

“THE EFFICIENT USE OF A OUTRIGGER AND BELT TRUSS IN TALL BUILDINGS”

Nilesh B Mahale¹, Pallavi Pasnur², Navnath Khadake³

1PG Student, Civil Engineering Department, JSPM's ICOER Wagholi, Pune 412207, Maharashtra, India

2 Assistant Professor, Civil Engineering Department, JSPM's ICOER Wagholi, Pune 412207, Maharashtra, India,

3Professor and Head, Civil Engineering Department, JSPM's ICOER Wagholi, Pune 412207, Maharashtra, India.

Abstract : The development of tall building, and has been rapidly growing worldwide by introducing new challenges that need to meet by engineering considerations and judgments. In tall buildings generally lateral loads are often resisted by a system of varied sorts of shear or core wall. But when the peak of the building increases and when some irregularities are present in buildings, the stiffness of building is reduced. So the introduction of outrigger beams and its position in tall buildings with shear walls are wont to provide sufficient lateral stiffness to the structure. This paper is about the behaviour of tall buildings with and without outriggers, its location, optimization and the efficiency of outrigger for tall buildings under earthquake load conditions. A g+15 storey with single belt truss, g+30 storeys with two belt trusses and g+40 storey with three belt trusses structure are investigated with three different shape outrigger belt trusses that are X, V and N. From the analysis a comparative study is made with and without variation of shape of outrigger with belt truss with parameters likes storey displacement and storey drift under earthquake loading and get an optimum position of outrigger belt truss by using ETABS Software.

Keywords: Outrigger System, Earthquake load, Optimum shape, and position of belt truss, Storey Drift, Lateral Displacement.

INTRODUCTION

1.1 General

Due to increase in demand for living space in developed and developing area leads the way to the development in construction techniques. Hence, tall buildings play an important role in the new generation of structure. The sensitivity of tall buildings against strong earthquakes and wind has increased. This has resulted in understanding the structural behavior of modern tall buildings under lateral loads. When the height of the building increase, the risk of horizontal and vertical forces also increases. The moment resisting frame or braced core wall at a specific height is insufficient to provide stiffness against lateral loads. Outrigger is provided with a shear Or core wall in tall buildings with certain height ratio to increase the stiffness and to decrease deflection against lateral loads. The outrigger and belt truss system is one among the lateral loads resisting system during which the external columns are tied to the central core wall with very stiff outriggers and belt truss at 1 or multi levels. The belt truss tied the exterior column of the building while the outriggers engage them with the main or central shear wall.

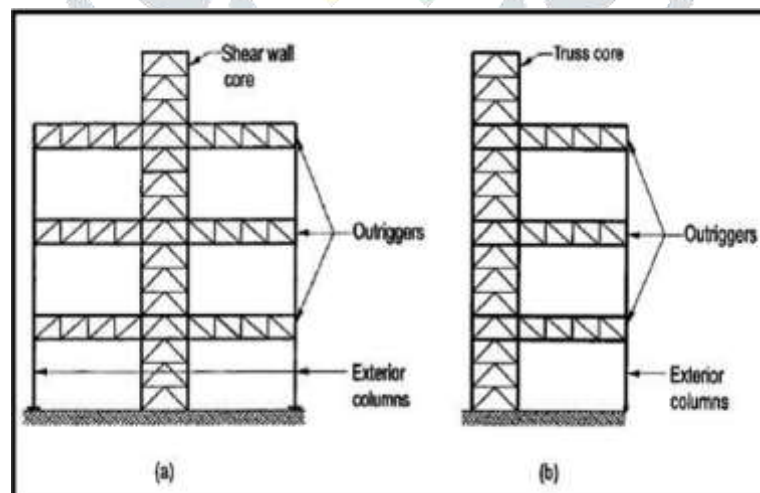


Figure 1: (a) Outrigger with a central core
(b) Outrigger system with offset core.

