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Comparative Study on Conventional Outrigger and Virtual Outrigger on RC High Rise Structure under Earthquake Load

Nishit Shah[1], Prof.N.G.Gore[2]

1(Department of Civil Engineering, MGM's College of Engineering & Technology, Kamothe, Navi Mumbai)

2 (Department of Civil Engineering, MGM's College of Engineering & Technology, Kamothe, Navi Mumbai)

Abstract:

The development in tall buildings has evolved rapidly in recent years. Population from rural areas is migrating in large numbers to metro cities. Due to this, metro cities are getting densely populated in recent years. As population is getting denser the availability of land is diminishing and cost is also increasing. Hence to overcome these problems multi-storey buildings is most prominent and efficient solution.

Outrigger system is used to control the deflection of the structure under earthquake load. It is a beam or truss or girder which connects the core of the building and the exterior column of the building. Virtual outrigger is the type of the outrigger system, which connect only exterior columns of the structure. In this study, it shown that using the outrigger system in high rise building with the optimum position it reduces the deflection, story drift and time period effectively. The virtual outrigger can also reduce the displacement, story drift, time period and base shear. Increase the depth of virtual outrigger it gives the more efficient results as compare to conventional outrigger.

Keywords — **High rise building, Conventional outrigger, Virtual outrigger, Dynamic Analysis, Story Displacement, Story Drift**

I. INTRODUCTION

In developing country like India tall buildings could be effectively used to meet the demands of the technologically advancing society of our generation and solve the problem of limited availability of land for construction and is most suitable option. Many numbers of multi-storey buildings have come up in India.

Conventionally tall buildings are built for the function of commercial office, hotels, and shopping malls, suburban. Development in tall buildings involves various compound aspects for example money matters, requirements, technology, construction regularities and so on. The challenges are more for the designer as the height of the building and building plan becomes complex. Adequate and economical tall buildings cannot be designed without taking into account the detailed forbearing of denoting factors that affect for the selection of structural system for tall buildings. Self-weight of the building, live load acting, and earthquake loads and along with wind forces are significant factors and play major role in the design.

A. Lateral Load Resisting System:

Following are the lateral load resisting system which can be used in tall building to control the deflection or story drift,

- Rigid frame system
- Braced frame system
- Shear wall frame system
- Outrigger system
- Tube system

a. Frame tube system
b. Braced tube system
c. Bundled tube system
d. Trussed tube

- Diagrid Frame

B. Need for the Present Study:

Increase in the height of the building, affects the stiffness of the building. When the lateral load acts on building, it increases the deflection and drift of the structure. To control the deflection and drift, building should be strong enough to control the lateral load. Outrigger is the one of the structural system that can be used in tall building to control the lateral load. Outrigger is a beam or truss or girder which connects the core of the building and the exterior column of the building. There are many researchers who have studied on performance and behaviour of the conventional outrigger system but very few researches has done in virtual outrigger. Researchers have carried out analysis by taking the static and dynamic behaviour of the building under the elastic limit. Nowadays, due to advances in software and technology we can analyse building under non-linear dynamic method i.e. Response spectrum method and time history method.

C. Objective of Present Work:

The main focus of this study is introducing the virtual outrigger system in high rise structure and study the behaviour of virtual outrigger structure under earthquake loads.

1. To study the needs of high rise buildings in India and analysis the problems on high rise buildings under the lateral loads.
2. To study the various lateral load resisting systems, to control the lateral displacement in high rise structure
3. To study the concept of outrigger structure and its utilizations.
4. To develop the model of structure in finite element software call ETABs 15.0 with taking three different height of the structure G+40 and G+50
5. Analyze the structure by static equivalent method, response spectrum method and time history method under the earthquake load in zone iv
6. To compare efficiency of Virtual Outrigger to Conventional outrigger in RC tall building terms of base shear, story drift, Displacement and base Moment

