respect the displacement, drift, time period and base shear are found out for all geometric configurations.

2. Modelling Details

The model considered for this study is an 84.7m high rise reinforced concrete building frame. The data of the modeled building considered for the study is given in following table.

Plan area of the Structure	36 x 36m
Total height of building	84.7m
Number of stories	B+G+24
Height of each storey	3.2m
Spacing of columns	6m c-c

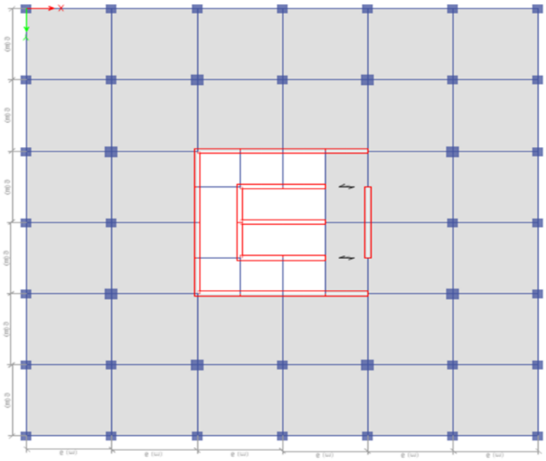


Fig -3: Name of the figure

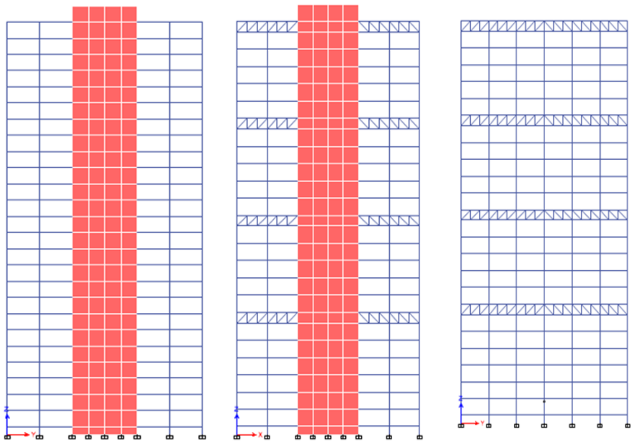


Fig-4 a) Conventional b) Outrigger c) Offset Outrigger

a) Structural Model without Outrigger, i.e, Conventional system.

b) Structural Model with Outrigger at every 5th storey, i.e, Outrigger System.

c) Structural Model with Offset Outrigger at every 5th storey, Offset Outrigger.

The models are analyzed for three seismic zones; Zone II, Zone III, Zone IV.

2.1 Material Properties

M25 grade is used for beams

M40 grade is used for columns

M30 grade for Shear walls

Fe500 is used for steel rebar

2.2 Section properties

Section	Sizes (mm)	Grade
Beams	300 x 600	M25
	350 x 750	

	400 x 750	
Columns	750 x750	M40
	900 x 900	
Slabs	200	M20
Bracing	300 x 600	M25
Shear wall	400	M30

2.3 Design loads

The loads which have been used for the modelling are as follows:

- Self-weight of the structure, Floor finish, Wall load.
- Typical live load
- Roof live load
- Seismic load

1. Dead load as per IS: 875 (Part I)-1987
i) Self weight of slab (150 mm thick) - 3.75 kN/m2
ii) Loading due to Floor Finishes - 1.50 kN/m2

2. From masonry walls – 5.72kN/m .

3. Live load as per IS: 875 (Part-II)-1987
i) Live load on floor – 3.00 kN/m2
ii) Live load on roof - 1.50 kN/m2

4. Earthquake load. IS: 1893-2016
For conventional model

	Zone II	Zone III	Zone IV
Zone Factor	0.1	0.16	0.24
Soil Type	II	II	II
Importance Factor	1	1	1
Time period, X direction	1.2	1.2	1.2
Time period, Y direction	1.2	1.2	1.2

For outrigger model and offset outrigger

	Zone II	Zone III	Zone IV
Zone Factor	0.1	0.16	0.24
Soil Type	II	II	II
Importance Factor	1	1	1
Time period, X direction	1.128	1.128	1.128
Time period, Y direction	1.128	1.128	1.128

3. RESULTS AND DISCUSSION

3.1 Results

3.11 Displacements

The maximum values of displacements are tabulated by comparing X and Y directions. The values of displacement of different models are obtained by subjecting the models to response spectrum analysis and time history analysis (linear) shows max displacement. Further the tabulated results are plotted in a graph and can be seen in Figure 5.1

Table 1: Max Displacement (Response spectrum X direction)

SL NO	ZONES	MAX DISPLACEMENT Conventional model (mm) SPECX	MAX DISPLACEMENT Outrigger (mm) SPECX	MAX DISPLACE-MENT Offset Outrigger (mm) SPECX
1	ZONE II	16.409	12.17	13.924
2	ZONE III	26.255	19.472	22.278
3	ZONE IV	39.382	29.208	33.416

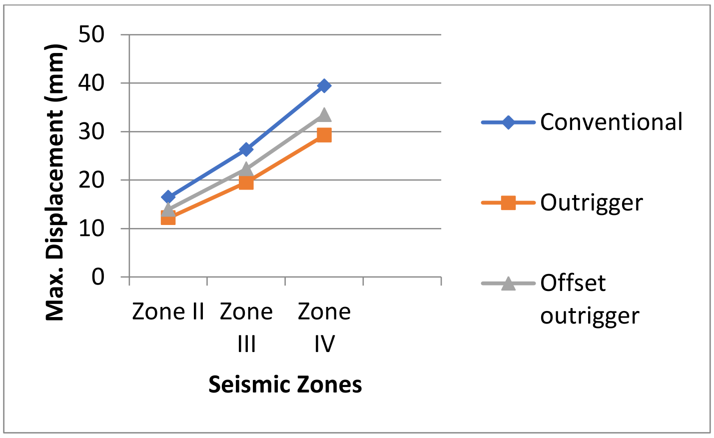


Fig 5.1 Graph of displacement variation

Table 2: Max Displacement values (Response spectrum Y direction)

SL NO	ZONES	MAX DISPLACEMENT Conventional model (mm) SPECY	MAX DISPLACEMENT Outrigger model (mm) SPECY	MAX DISPLACEMENT Offset Outrigger model (mm) SPECY
1	ZONE II	26.752	19.849	22.145
2	ZONE III	42.803	31.759	35.432
3	ZONE IV	64.205	47.639	53.148

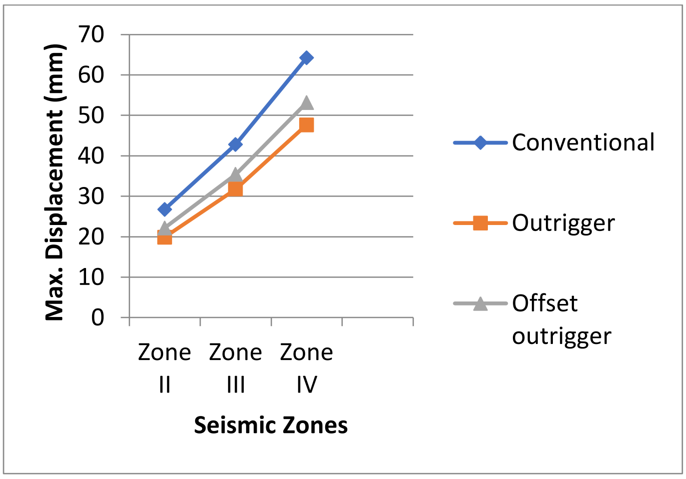


Fig 5.2 Graph of displacement variation

Table 3: Max Displacement values (Time history X direction)

SL NO	ZONES	MAX DISPLACEMENT Conventional model (mm) TH-X	MAX DISPLACEMENT Outrigger model (mm) TH-X	MAX DISPLACEMENT Offset Outrigger model (mm) TH-X
1	ZONE II	11.891	10.131	10.184
2	ZONE III	19.003	16.209	16.295
3	ZONE IV	28.532	24.312	24.441

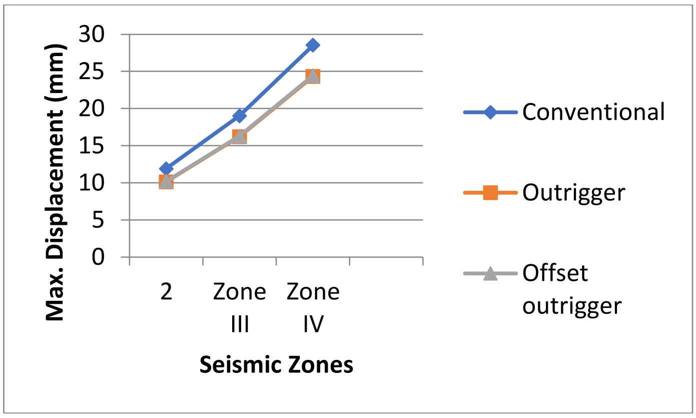


Fig 5.3 Graph of displacement variation

Table 4: Max Displacement values (Time history Y direction)

SL NO	ZONES	MAX DISPLACEMENT (mm) Conventional model TH-Y	MAX DISPLACEMENT (mm) Outrigger model TH-Y	MAX DISPLACEMENT (mm) Offset Outrigger model TH-Y
1	ZONE II	34.964	29.846	29.245
2	ZONE III	55.888	47.753	46.798
3	ZONE IV	83.665	71.626	70.186

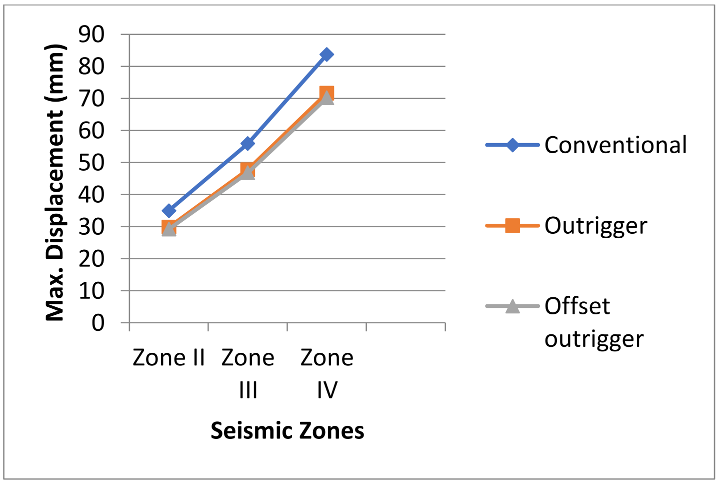
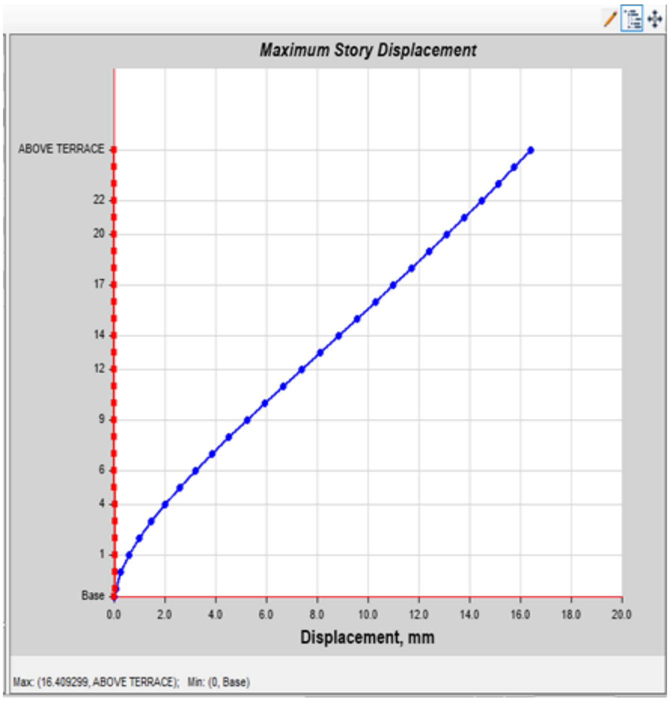
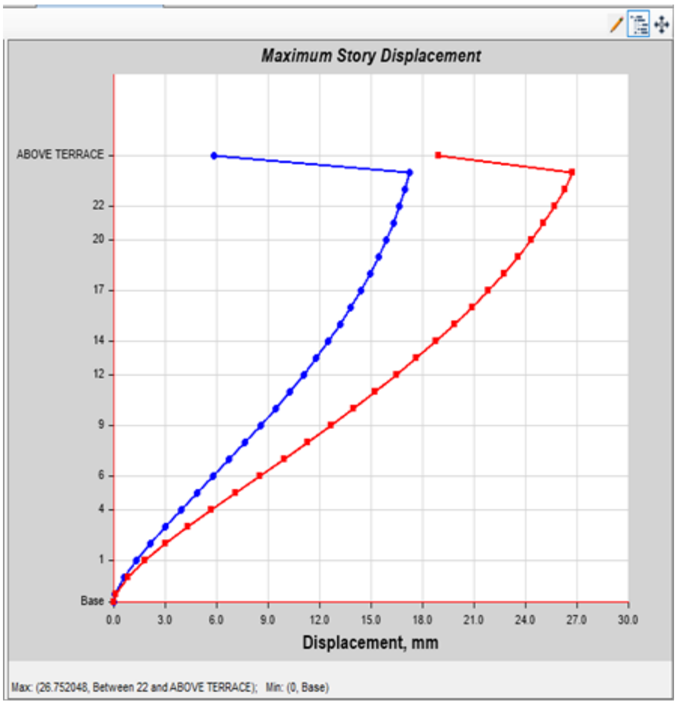