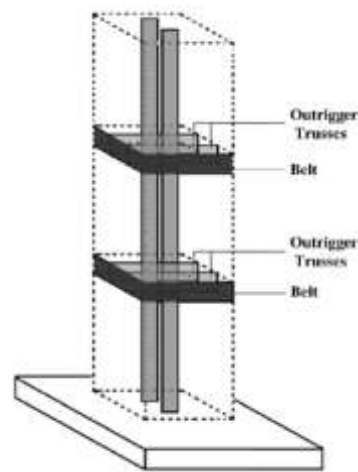


Figure 2: Tall building with conventional outriggers and belt truss.

1.2 Behaviour of Outrigger

The structural arrangement for this technique consists of a main concrete core connected to exterior columns by relatively stiff horizontal members like a 1 or two-story deep walls commonly referred to as outriggers. The core may be centrally located with outriggers extending on both, or it may be located on one side of the building with outriggers extending to the building columns on one side. The basic structural response of the system is sort of simple. Because the outrigger act as a stiff arm engaging exterior columns, when central cores tries to tilt its rotation at outrigger level induced a tension compression couple in exterior columns and acting in opposite to that moment. The result's the sort of restoring moment working on the core at that level. As a result, the effective depth of the structure for resisting bending is increased when the core bends as a vertical cantilever, by the event of tension within the windward columns, and by compression within the leeward columns. In addition to those columns located at the end of the outriggers, it's usual also to mobilize other peripheral columns to help in restraining the rotation of outriggers. This is achieved by tying the outside columns with a one- or two-story deep wall commonly mentioned as a "belt wall," round the building.

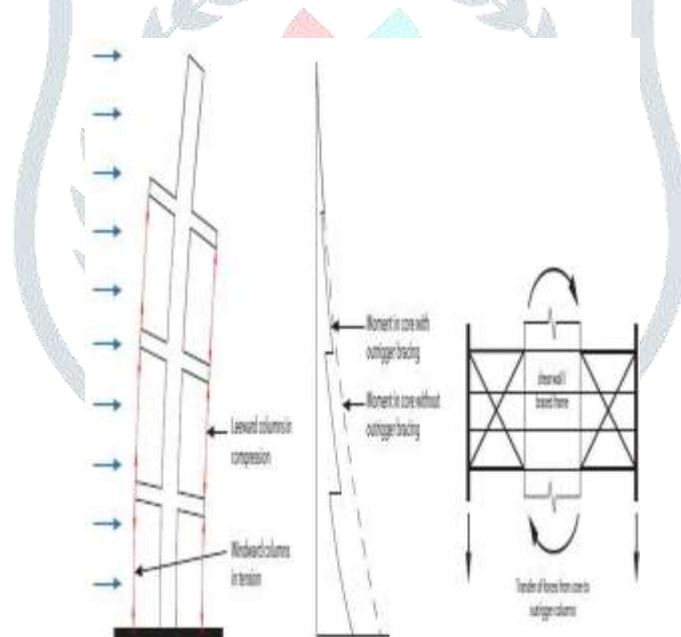


Figure 3: Behaviour of Outrigger Structural system.

1.3 Types Of Outrigger Truss System

On the idea of connectivity of core to exterior columns, this technique may be divided into two types:

Conventional outrigger concept.

Virtual outrigger concept.

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. Conventional outrigger as shown in Fig.4

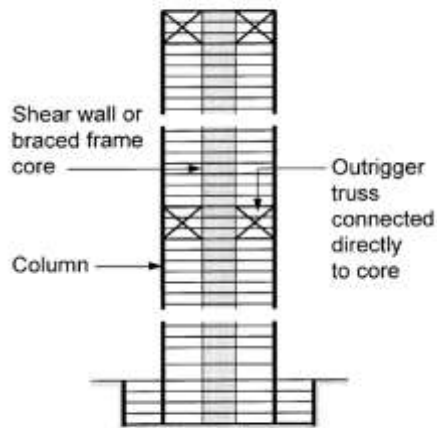


Figure 4: Tall building with conventional outriggers

2. Virtual outrigger concept

In the “virtual” outrigger concept, an equivalent transfer of overturning moment from the core to elements outboard of the core is achieved, but without an immediate connection between the outriggers trusses, and the core. The basic idea behind the virtual outrigger concept is to use floor diaphragms, which are typically very stiff and powerful in their plane.