II. LITERATURE REVIEW:

P.M.B. Raj kiran Nanduri et. al., investigated, the use of outrigger with belt truss in high rise building increases the stiffness of the building and makes the structure efficient under the lateral load. The maximum drift has reduced by using the outrigger with belt truss but it has shown nearly the same result when outrigger without belt truss. **In 2009, N Herath et al. studied,** the location of the outrigger beam has a critical influence on the lateral behaviour of the structure under the earthquake load and the optimum outrigger locations of the building have to be carefully selected in the building design. The behaviour of a structure under the earthquake load is different from earthquake to earthquake. The optimum position of the outrigger is between the 0.44-0.48 times of the height of the bilging from bottom of the building. **In 2012,Abbas haghollahi presented a study on** outrigger locations in steel tall buildings subjected to earthquake load. It conclude that, The analysing the two different storey models under the response reduction method, the optimum location of the outrigger in building was 0.44 and 0.5 from top of the building and by time history method 0.3 and 0.36 from top of the building. Shivacaran **K. et.al., May-2015, investigated,** Vertical Irregular building is more effectual than regular building as the vertical floor irregularity reduces the self weight of the building, but at same time it reduces the stiffness of the structure. The uses of the outrigger with belt trusses it's given the stiffness of the structure and resists the lateral load. Outrigger at 0.67h and 0.5 h (h is the height of the building) shows the maximum % of reduction in drift and deflection. **In August 2015, Vijaya kumara gowda M R and Manohar B C carried out a study on** dynamic analysis of tall structure under the different seismic zones. The study conclude that, The usage of the belt truss system or virtual outrigger system in building plays the important role in increasing the structural stiffness by reducing the base shear under the earthquake and wind load. Concrete belt truss is more efficient in reducing the lateral displacement and storey drift with shear core. In high seismic active region such as zone III, IV, V belt truss with central shear core plays the significant role to reduce the lateral displacement and storey drift. Different type of the belt truss was used but inverted 'V' shape belt truss is best for all seismic zones.

III. OUTRIGGER SYSTEM:

Outriggers are firm horizontal structures designed to mend building overturning stiffness and strength by connecting the building core shear wall to the distant column. Outrigger system for tall buildings has been used for narrow and tall buildings to provide resistance to lateral loads

A. Type of Outrigger System:

There are two types of outrigger system,

1 Conventional outrigger concept
2 Virtual outrigger Concept

1. **Conventional Outrigger:** 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. The outrigger trusses, which are connected to the core and to columns outboard of the core, restrain rotation of the core and convert part of the moment in the core into a vertical couple at the columns.

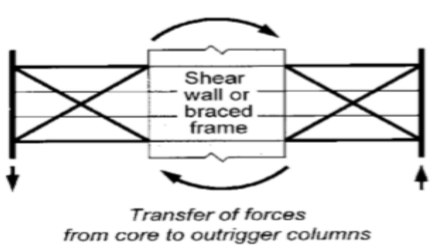

Fig.1 Force Transfer in Conventional Outrigger
(Source: R.Shankar Nair)

2. **Virtual Outrigger:** In the "virtual" outrigger concept, the same transfer of overturning moment from the core to elements outboard of the core is achieved, but without a direct connection between the outrigger trusses and the core. The elimination of a direct connection between the trusses and the core avoids many of the problems associated with the use of outriggers. The basic idea behind the virtual outrigger concept is to use floor diaphragms, which are typically very stiff and strong in their own plane, to transfer moment in the form of a horizontal couple from the core to trusses or walls that are not connected directly to the core. The trusses or walls then convert the horizontal couples into vertical couples in columns or other structural elements outboard of the core. Belt trusses and basement walls are well suited to use as virtual outriggers.

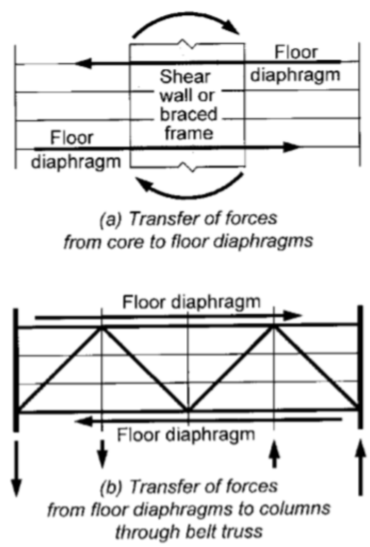

Fig.2 Force Transfer Using Belt Truss as Virtual Outrigger
(Source: R.Shankar Nair)

B. Problems with Outrigger Systems:

1. The space occupied by the outrigger trusses (especially the diagonals) places constraints on the use of the floors at which the outriggers are located. Even in mechanical- equipment floors, the presence of outrigger truss members can be a major problem.
2. Architectural and functional constraints may prevent placement of large outrigger columns where they could most conveniently be engaged

by outrigger trusses ex- tending out from the core.