Fig 5.4 Graph of displacement variation

Maximum story displacement for Conventional model at zone II, III and IV

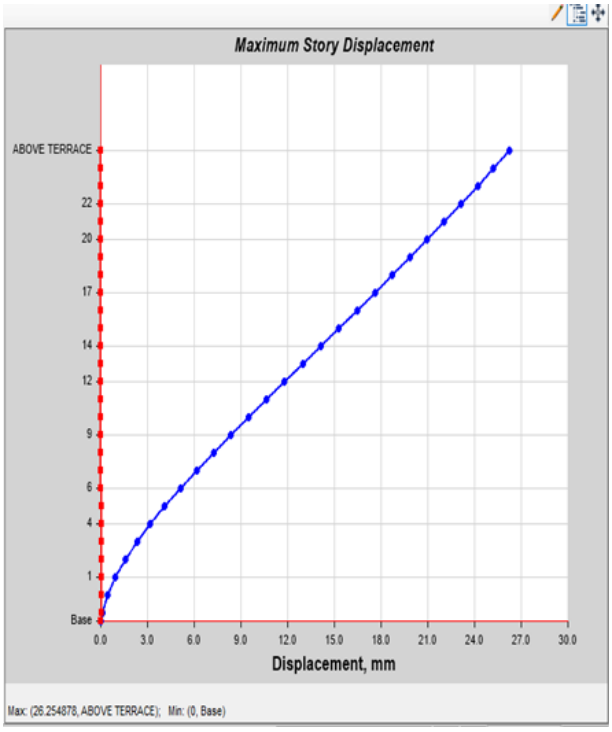


(a) Displacement X direction.

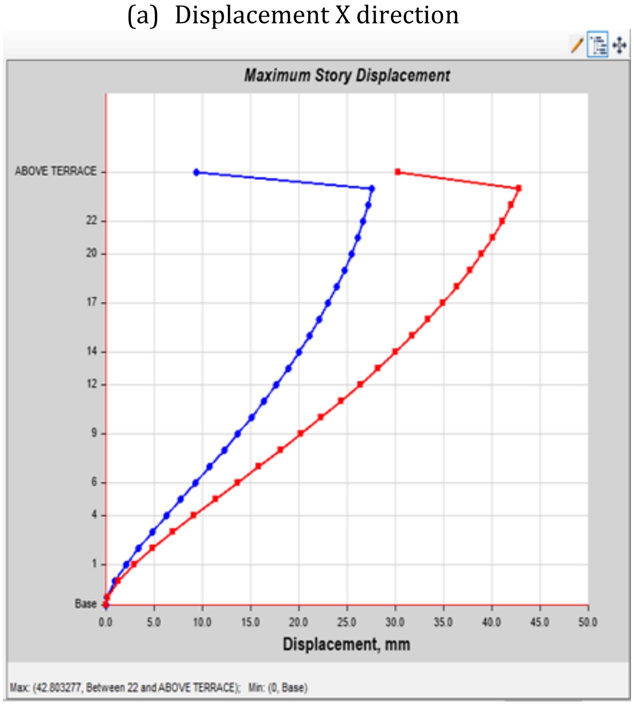


(b) Displacement Y direction

Fig 5.5 Maximum story displacement for zone II conventional system

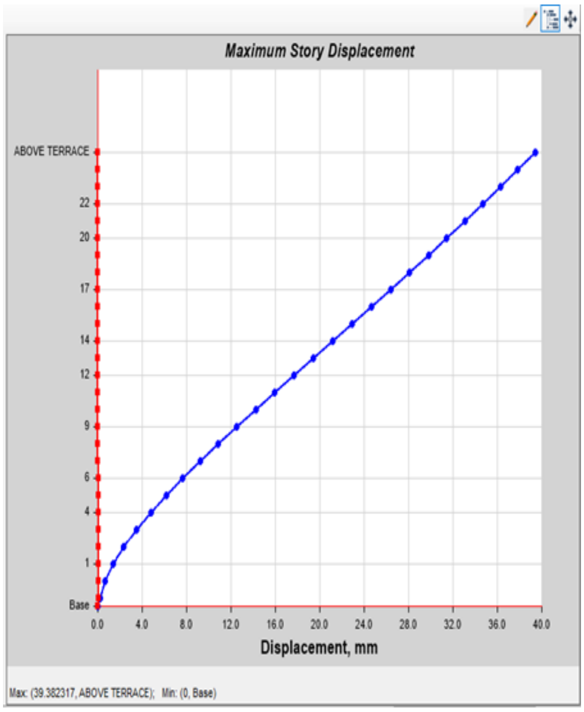


(a) Displacement X direction

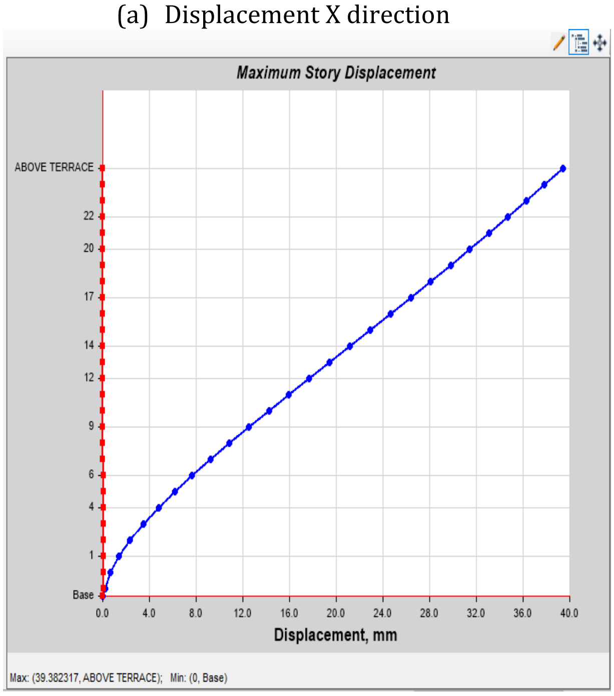


(b) Displacement Y direction

Fig 5.6 Maximum story displacement for zone III conventional system



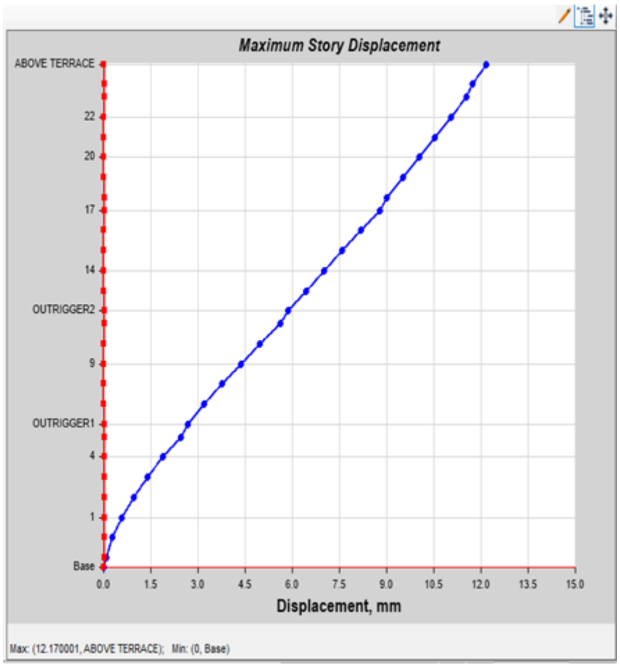
(a) Displacement X direction



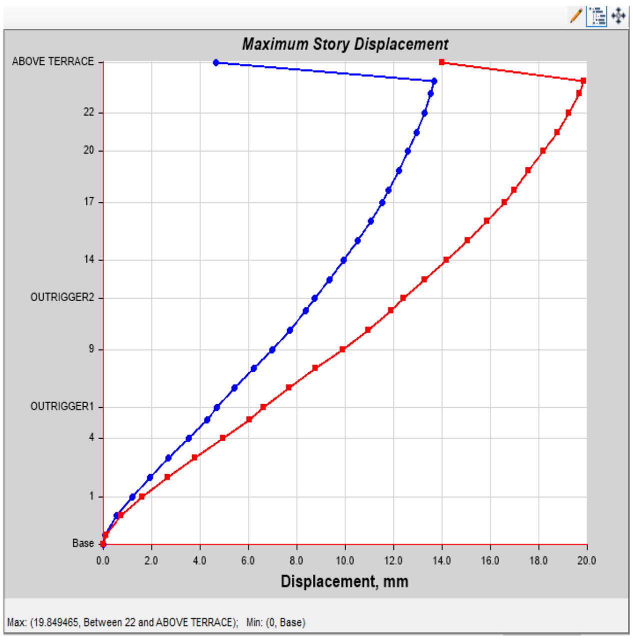
(b) Displacement Y direction

Fig 5.7: Maximum story displacement for zone IV conventional system:

Maximum story displacement for Outrigger system

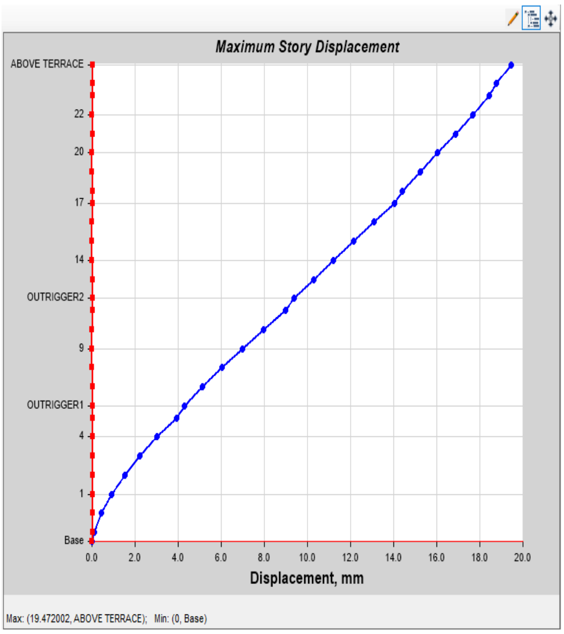


(a) Displacement X direction

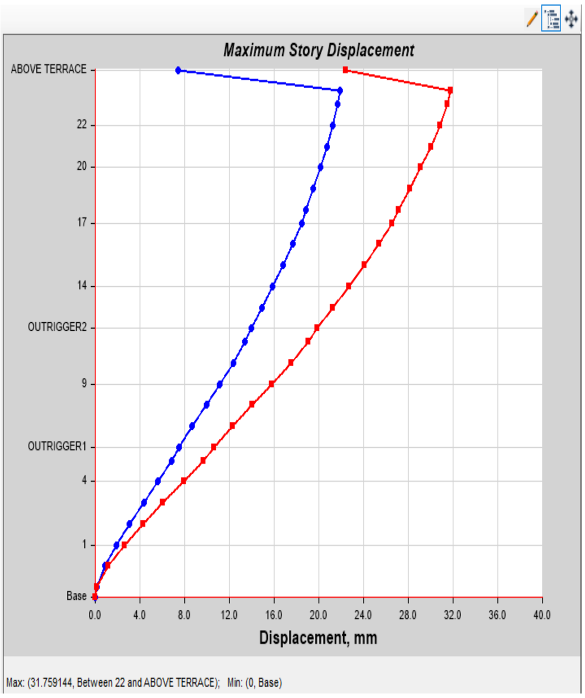


(b) Displacement Y direction

Fig-5.8 Maximum story displacement for zone II Outrigger system

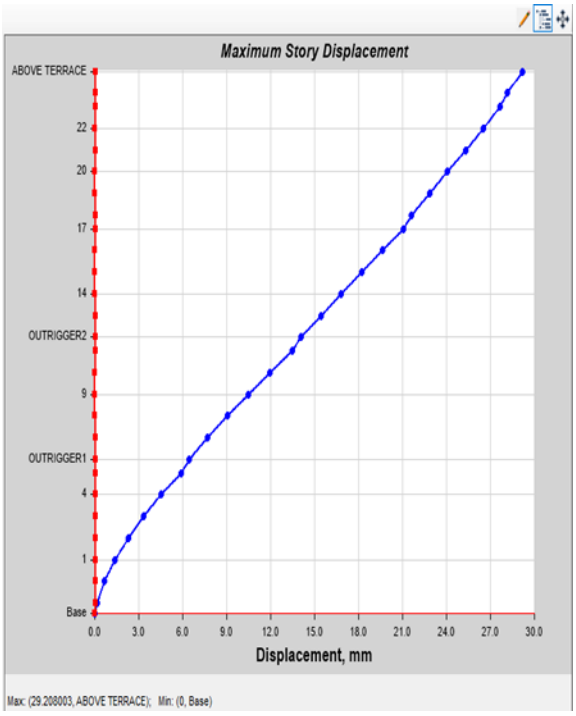


(a) Displacement X direction

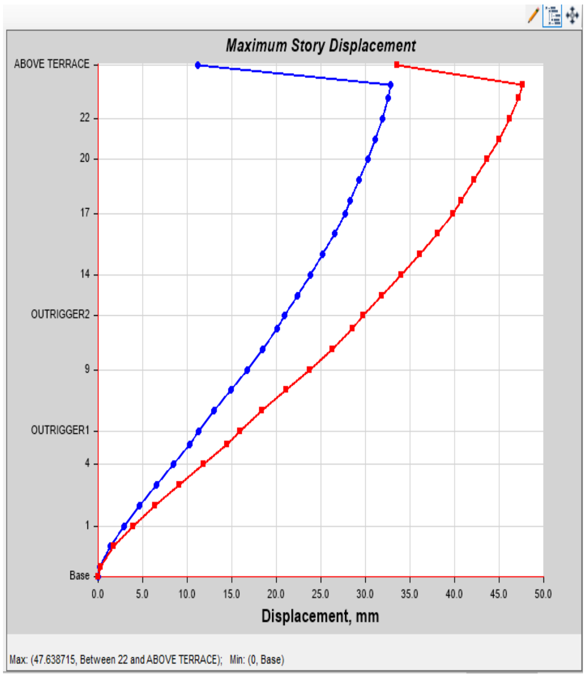


(b) Displacement Y direction

Fig 5.9 Maximum story displacement for zone III Outrigger system



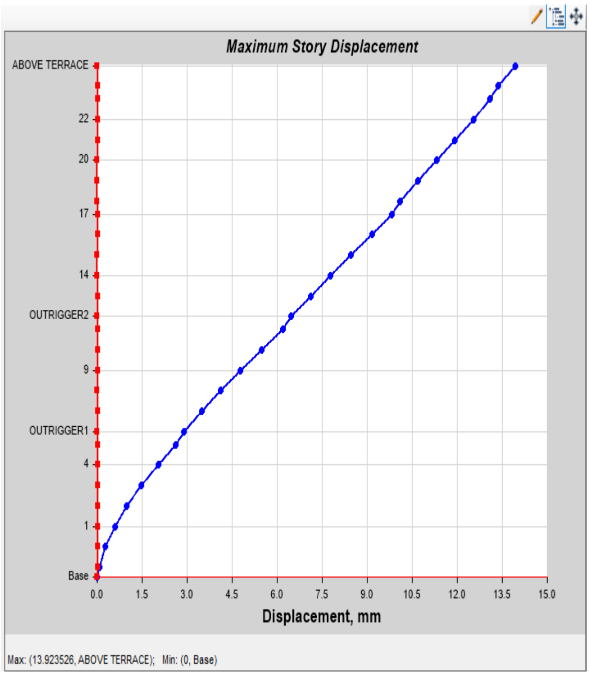
(a) Displacement X direction



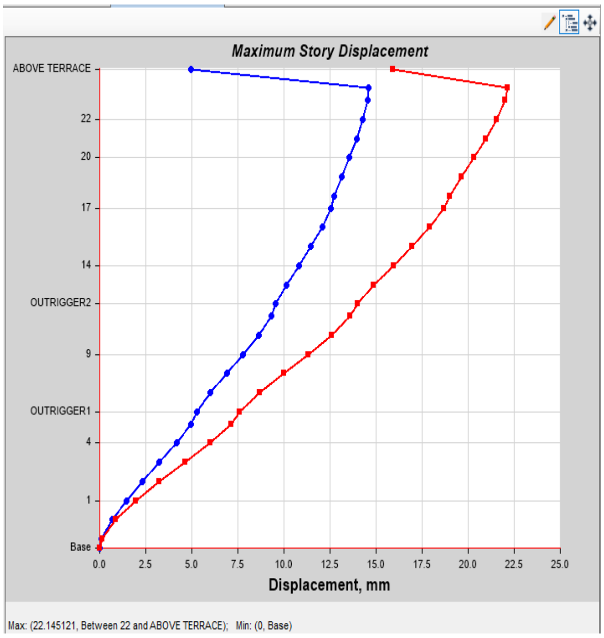
(b) Displacement Y direction

Fig 5.10 Maximum story displacement for zone IV Outrigger system

Maximum story displacement for Offset outrigger

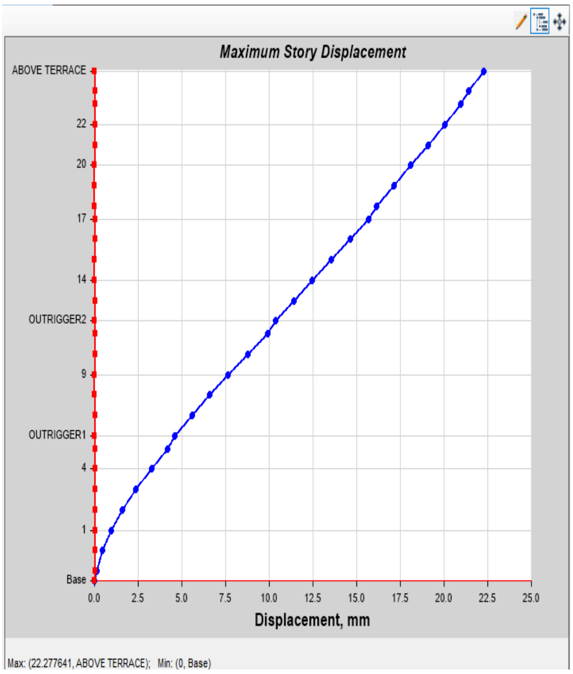


(a) Displacement X direction

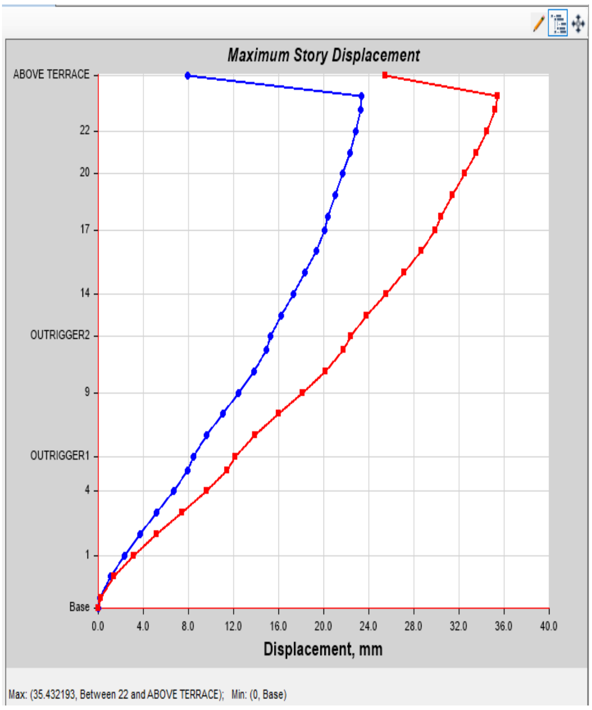


(b) Displacement Y direction

Fig- 5.11 Maximum story displacement for zone II Offset Outrigger system

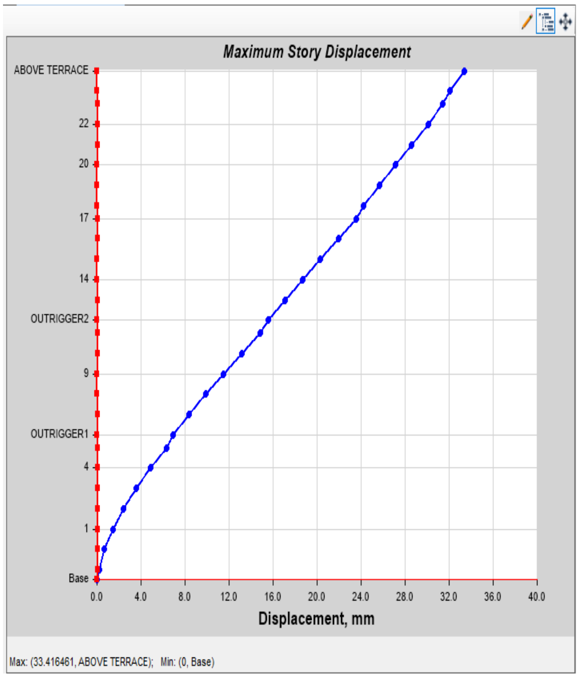


(a) Displacement X direction

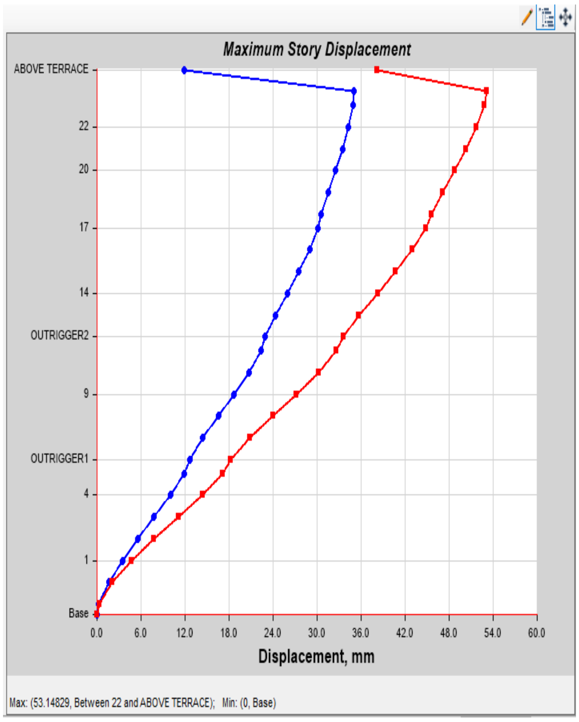


(b) Displacement Y direction

Fig 5.12 Maximum story displacement for zone III Offset Outrigger system



(a) Displacement X direction



(b) Displacement Y direction

Fig 5.13 Maximum story displacement for zone IV Offset Outrigger system

3.12 Story drift

Table 5: Max Story Drift values (Response spectrum X direction)