The use of belt trusses as virtual outriggers avoids many of the issues related to the utilization of conventional outriggers. And the principle is the same as when belt trusses are used as virtual outriggers. Some fractions of the moment in the core are converted into a horizontal couple in the floors at the top and the bottom of the basement. Belt truss as a virtual outrigger as shown in Fig. 5.

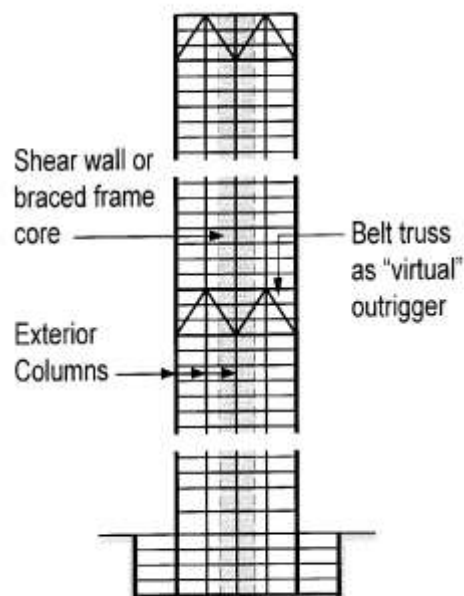


Figure 5: Tall building with belt trusses as “virtual” outriggers.

3. Factors Affecting The Effectiveness Of Outrigger System :

1. The stiffness and location of the outrigger and Belt truss system.
2. Geometry of the tall building.
3. Stiffness of the central core.
4. Floor-to-floor height of the tall building.

1. METHODOLOGY

In the present study a three-dimensional RCC building frame model of 45 m, 90 m & 120 m height having 9×8 Bay spacing of 5 m. vertically regular building, having symmetry along X and Y direction and square is considered. RCC building having concrete shear wall as a central core modeled in form of shell-thin with thickness of 400 mm and concrete slab in form of membrane with thickness of 180 mm. For the belt truss using ISA $200 \times 200 \times 12$ steel section for X, V & N type bracing in belt truss. The structure having fixed support, and every one joints designed as perfectly rigid. The floor height is assumed to be 3 m. Structure model having a different size of beams and columns, and other parameters used for the analysis are given in table no. 1 & 2. All the dimensions of the building used as per code IS 456-2000.