3. The connections of the outrigger trusses to the core can be very complicated, especially when a concrete shear- wall core is used.
4. In most instances, the core and the outrigger columns will not shorten equally under gravity load. The outrigger trusses, which need to be very stiff to be effective as outriggers, can be severely stressed as they try to restrain the differential shortening between the core and the outrigger columns. Elaborate and expensive means, such as delaying the completion of certain truss connections until after the building has been topped out, have been employed to alleviate the problems caused by differential shortening.

IV. PROBLEM FORMULATION:

Based on literature study, the problem formulation is prepared for studying the problems and deciding the approach and parameters for analysis. It is very important to develop a computational model on which linear / non-linear, static/dynamic analysis is performed. Three dimensional models are to be prepared using Finite Element based software's, such as ETABS 15.0 the software specially designed for design and analysis of three dimensional building frames.

A. General Data for Model:

TABLE I

Structure	Reinforced concrete structure
Plan	Rectangular (Actual Plan)
Frame type	SMRF
Floor Height	3.5m
Model Height	G+40 storey G+50 storey
Column size	G+40 – 700x700mm G+50 – 800x800mm
Beam size	G+40 – 300x600mm G+50 – 350x750mm
Slab thickness	150mm
Shear wall	500mm thik
Outrigger beam	500x500x25mm (steel Box Section
Grade of concrete	M30 – Beam M70 – Column and shear wall
Steel grade	FE415 & Fe490
Seismic zone	IV

B. Structural plan (model):

The plan is in rectangular in shape and size of plan is 56x25m. It is modelled in Etabs 15.0.

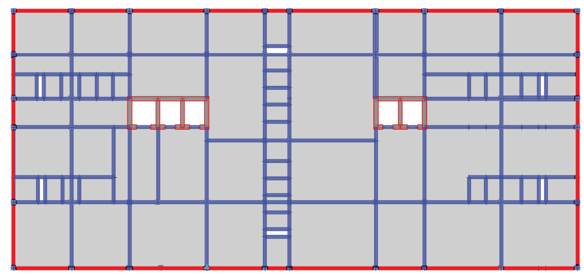

Fig.3 Position of Virtual Outrigger

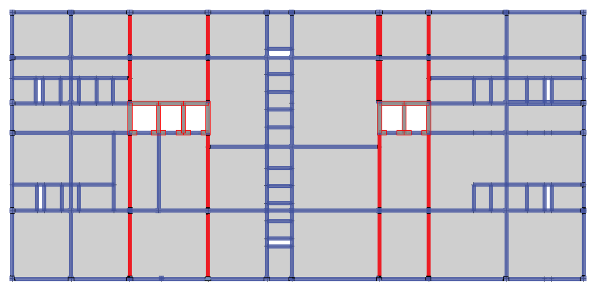

Fig.4 Position of Conventional Outrigger

4.3 Model Configuration:

TABLE II

Sr. No.	Model Name	Outrigger Location
For G+40 Storey		
1	G+40-I without outrigger	---
2	G+40-II with virtual outrigger	At 1H,0.7 and 0.4 H
3	G+40-III with conventional outrigger	At 1H,0.7 and 0.4 H
For G+50 Storey		
4	G+50-I without outrigger	---

5	G+50-II with virtual outrigger	At 1H,0.7 and 0.4 H
6	G+50-III with conventional outrigger	At 1H,0.7 and 0.4 H

Location of outrigger is a optimum location of outrigger after analysing different combination of outrigger location in building.

D. Method of Analysis:

1. Static analysis
2. Response spectrum analysis
3. Time history

V. RESULTS AND DISCUSSION:

1. Time Period: Time period is the natural period of the building with undamaged zero vibration. For calculating time period there are two method, first is by using formula Ta=0.075H0.75 per the IS code 1983(part 1) 2002 and second is by modal analysis. Increasing the stiffness of the structure it decreases the time period of the structure.