SL NO	ZONE	MAX STORY DRIFT Conventional SPECX	MAX STORY DRIFT Outrigger SPECX	MAX STORY DRIFT Offset Outrigger SPECX
1	Zone II	0.000242	0.000199	0.000231
2	Zone III	0.000387	0.000318	0.000369
3	Zone IV	0.000581	0.000478	0.000554

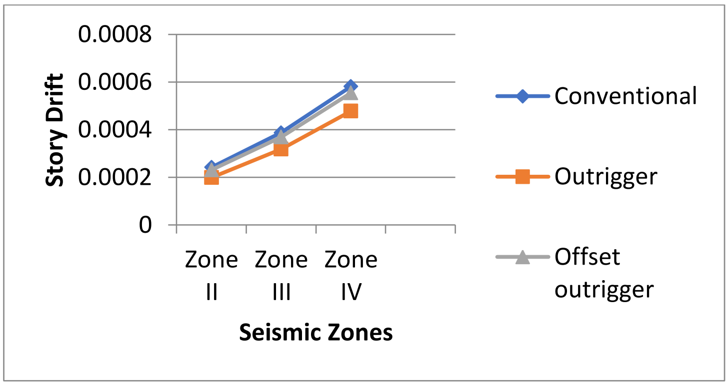


Fig 5.14 Graph of Story drift variation

Table 7: Max Story Drift values (Time History X direction)

SL NO	ZONE	MAX STORY DRIFT Conventional THX	MAX STORY DRIFT Outrigger THX	MAX STORY DRIFT Offset Outrigger THX
1	Zone II	0.000178	0.000163	0.000179
2	Zone III	0.000285	0.000261	0.000286
3	Zone IV	0.000428	0.000392	0.000429

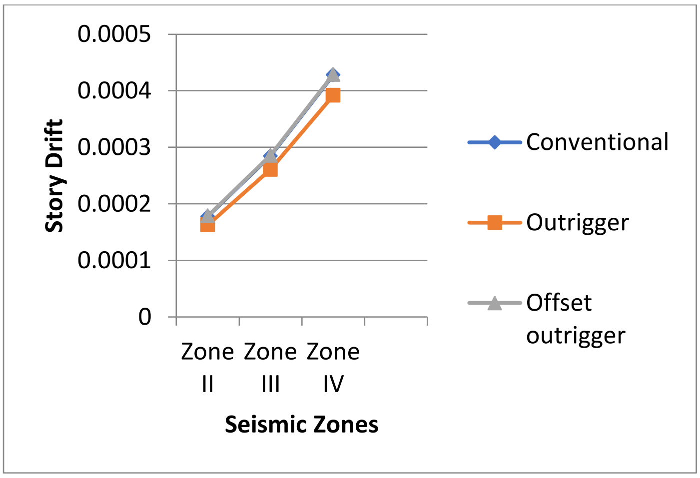


Fig 5.16 Graph of Story drift variation

Table 8: Max Story Drift values (Time History Y direction)

SL NO	ZONE	MAX STORY DRIFT Conventional THY	MAX STORY DRIFT Outrigger THY	MAX STORY DRIFT Offset Outrigger THY
1	Zone II	0.000554	0.000482	0.000487
2	Zone III	0.000886	0.000771	0.000779
3	Zone IV	0.001326	0.001157	0.001168

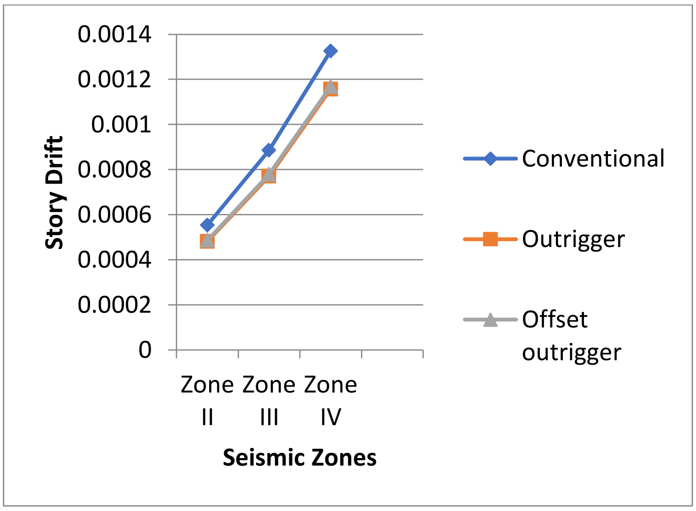
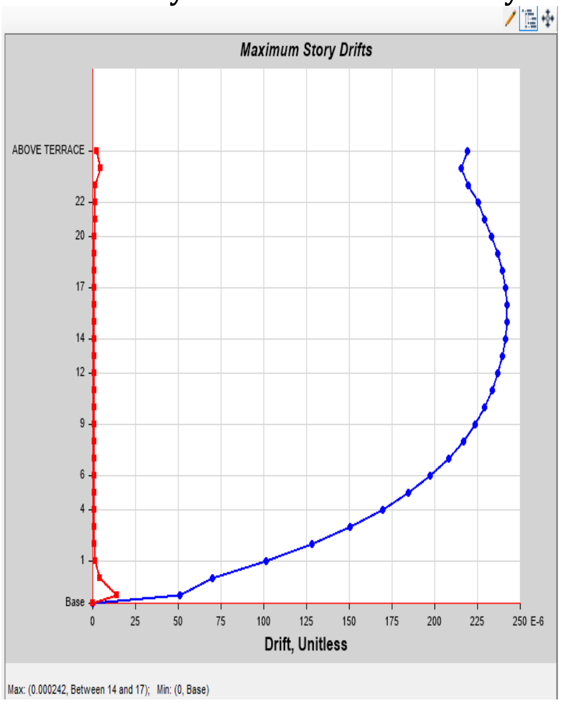
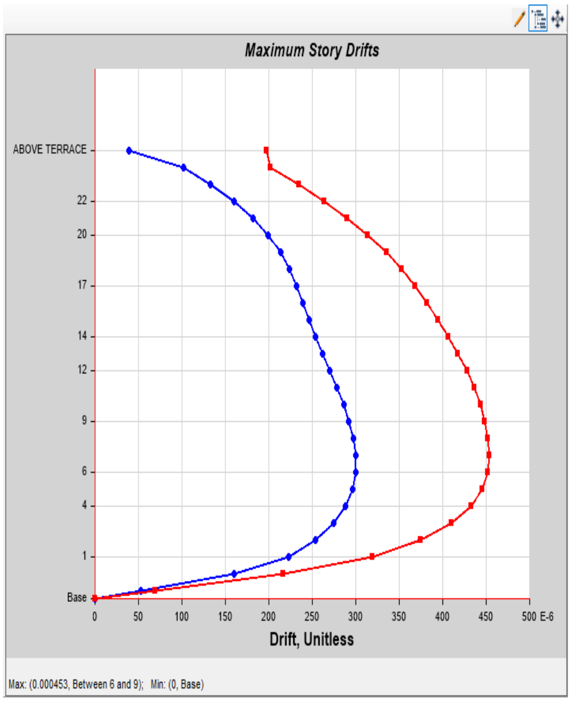


Fig 5.17 Graph of Story drift variation

Maximum story drift for Conventional system

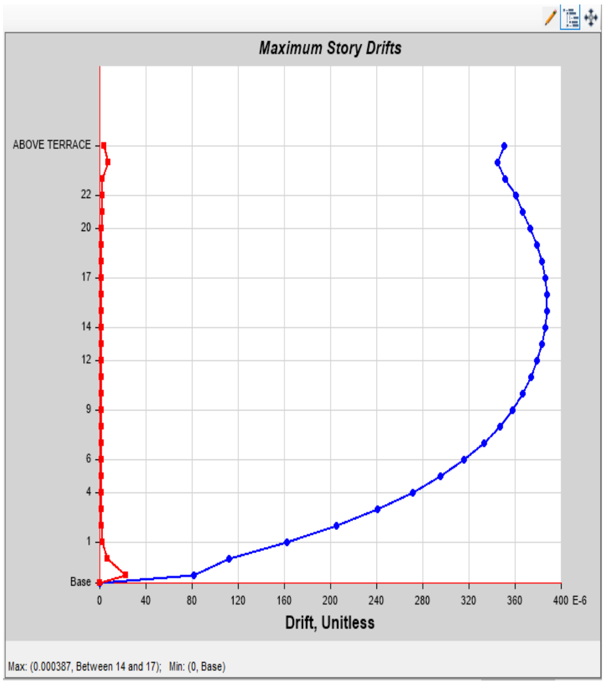


(a) Story Drift X direction

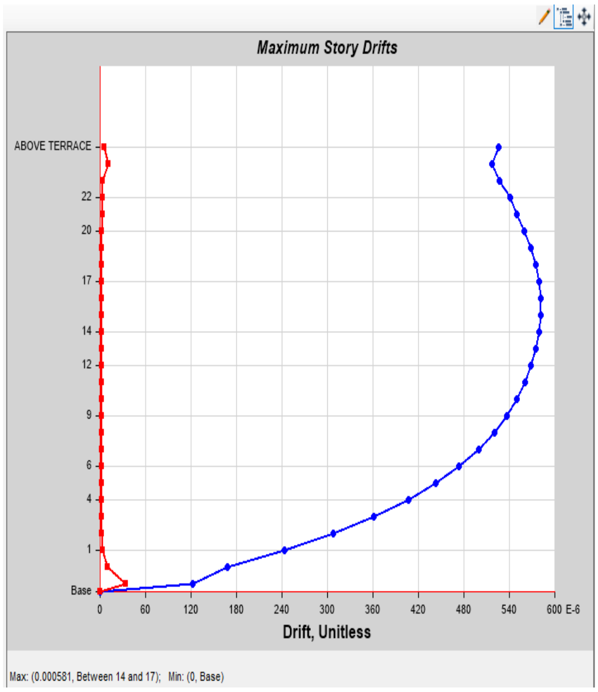


(c) Story Drift Y direction

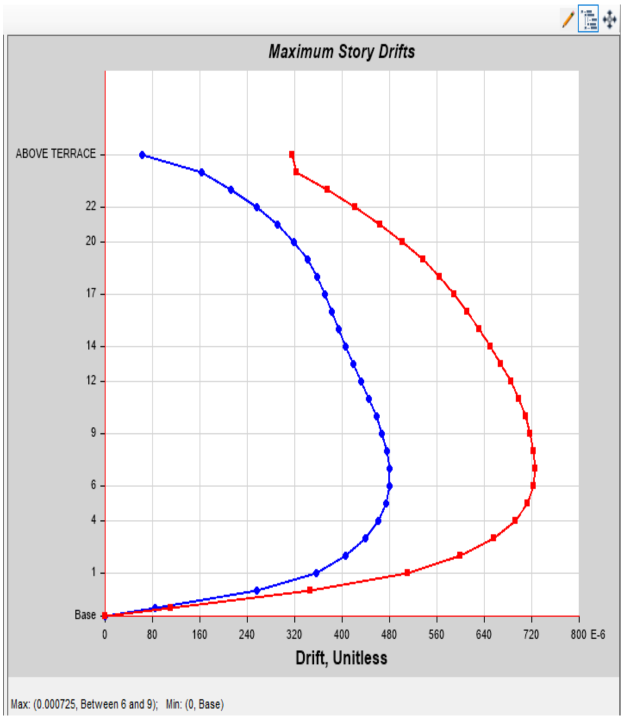
Fig 5.18 Maximum story drift for zone II Conventional system