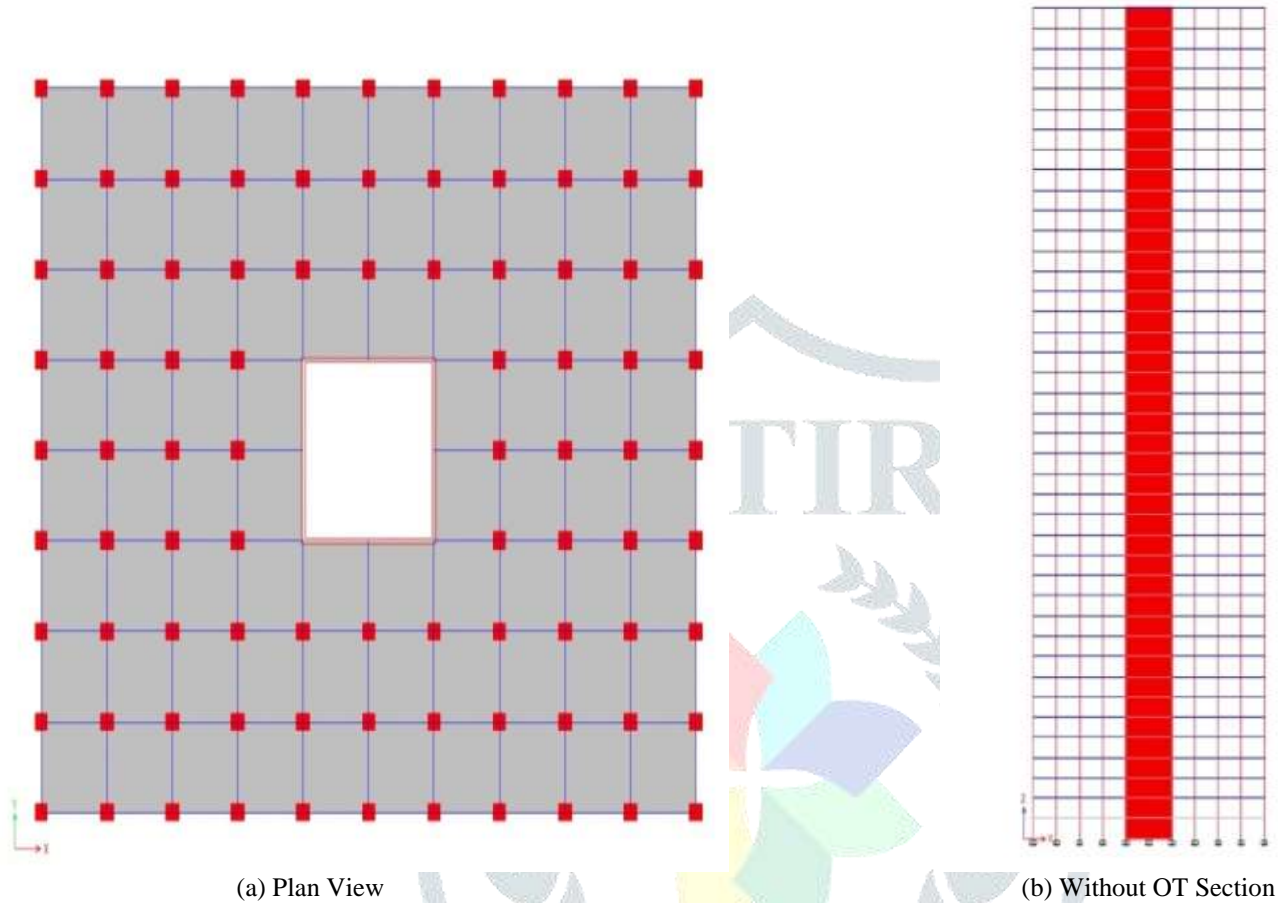
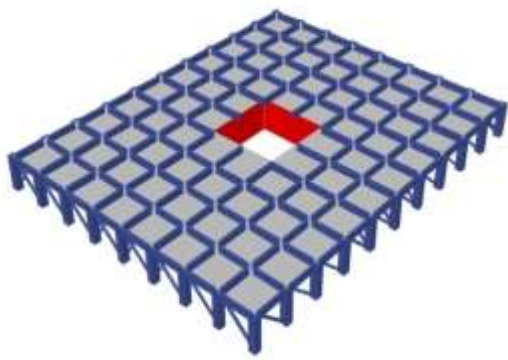


Table 1. Parameters of the Structures

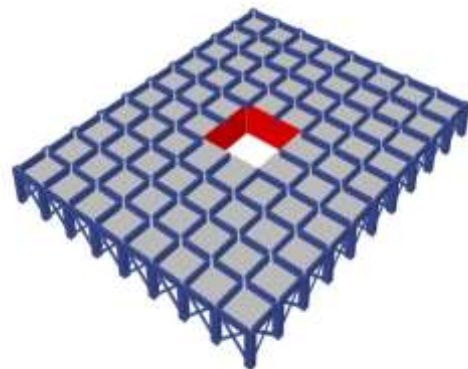
	Parameter	Value		
1	Type of Frame	Building with shear wall		
2	No. of story	G + 15 + Terrace	G + 30 + Terrace	G + 40 + Terrace
3	Floor Height	3 m	3 m	3 m
4	Length of Building	50 m	50 m	50 m
5	Width of Building	40 m	40 m	40 m
6	Column Size	600 × 600 mm	750 × 750 mm	900 × 900 mm
7	Beam Size	230 × 600 mm	230 × 600 mm	230 × 600 mm
8	Slab Thickness	150 mm	150 mm	150 mm
9	Concrete Grade			
	Wall & Column	M30	M40	M50
	Beam & Slab	M25	M30	M35
10	Reinforcement Grade	Fe 500	Fe 500	Fe 500