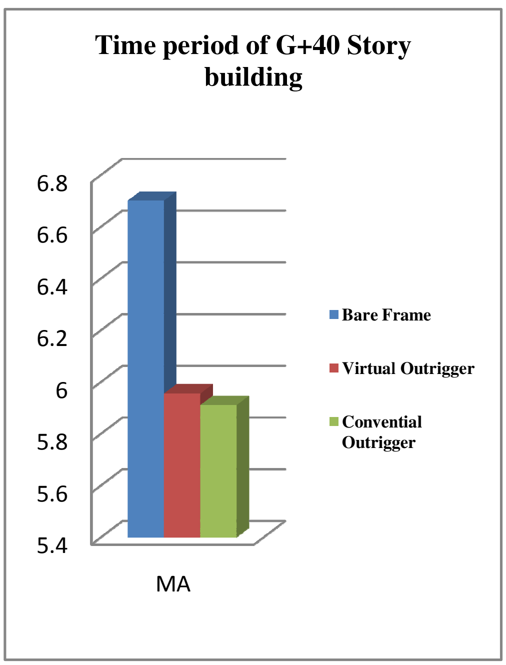

Fig. 5 Time period of G+ 40 stories Building by Modal Analysis method

After modal analysis for 40 stories building, there is 11% reduction in time period of building by using the virtual outrigger. Comparing the virtual outrigger to conventional outrigger it shows only 1% of reduction in time period.

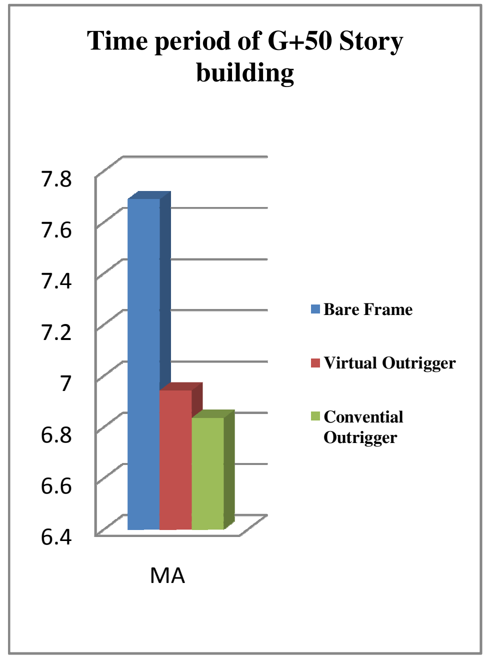

Fig. 6 Time period of G+ 50 stories Building by Modal Analysis method

After modal analysis for 50 stories building, there is 11% reduction in time period of building by using the virtual outrigger. Comparing the virtual outrigger to conventional outrigger it shows only 2% of reduction in time period.

2. Story Displacement: When the lateral load say earthquake load act in building, building deflect it original position. More flexible building it will be more displacement. As per IS 456:2000 building or structure should not be deflect H/250 (where H is the total height of the building).