(a) Story Drift X direction

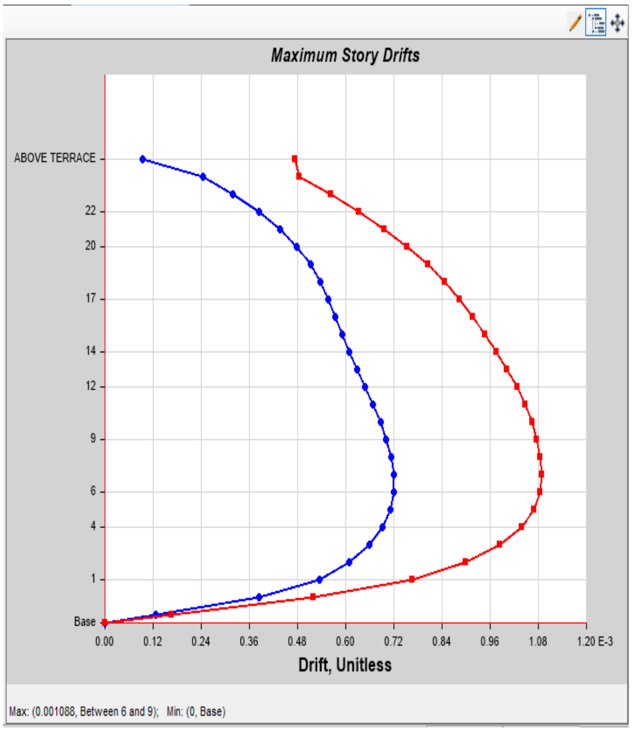


(a) Story Drift X direction



(b) Story Drift Y direction

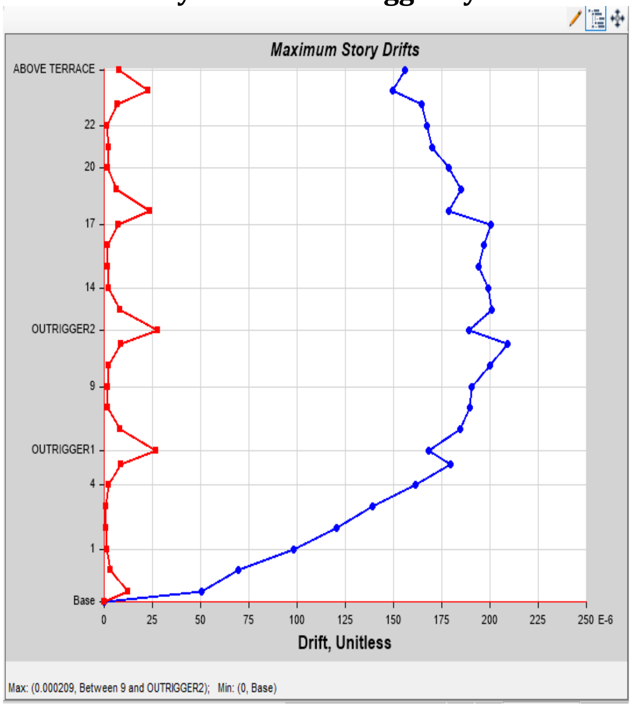
Fig 5.19 Maximum story drift for zone III Conventional system



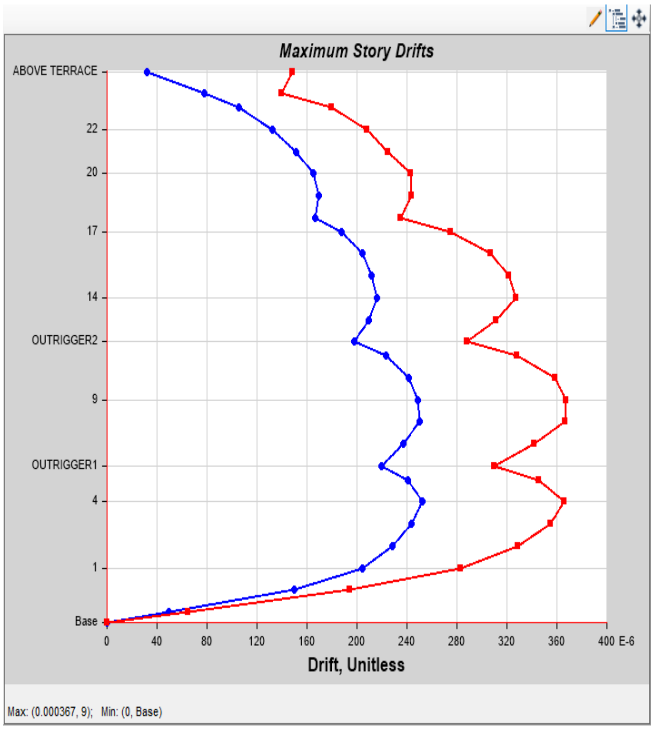
(b) Story Drift Y direction

Fig 5.20 Maximum story drift for zone IV Conventional system

Maximum story drift for Outrigger system

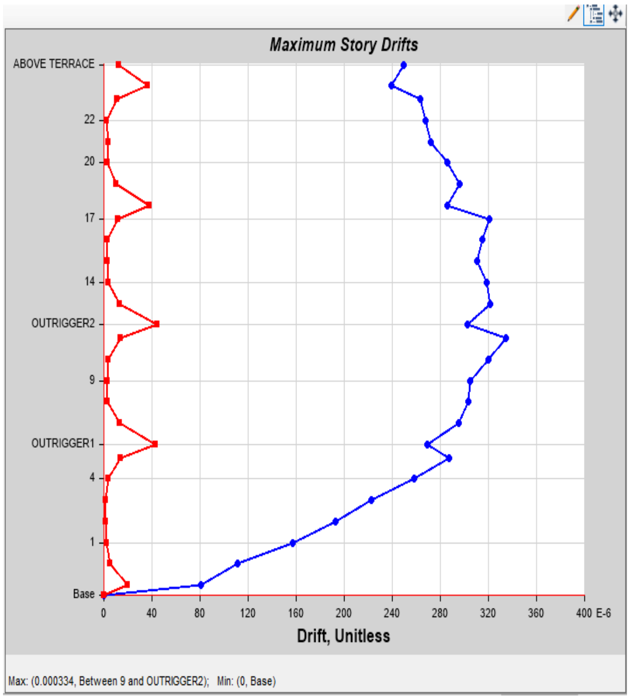


(a) Story Drift X direction

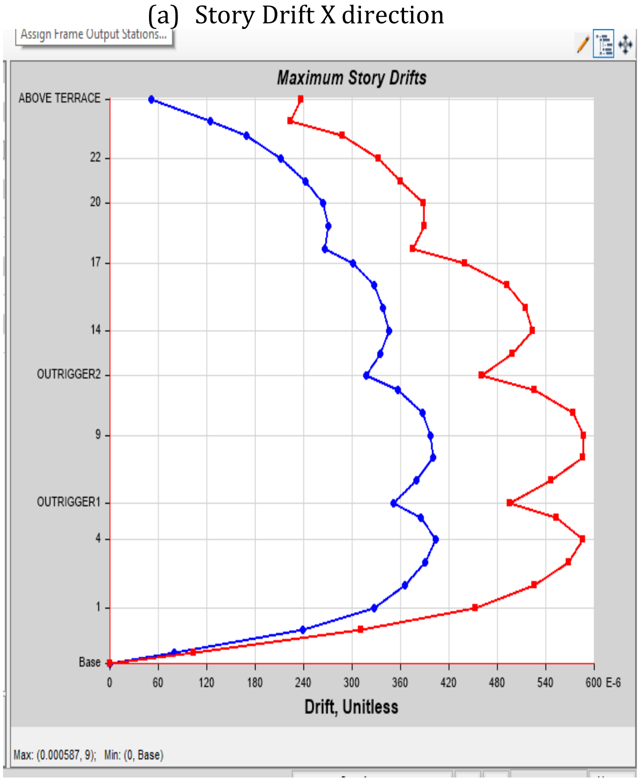


(b) Story Drift Y direction

Fig 5.21 Maximum story drift for zone II Outrigger system



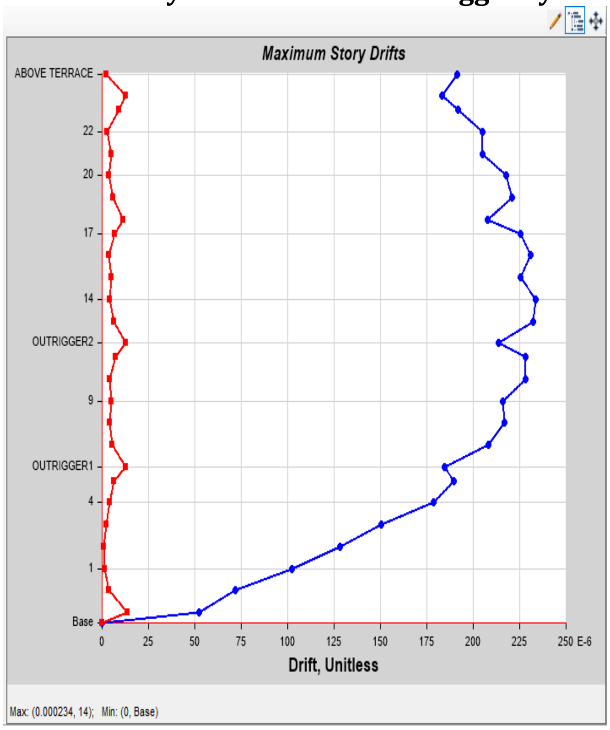
(a) Story Drift X direction



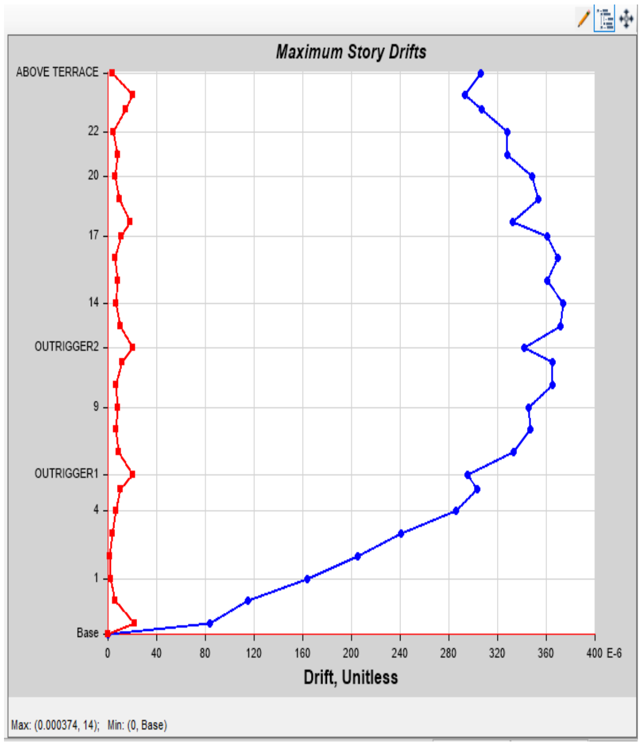
(b) Story Drift Y direction

Fig 5.22 Maximum story drift for zone III Outrigger system

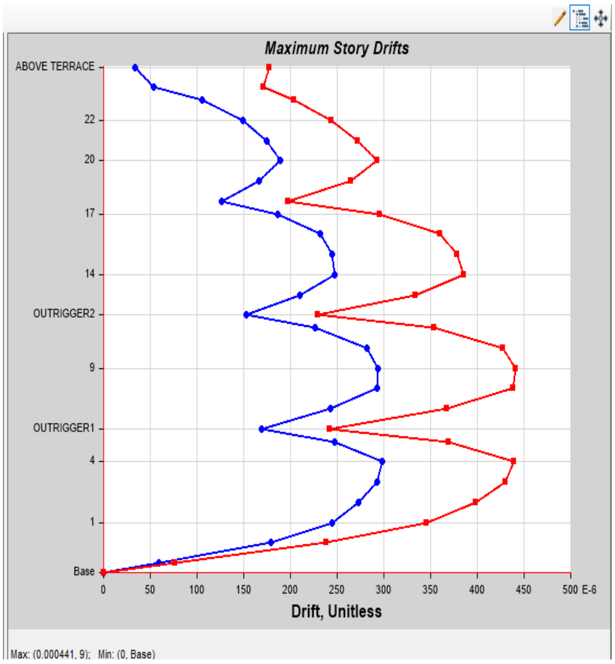
Maximum story drift for Offset Outrigger system