Table 2. Some parameters used for the analysis of building

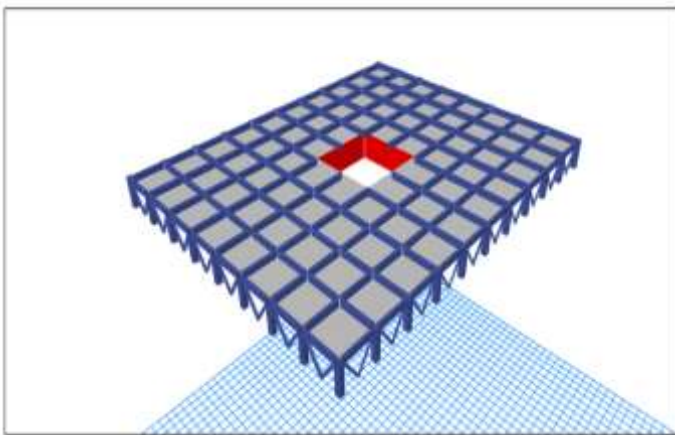
Serial No.	Particulars	Model Data
1.	Analysis Type	Response Spectrum
2.	A Software Selection	ETABs
3.	Data Analysis	Max. Displacement Value, Story Drift Rotation Value
4.	Load Pattern	Live Load, Dead Load, EQx & E _{gy}
5.	Zone Factor	III Zone (Z=0.16)
6.	Importance of Structure	1
7.	Soil Type	II (Medium)
8.	Type of Structure	RC Moment Resisting Building.