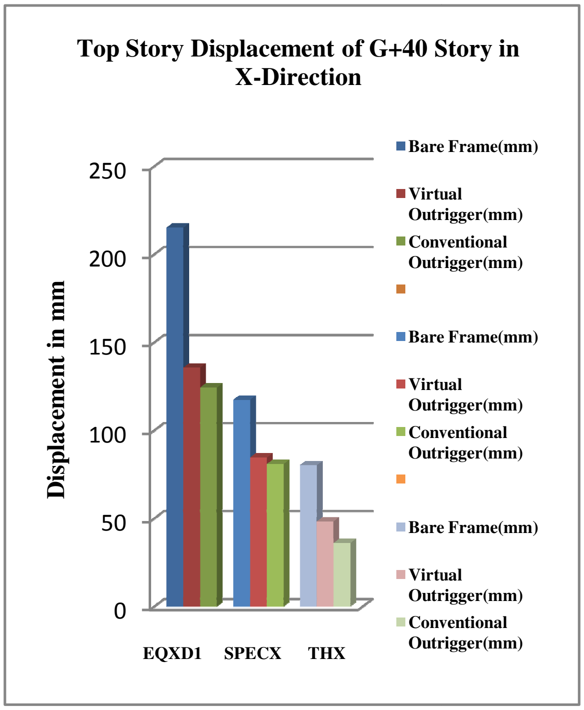

Fig.7 Top Story displacement of G+ 40 stories building in X-direction

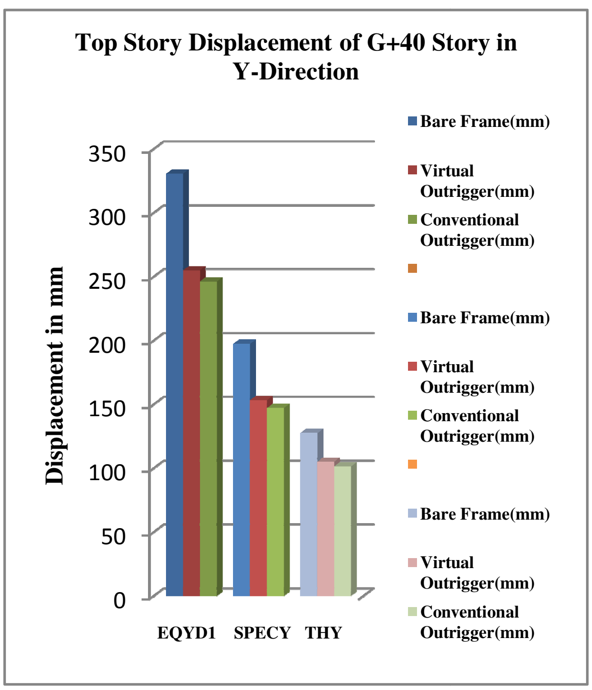

Fig.8 Top Story displacement of G+ 40 stories building in Y-direction

Fig. 8 & 9 represent the top story displacement of G+40 story building in X and Y direction respectively. In X-direction, using conventional outrigger maximum reduction of displacement is 42%. While Virtual outrigger it is 37%. In Y-direction, using conventional outrigger maximum reduction of displacement is 26%. While virtual outrigger it is 23%.