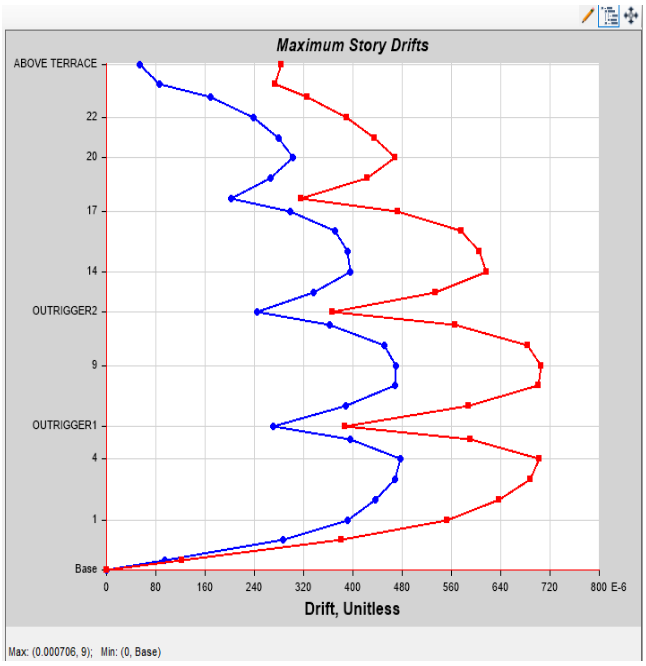
(a) Story Drift X direction



(a) Story Drift X direction



(c) Story Drift Y direction



(b) Story Drift Y direction

Fig 5.24 Maximum story drift for zone II Offset Outrigger system

Fig 5.24 Maximum story drift for zone III Offset Outrigger system

3.13 Time period

Table 9: Time period values for different Models

SL NO	ZONES	MAX TIME PERIOD Conventional Seconds	MAX TIME PERIOD Outrigger Seconds	MAX TIME PERIOD Offset Outrigger Seconds
1	Zone II	2.843	2.531	2.423
2	Zone III	2.843	2.531	2.423
3	Zone IV	2.843	2.531	2.423

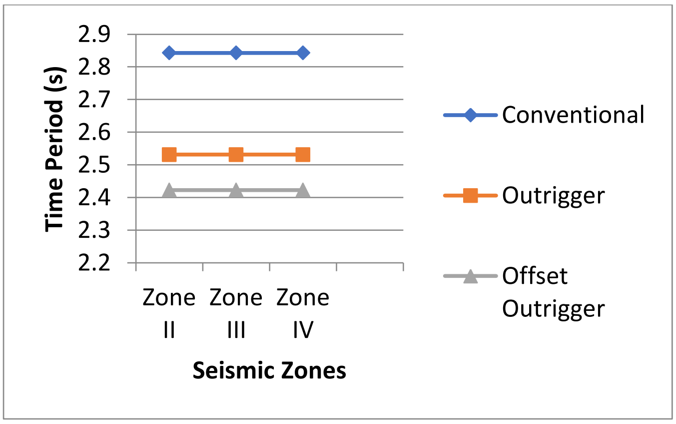


Fig 5.25 Graph of variation in time period.

3.14 Base shear

Table 10: Base shear values

SL NO	ZONES	MAX BASE SHEAR Conventional RCC kN	MAX BASE SHEAR Conventional Outrigger kN	MAX BASE SHEAR Offset Outrigger kN
1	Zone II	4627.3124	4888.5415	4909.5271
2	Zone III	7403.6998	7821.6663	7855.2434
3	Zone IV	11106.3117	11732.4995	11783.3829

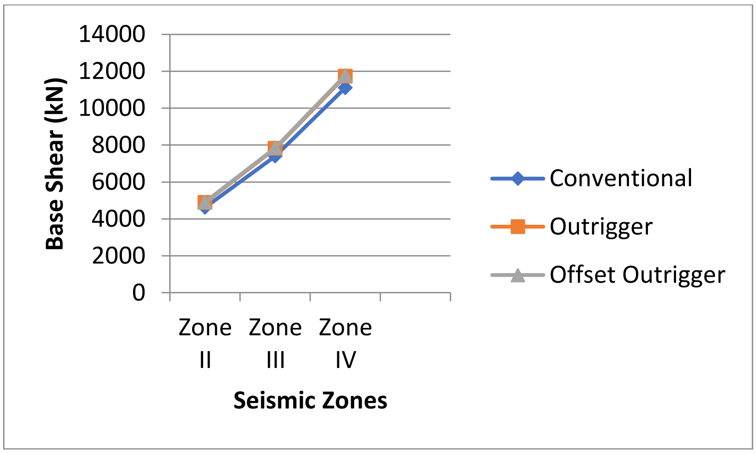
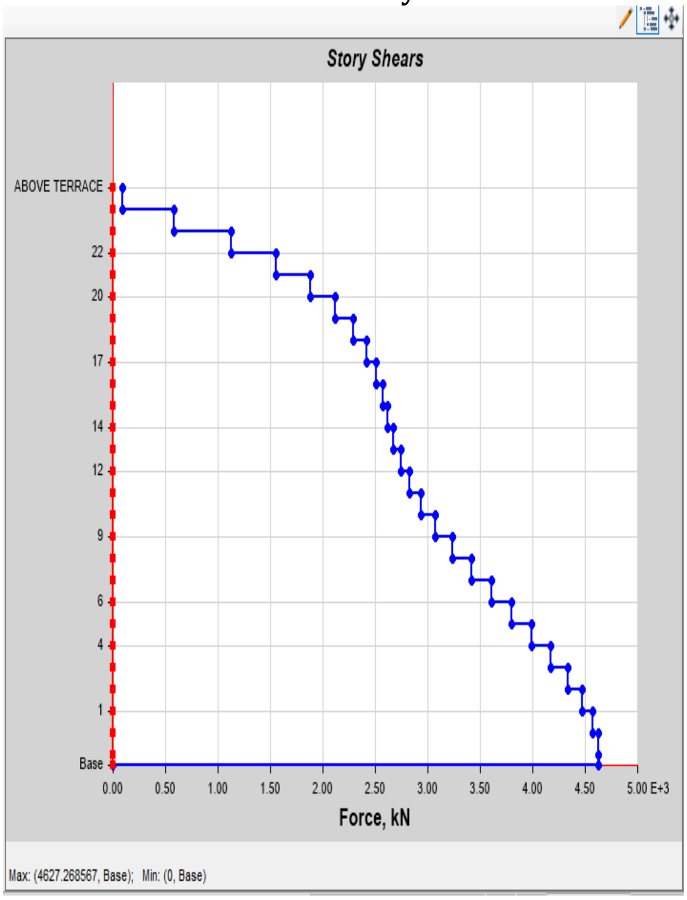
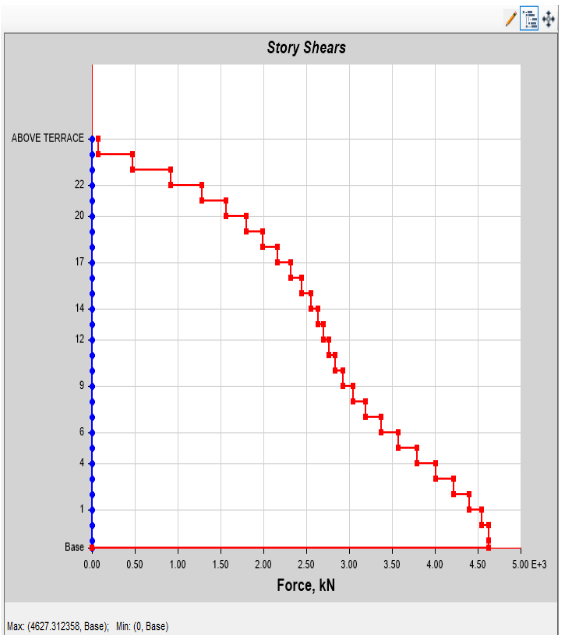


Fig 5.26 Graph of variation in base shear.

Base shear for Conventional system

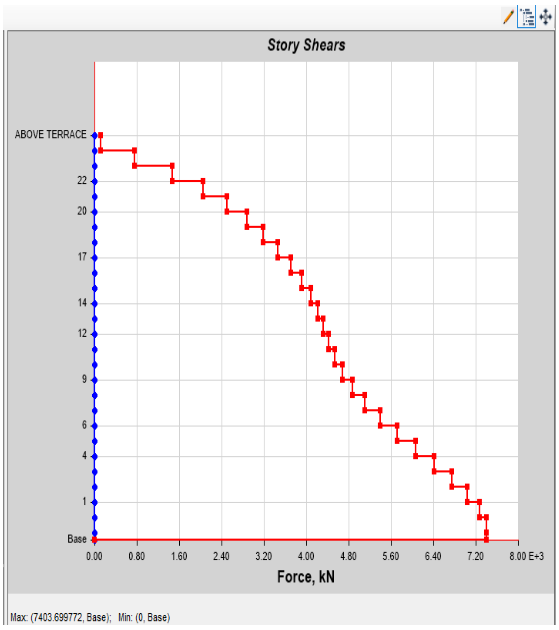


a) Base Shear X direction (Fig-5.27)



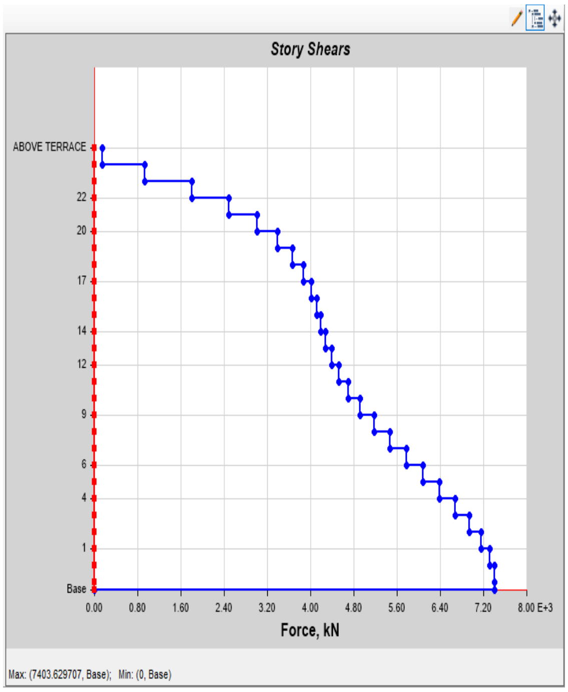
(b) Base Shear Y direction

Fig 5.27 Base Shear for zone II Conventional system

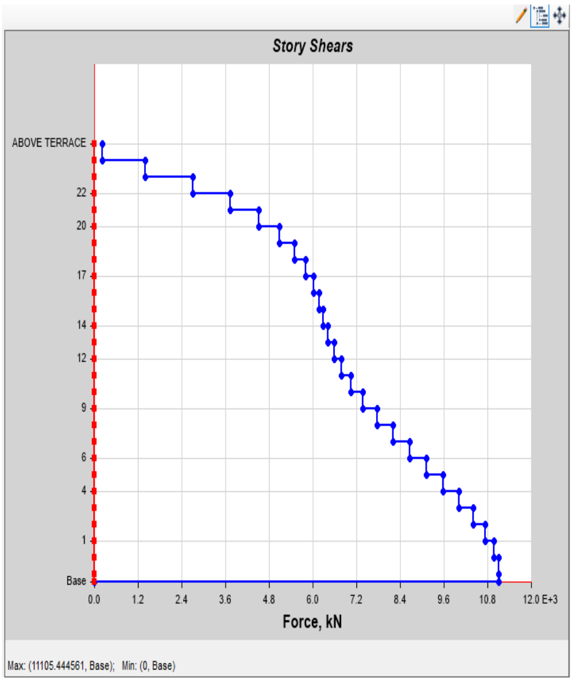


(c) Base Shear Y direction

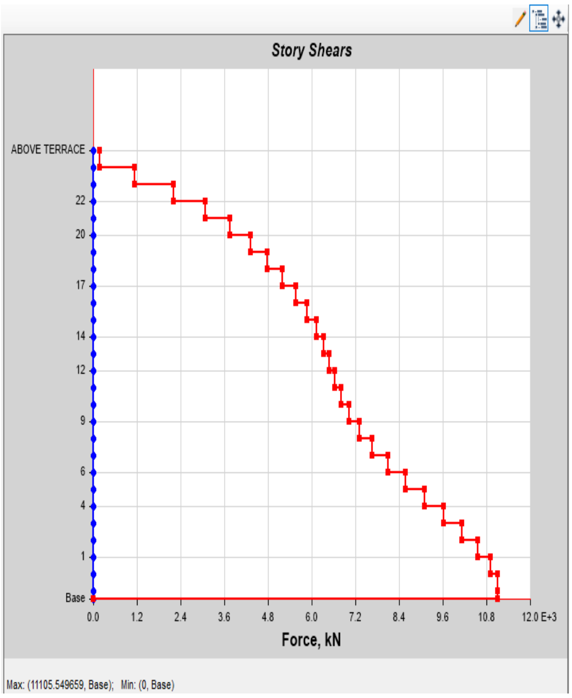
Fig 5.28 Base Shear for zone III Conventional system



a) Base Shear X direction (Fig-5.28)