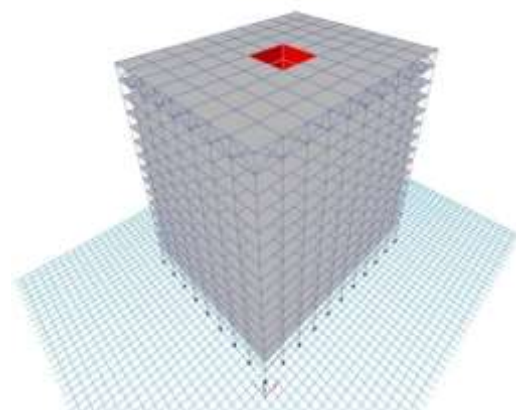
(c) N-Type Belt Truss



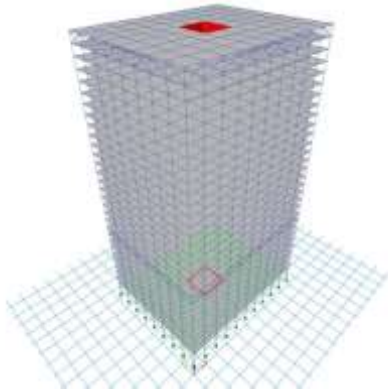
(d) X-Type Belt Truss



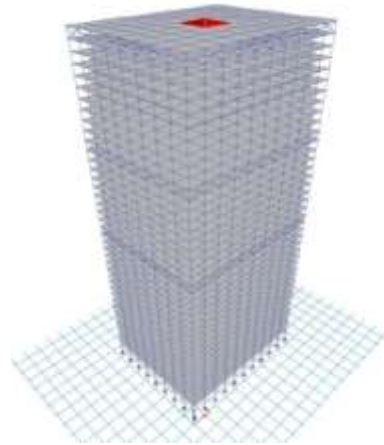
(e) V-Type Belt Truss



(f) 3D View With OT G+15 Story



(g)3D View With OT G+30 Story



(h) 3D View With OT G+40 Story

Figure 6: Building view and story plan with their details

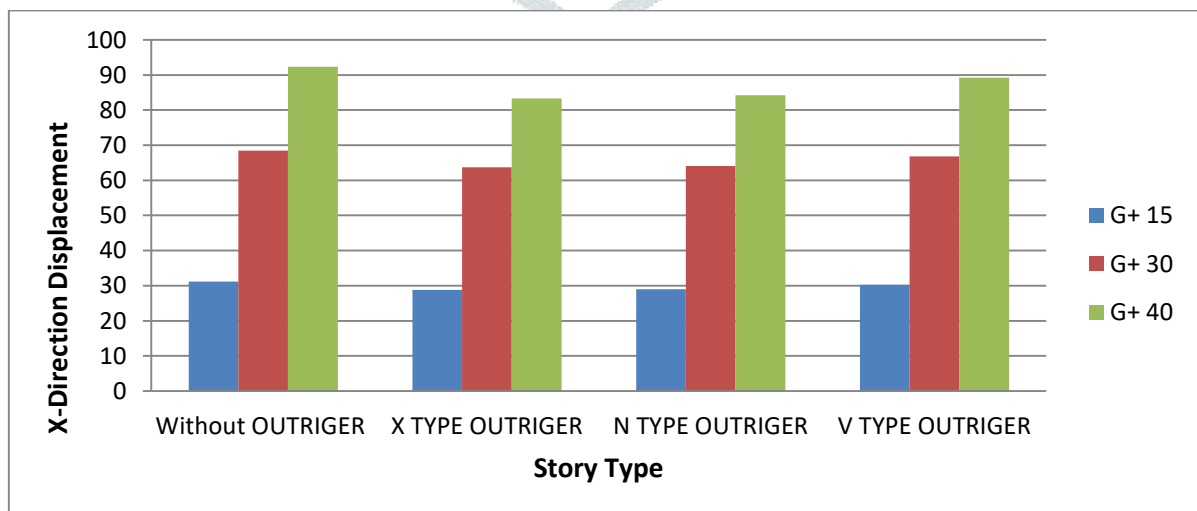
1.4 Objectives of the Project

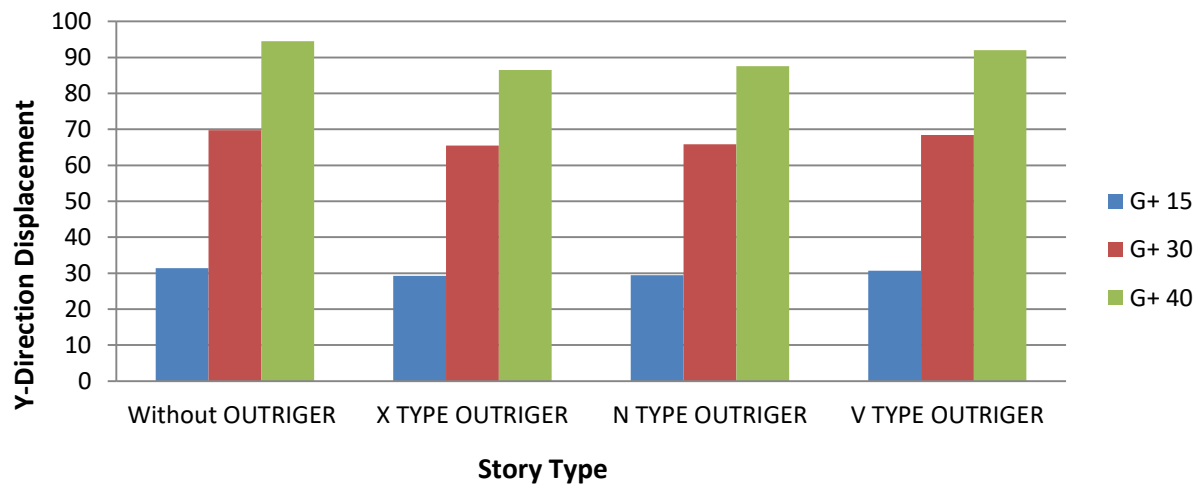
Following are the objectives of dissertation work.