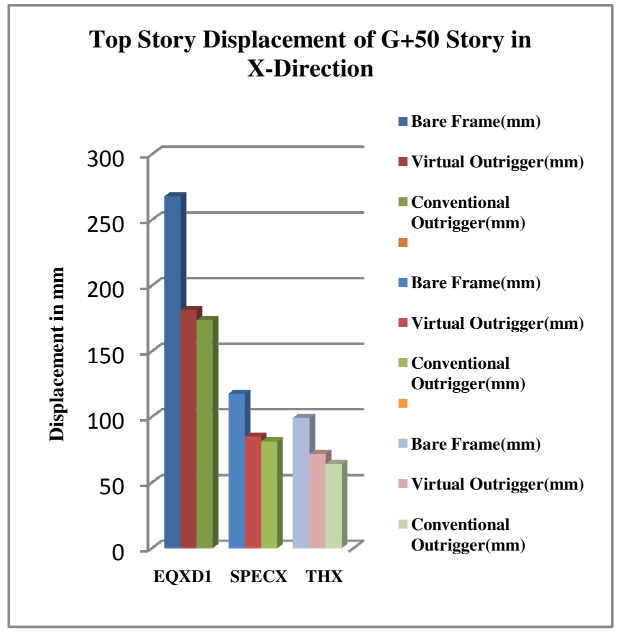

Fig. 9 Top Story displacement of G+ 50 stories building in X-direction

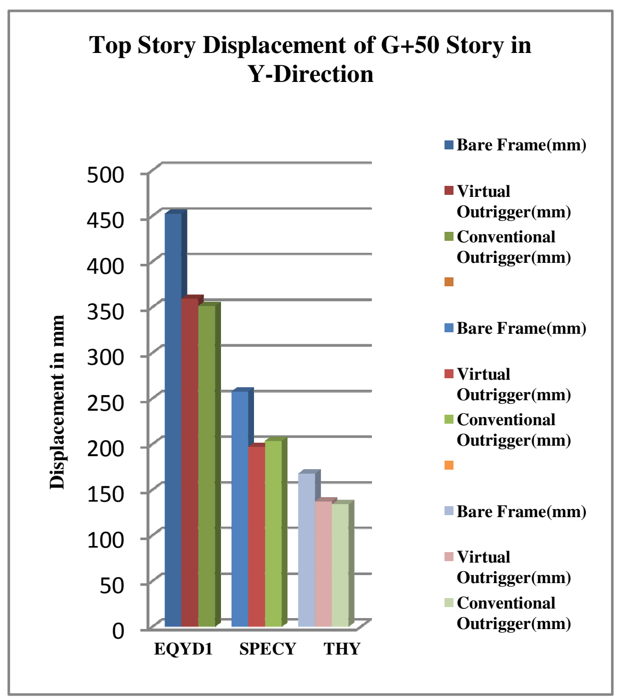

Fig. 10 Top Story displacement of G+ 50 stories building in Y-direction

Fig.9 & 10 represents graph of the top story displacement of G+ 50 stories building in X-direction. In X-direction, using conventional outrigger maximum reduction of displacement is 35%. While Virtual outrigger it is 32%. In Y-direction, using conventional outrigger maximum reduction of displacement is 22%. While virtual outrigger it is 21%.

3. Story Drift: It is the displacement of one level relative to the other level above or below. According to Clause7.11.1 of IS 456:2000, the maximum allowable drift is 0.04h. Where h is the story height.

Fig. 12, 13&14 represents Graph of the max. story drift of G+40 story building with respect to X direction for the different method of analysis. In the graphical representation it has clearly shown that where the outrigger has located in there more that 40%-50% of reduction in story drift has occurred.