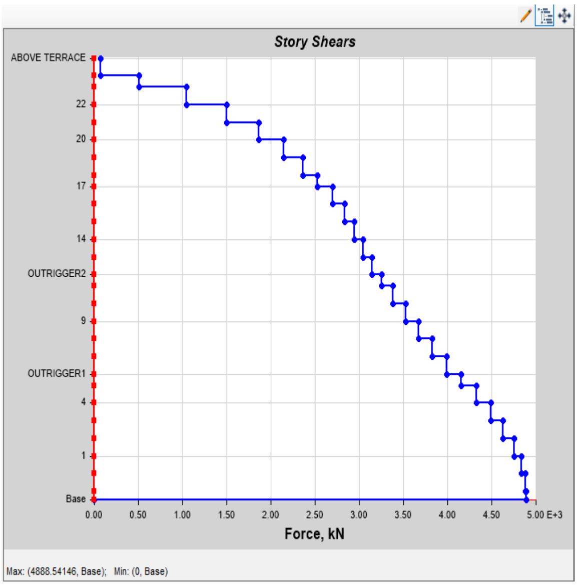
a) Base Shear X direction(Fig-5.29)



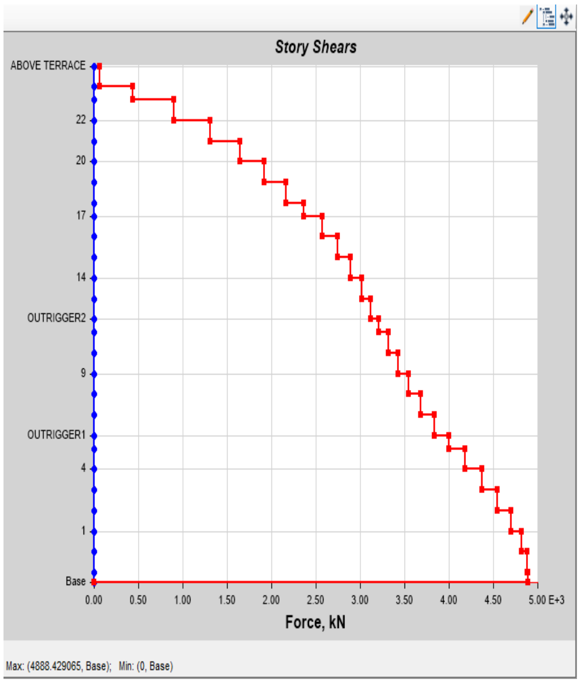
(c) Base Shear Y direction

Fig 5.29 Base Shear for zone IV Conventional system

Base shear for Outrigger system

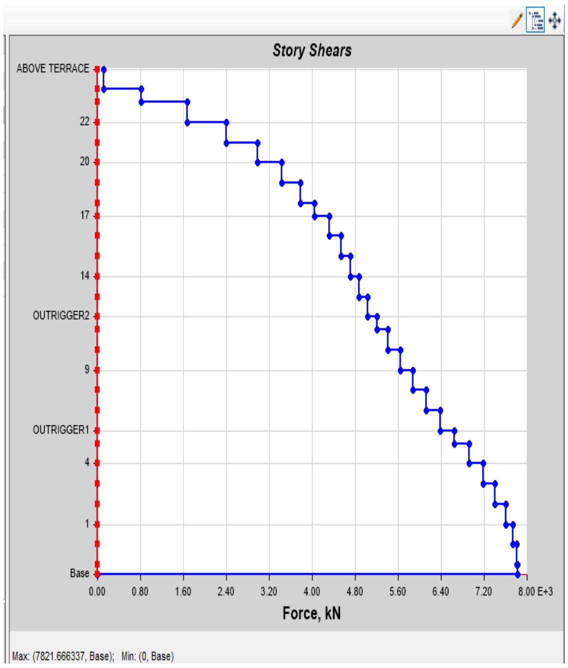


a) Base Shear X direction

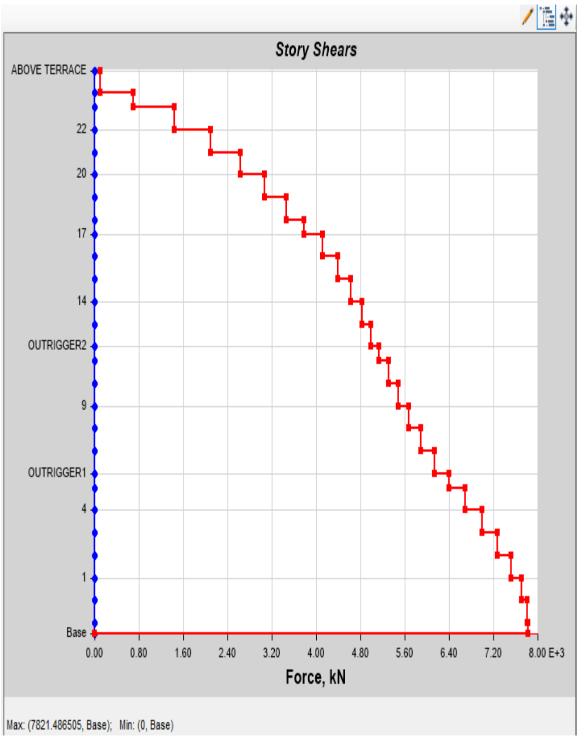


(c) Base Shear Y direction

Fig 5.30 Base Shear for zone II Outrigger system

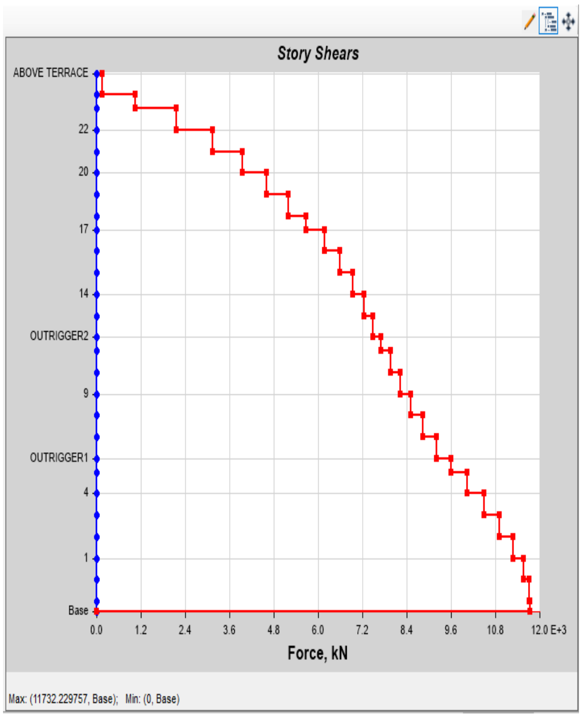


a) Base Shear X direction



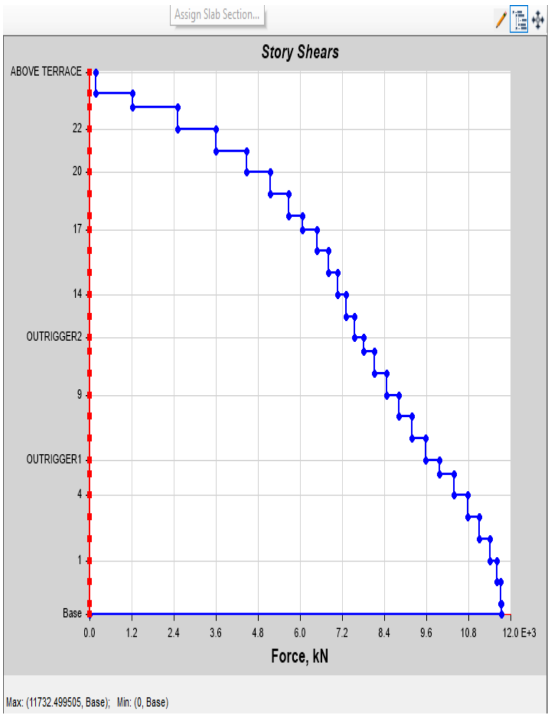
b)Base Shear Y direction

Fig 5.31 Base Shear for zone III Outrigger system



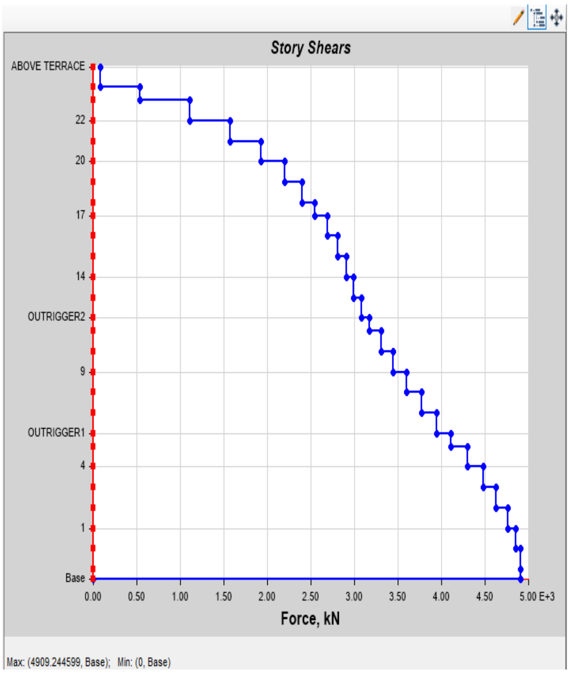
(b) Base Shear Y direction

Fig 5.32 Base Shear for zone IV Outrigger system

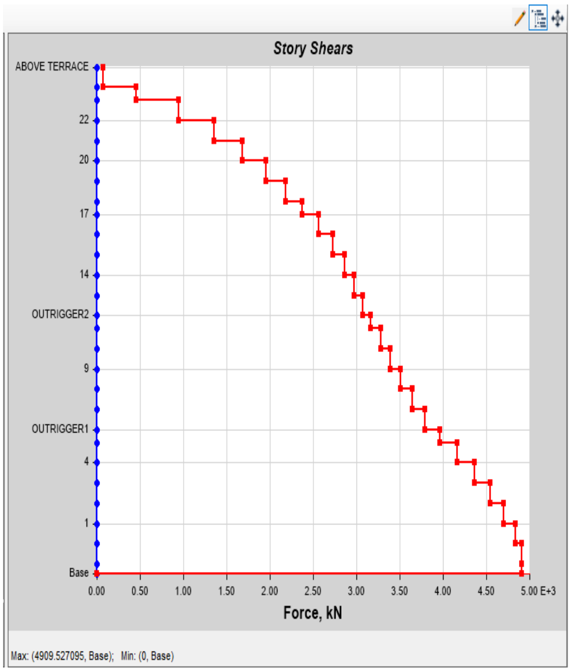


a) Base Shear X direction(Fig-5.32)