1. Analysis of high rise building without the use of outriggers under earthquake loading.
2. To study the effect of the introduction of Outriggers in high rise building subjected to seismic loading.
3. Analysis with the change of shape of outrigger (X, V & N) in building.
4. The results for different outrigger positions are interpreted and conclusions are made as to which condition buildings taken in the consideration are most stable.
5. The results of different parameters such as displacement, drift, Base shears and time period are studied.
6. Reduction in drift, deflections and fundamental time period of the regular and irregular building is studied.

RESULTS AND CONCLUSION

Displacement at Terrace Level –

**Displacement in X-Direction**



Displacement in Y-Direction

Table 3. X Direction Displacement @ Terrace

X Direction Displacement @ Terrace					
DISPLACEMENT	92.312	83.32	84.223	89.24	G+ 40
	68.438	63.684	64.104	66.8	G+ 30
	31.139	28.79	28.957	30.249	G+ 15
	Without OUTRIGER	X TYPE OUTRIGER	N TYPE OUTRIGER	V TYPE OUTRIGER	Story Type

Table 4. Y Direction Displacement @ Terrace

Y Direction Displacement @ Terrace					
DISPLACEMENT	94.525	86.549	87.618	91.99	G+ 40
	69.77	65.49	65.89	68.41	G+ 30
	31.398	29.23	29.395	30.65	G+ 15
	Without OUTRIGER	X TYPE OUTRIGER	N TYPE OUTRIGER	V TYPE OUTRIGER	Story Type