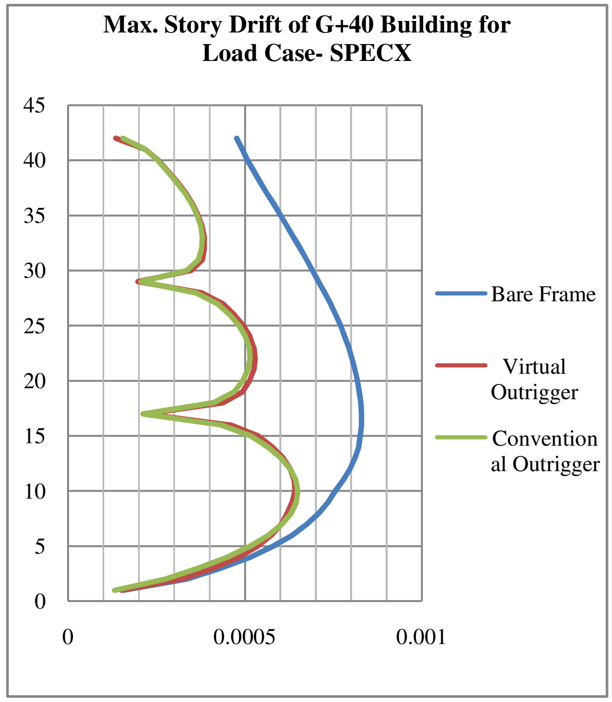

Fig.12 Story v/s Story drift of G+ 40 stories building for load case SPECX

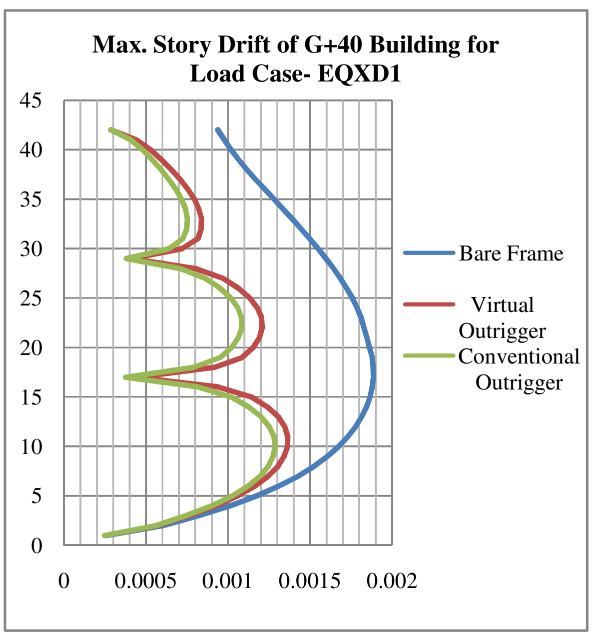

Fig.11 Story v/s Story drift of G+ 40 stories building for load case EQXD1

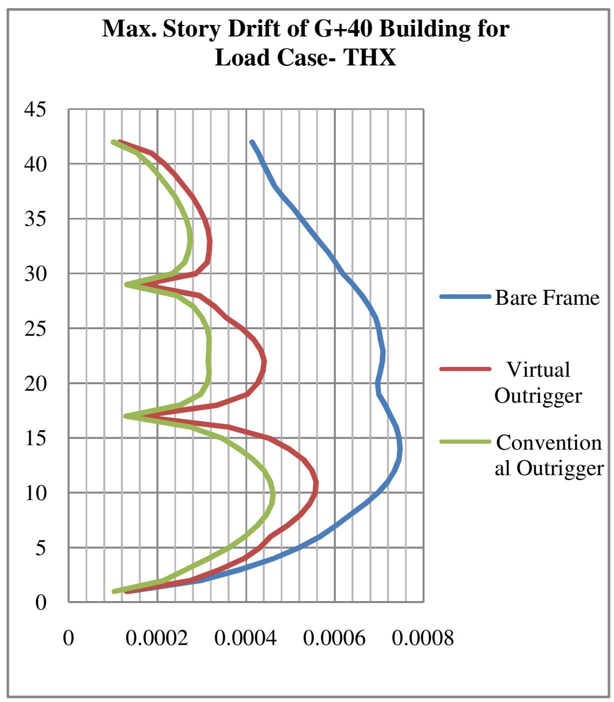

Fig.13 Story v/s Story drift of G+ 40 stories building for load case THX

VI. CONCLUSION:

After studying, it concluded that by using the outrigger system, it has given the effective results in building displacement, drift and moment of the structure. The following conclusions are made from the present study.

1. The use of outrigger system in high rise structure increases the stiffness of the structure and decreases the flexibility of the structure. Also make structure more efficient under earthquake loads
2. In this study, it conclude that the Virtual Outrigger system can also reduce the displacement, drift, base shear and base moment of structure which are the prime aspect of design the tall buildings.
3. It has observed that placing the virtual outrigger at 1H, 0.7H and 0.4H give the maximum results in story displacement and story drift.
4. Overall maximum 35% to 39% of displacement reduces in X-direction and 22% to26% in Y-direction after placing three outriggers at 1H, 0.7H and 0.4H location in the building. H= Total Height of a building.
5. More than 50% of story drifts reduction observed in the building where an outrigger has placed.
6. There is no significant changes have seen in base shear and base moment after incorporating the virtual outrigger.
7. Using the outrigger in building it reduces the time period of the building. Maximum 11% of the reduction in time period has observed by using virtual outrigger.
8. Comparing the virtual outrigger to convention outrigger, it shows that virtual outrigger results are around the conventional outrigger results particularly in this plan. The conventional outrigger is little good to virtual outrigger.
9. It can conclude that Instated of using the Conventional Outrigger, Virtual outrigger can also be used because of its own advantages.

REFERENCES

1. P.M.B. Raj Kiran Nanduri, B.Suresh, Md. Ihtesham Hussain(2013), Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings Under Wind And Earthquake Loadings, American Journal of Engineering Research (AJER).
2. N. Herath, N Haritos, T. Ngo and P. Mendis,'Behaviour Of Outrigger Beams in High Rise Buildings Under Earthquake loads, Australian Earthquake Engineering Society 2009 Conference
3. Abbas Haghollahi,'Optimization of outrigger locations in Steel Tall building Subjected to Earthquake load.
4. Shivacharan K, Chandrakala S, Narayana G, Karthik N M(2015), Analysis of outrigger system for tall vertical irregularities structures subjected to lateral loads, IJRET: International Journal of Research in Engineering and Technology
5. Vijay Kumara Gowda M R, Manohar B C,'A Study On Dynamic Analysis Of Tall Structure With Belt Truss Systems For Different Seismic Zones, International Research Journal Of Engineering And Technology (IRJET).
6. Indian standard code IS code 456-2000 for Reinforced Concrete Structure.
7. IS code 1983-2002 part 1 Earthquake load
8. IS code 875 part-1, 2, 3
9. A - Earthquake Codes IITK-GSDMA Project on Building Codes