Base shear for Offset Outrigger system

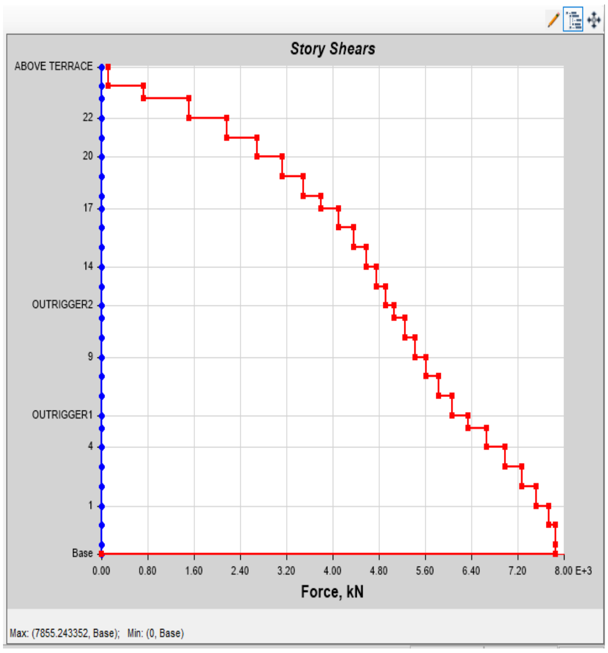


a) Base Shear X direction



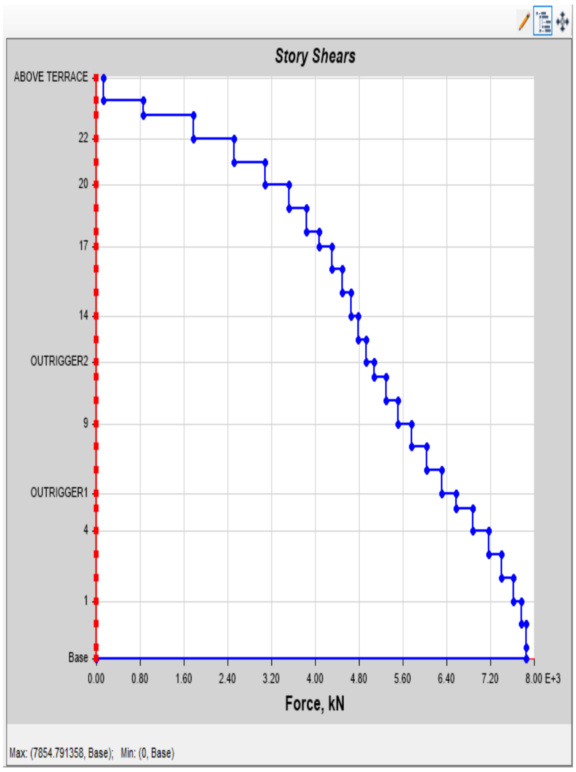
(b) Base Shear Y direction

Fig 5.33 Base Shear for zone II Offset Outrigger system

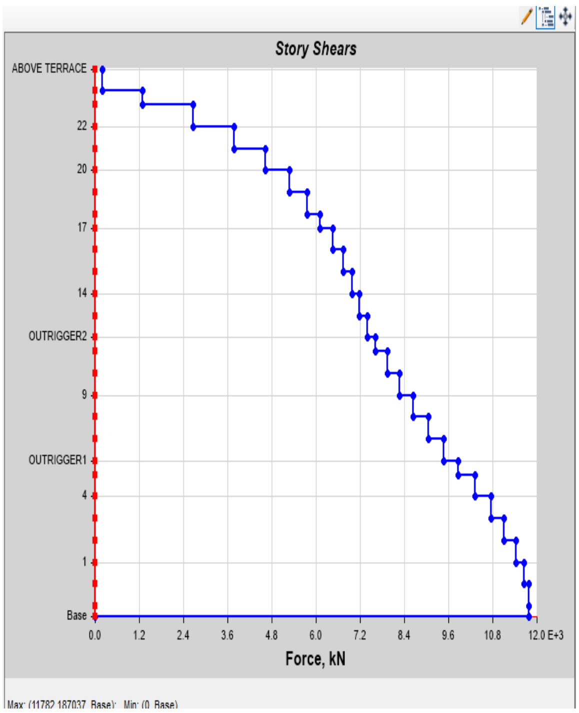


(c) Base Shear Y direction

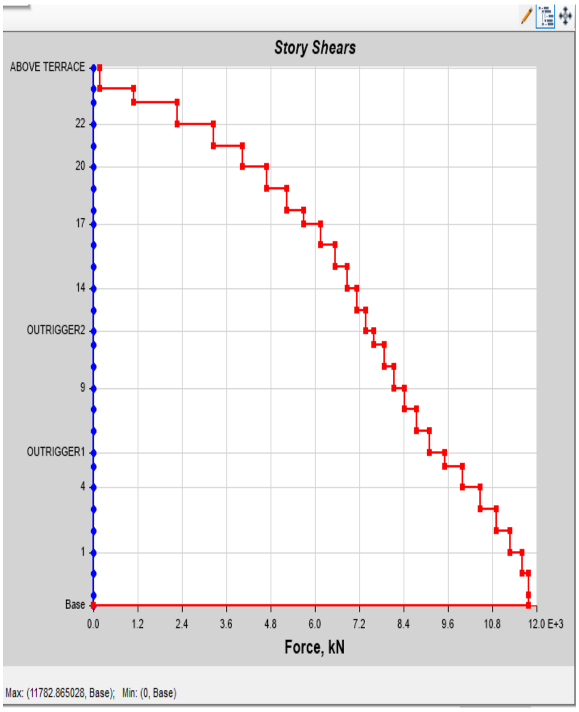
Fig 5.34 Base Shear for zone III Offset Outrigger system



a) Base Shear X direction(Fig-34)



a) Base Shear X direction



(c) Base Shear Y direction

Fig 5.34 Base Shear for zone IV Offset Outrigger system

3.2 Discussion of result

In this study a B+G+ 24 structure was analysed.

- Conventional system includes dead load, live load and dynamic (Response spectrum and Time history analysis) earthquake loading.
- Outrigger system includes dead load, live load and (Response spectrum and Time history analysis) dynamic earthquake loading.
- Offset Outrigger system includes dead load, live load and (Response spectrum and Time history analysis) dynamic earthquake loading.

All the above three models were checked for displacement, story drift, time period and base shear for zone II, zone III and zone IV. The comparison between them was drawn and following results were obtained.

A. Displacement

From the results of displacement, it is noted that the maximum reduction in lateral displacement for response spectrum in Zone IV is seen in Outrigger system for 25.834% in X direction and 25.80% in Y direction. For linear Time history analysis Outrigger system and Offset Outrigger system shows a reduction in lateral displacement by 14.790% and 14.33% in X direction. For linear Time history analysis, the Outrigger system shows a reduction in lateral displacement by 14.389% in Y direction and Offset Outrigger system shows a reduction in lateral displacement by 16.110% in Y direction. By considering both the X and Y directions it is concluded that Outrigger system gives the best results for reducing the displacement for response spectrum. Outrigger and Offset Outrigger system gives best results for reducing the displacement for Time History Analysis.

B. Time period

From the graphs and tables of time period in the results section it is clearly observed that the Offset Outrigger system has reduced the maximum amount of time period. It is noted that in Offset Outrigger system the time period of the building was reduced by about 14.773%. Hence Offset Outrigger system is most effective in handling the lateral loads and reducing the time period of the building.

C. Base shear

Since base shear value directly proportional to weight of the building, the regular model is having fewer loads compared to other models. It is observed from the graphs and tables that the results of analysis the Outrigger and Offset Outrigger system showed a slight increase in the base shear in all zones. The increase in the base shear of Offset Outrigger is 5.337% and 5.745% for Outrigger system compared to Conventional system in Zone IV.

D. Story drift

From the results of drift, it is noted that the maximum reduction in lateral drift for response spectrum for Zone IV is seen in Outrigger system for 17.72 % in X direction and 23.27 % in Y direction. For linear Time history analysis, the Outrigger system in Zone IV shows a reduction in drift by about 8.411% in X direction and increase in drift by 12.745% in Y direction.

From the results of drift, it is noted that the reduction in lateral drift for response spectrum for Zone IV is seen in Offset Outrigger system for 4.6 % in X direction and 14.11 % in Y direction. For linear Time history analysis, the Outrigger system in Zone IV shows a reduction in drift by about 0.23% in X direction and increase in drift by 11.91% in Y direction.

4. CONCLUSION

By considering all the models and their behaviour in dynamic earthquake loading. It is concluded that Outrigger gives the most suitable results. As it tends to reduce the lateral displacement and story drift in both X and Y direction by a good margin.

Scope for future works

- In this study a B+G+24 structure was considered and the same study can be carried out in high rise building.
- In response spectrum, Three zones were considered and soil type as II. Other soil types can be taken and a future study can be carried out.
- With the help of accurate data the same model can be subjected to time history analysis in the future

and the behaviour of all the models can be re-evaluated.

- Steel bracing can be used for outrigger system.
- Arrangement, and location of Outrigger bracing can changed and evaluation can be done for the same.

5. REFERENCES

1) Vahid Mohsenian (2020) "Seismic performance evaluation of deficient steel moment-resisting frames retrofitted by vertical link elements"
2) P. Castaldo (2020) Seismic performance of an existing RC structure retrofitted with buckling restrained braces .
3) Mingke Deng(2019) "Shaking table tests of a half-scale 2-story URM building retrofitted with a high ductility fiber reinforced concrete overlay system".
4) Hyunsu Seo (2018) "Optimal seismic retrofitted RC column distribution for an existing school building".
5) I.E.J. Henderson(2016) "Dynamic behavior of steel-concrete composite beams retrofitted with various bolted shear connectors"
6) G. Navya, Pankaj Agarwal(2016) Seismic Retrofitting of Structures by Steel Bracings
7) Franchise Pardo-Bosch (2019) key aspects of building retrofitting
8) Gabriele Milani, et.al (2 February 2018) . Alternative retrofitting strategies to prevent the failure of an under designed reinforced concrete frame.
9) Charu Gupta, et.al (Mar-2016) . Review Paper on Retrofitting of RCC Beam Column Joint Using Ferro cement.
10) Saeid Tarfan, et.al (October 2018) . Probabilistic seismic assessment of non-ductile RC buildings retrofitted using pre-tensioned aramid fiber reinforced polymer belts.
11) Trishna Choudhurya, (2019) Treatment of uncertainties in seismic fragility assessment of rc frames with masonry infill walls.
12) Marko Marinkovića (2019) Innovative decoupling system for the seismic protection of masonry infill walls in reinforced concrete frames.
13) Hamood Alwashalia (2019) Experimental investigation of influences of several parameters on seismic capacity of masonry infilled reinforced concrete frame.
14) Daniele Perronea (2019) Probabilistic estimation of floor response spectra in masonry infilled reinforced concrete building portfolio.
15) N. Krishna Raju (2005) Advanced reinforced concrete design, 2nd edition, as per IS 456:2000, CBS publishers and distributers pvt.Ltd.
16) IS 456 -2000, Plain and reinforced concrete - Code of practice, Bureau of Indian Standards, New Delhi.
17) IS 875 (Part 1, 2, 3): 1987, Code of practice for design loads (other than earthquake for buildings and structures): Dead, Imposed loads, Wind loads, Bureau of Indian Standards, New Delhi.
18) IS 1893-2016 Criteria for earthquake resistant design of structures.

BIOGRAPHIES

Gufran Safi Baig, Completed Bachelor degree in Civil Engineering from Don Bosco Institute of Technology Bengaluru, Karnataka under VTU in the year 2019, Presently pursuing M. tech in Structural Engineering in Ghousia College of Engineering, Ramanagara, Karnataka, Under VTU. Also working on this topic for the dissertation under the guidance of Mr. Khalid Nayaz khan and Dr. N S Kumar.

Mr. Khalid Nayaz Khan,
Associate Professor Dept. of Civil Engineering GCE, Ramanagaram 562159. He has a teaching experience of 35 years. Has published about 17 papers in various journals Also working on this topic for the dissertation under the guidance of Khalid Nayaz khan and Dr. N S Kumar

Dr. N S Kumar, Graduated in the year 1985 from Mysore University, M.E. in Structural Engineering., in the year 1988 from Bangalore University and earned his PhD from Bangalore University during the year 2006 under the guidance of Dr. N Munirudrappa, the then Chairman and Prof. UVCE, Faculty of Civil Engineering, Bangalore University. Presently, working as Prof. & HoD, Department of Civil Engineering, Ghousia College of Engineering, Ramanagaram and completed 31 years of teaching. He is involved in the Research field related to the behaviour of Composite Steel Columns and

Nano Materials for a decade. To his credit, over 150 publications, and travelled abroad for his research presentations including world conferences too. Also, more than 3PhD's completed and ongoing 5 are working under his guidance. Also, authored more than 8 books to his credit.