Story Drift -

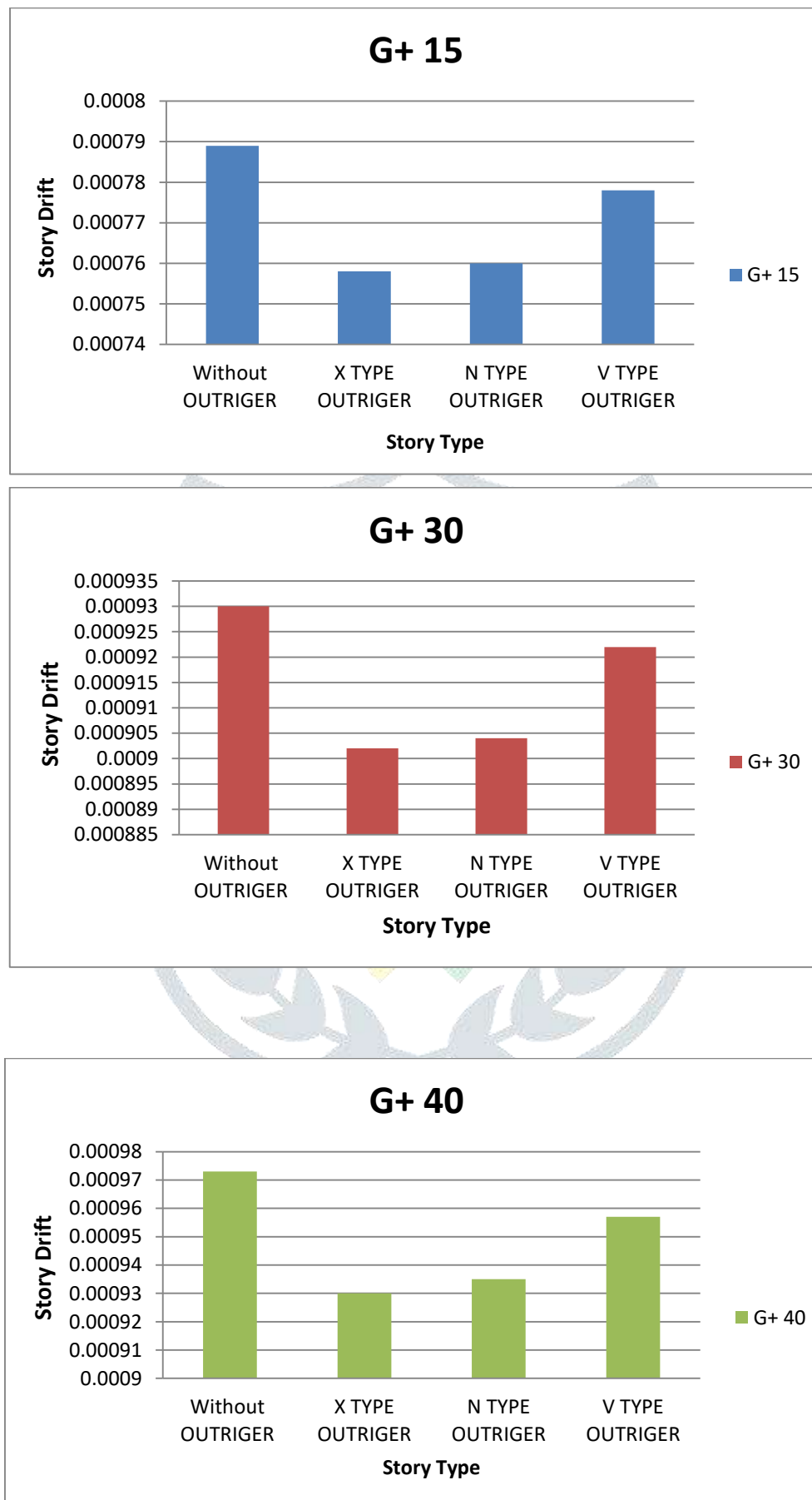


Table 5. Story Drift

STORY DRIFT					
STORY DRIFT	0.000973	0.00093	0.000935	0.000957	G+ 40
	18th story	15th story	15th story	17th story	
	0.00093	0.000902	0.000904	0.000922	G+ 30
	15th story	16th story	15th story	15th story	
	0.000789	0.000758	0.00076	0.000778	G+ 15
	9th story	8th story	8th story	9th story	
	Without outrigger	X TYPE OUTRIGGER	N TYPE OUTRIGGER	V TYPE OUTRIGGER	Story Type

Conclusion

This study evaluate the behaviour of outrigger belt truss system with change of shape of outrigger belt truss system for single outrigger belt truss system (15-story), double outrigger belt truss system (30 story) and triple outrigger belt truss system (40 story) and variation of position of outrigger belt truss system in 40 story building in which belt truss are placed in 20th story, 30th story & at top floor under seismic loads. The conclusion obtained from the above results is From above result that is from table 3, 4 & 5, for 15storey, 30-story and 40-story building we can say X-type outrigger belt truss system is more efficient than V-Shaped outrigger belt truss system and N-Shape outrigger belt system. The Variation of displacement and story drift are also varied as per the shape of outrigger & belt truss used, conclusion is for X-type outrigger belt truss system is more efficient than V and N type outrigger belt system.

- 1) The outrigger structural system has a significant influence on the global performance of the building structure, where it increases the stiffness and makes the structural configuration more efficient under lateral loads.
- 2) The outrigger system not only reduced the induced storey displacements, but also minimized the inter storey drifts ratios.
- 3) The level of outrigger has a significant role on the obtained response values under the seismic loads. Form storey displacements point of view, the optimum locations of outriggers are the mid height of the building in case of using single outrigger.

REFERENCES

- [1] Viren P. Ganatra, Prof. Rashida A. Jhummarwala& Dr. Kaushal B. Parikh, Study on Behaviour of Outrigger System on High Rise Structure by Varying Outrigger Depth- IJRASET -Volume 5 Issue IX, September 2017.
- [2] Reihaneh Tavakoli, Reza Kamgar and Reza Rahgozar Seismic performance of outrigger and belt truss system considering soil–structure interaction. International Journal of Advanced Structural Engineering (2019)
- [3] C. Bhargav Krishna, V. Rangarao Comparative Study of Usage of an Outrigger and Belt Truss System for High-Rise Concrete Buildings.IJRTE- Volume-7, Issue-6C2, April 2019
- [4] D. R shambale and A. A hamane Comparative Study of Wind Analysis of High Rise Building with Diagrid and Outrigger Structural System Using Gust Factor Method. IJNRD | Volume 3, Issue 7 July 2018
- [5] Indian standard code IS code 456-2000 for Reinforced Concrete Structure.
- [6] IS Code 1893-2016 part-I earthquake Load