# SEISMIC CONTROL AND PERFORMANCE OF IRREGULAR HIGH RISE BUILDING WITH OUTRIGGER

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**Abstract** – *We all know that the high rise buildings are more vulnerable to earthquake and wind loads. Even with this knowledge, the construction of high rise buildings goes on increasing around the globe. Higher magnitude earthquakes and wind loads may cause unfavorable vibrations or lead to serious structural damage and affect the stability. Numerous studies have been conducted by many researchers to overcome these problems in the structural behavior. From those findings, the best structural system was found to be outrigger and belt truss system. In this paper, study on static analysis of outrigger system was carried out for a 30-storeyed building with overall height of 90m. The objective is to understand the behavior of vertical stiffness irregularity in symmetrical core in comparison with asymmetrical core. Analysis is done for symmetrical and asymmetrical frames and its values are compared with that of corresponding bare frames. Thereafter, the less displacement control area is taken as the best position where outrigger and belt truss system is to be placed. In this best position, different outriggers such as V, K, X and hexagrid bracings were provided and analyzed for 30-storeyed building. Modeling and analysis was carried out using ETABS software and different parameters such as Maximum storey displacement, Maximum storey drift, storey shear was computed and tabulated separately for symmetrical and asymmetrical building.*

*Key Words*: High rise building, Outrigger and belt truss system, Static analysis, Stiffness irregularity, Symmetrical frame, Asymmetrical frame, ETABS

## 1. INTRODUCTION

The never ending human greed to reach the sky has developed far more from its historical advancements. At present the symbol of economic power and leadership is the skyscraper. The design of skyscrapers is usually governed by the lateral loads imposed on the structure. As the height of building increases, it is subjected to the action of lateral loads – seismic forces and wind forces. The outrigger concept is in widespread use today in the design of tall buildings. In this concept, "outrigger" trusses (or, occasionally, girders) extend from a lateral load-resisting core to columns at the exterior of the building. The core may consist of either shear walls or braced frames. Outrigger systems can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns to resist part of the overturning moment produced by lateral loading. There are, however, some important space-planning limitations and certain structural complications associated with the use of outriggers in tall buildings. The outriggers are generally in the form of trusses (one or two storey deep) in steel structures, walls in concrete structures that effectively act as stiff headers inducing a tension-compression couple in the outer columns. Belt trusses are often provided to distribute these tensile and compressive forces to a large number of exterior frame columns.

### 1.1 SCOPE OF STUDY

Strengthening the irregular building to determine the economic number of outriggers and optimum position of outriggers have to be provided to gain stability against earthquake loads.

### 1.2 OBJECTIVES OF STUDY

The objectives are: (i) To understand the behavior of vertical irregularity in symmetrical core in comparison with asymmetrical core buildings, (ii) To study the effect of number, position and arrangement of outriggers and belt truss system in symmetrical core and in asymmetrical core buildings. (iii) To find out the best configuration of outriggers and belt truss system for the symmetric core and asymmetric core buildings in comparison to the bare frame building. (iv) To find out the efficiency of high rise buildings with outriggers and belt truss system in terms of base shear, storey displacement, storey drift for the respective geometric configurations.

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## 2. STRUCTURAL MODELLING AND ANALYSIS

## 2.1 RESEARCH METHODOLOGY

In this research, a 30 storey building was considered having 3m of storey height. Model dimension from 1-10 storey is 7 x 7 bay, from 11-20 storey is 7 x 6 bay and from 21-30 storey is 7 x 5 bay. The spacing is 5.5m between all the bays. Total height of building was 90m. M40 grade of concrete and Fe500 steel was used in all members of structures. Size of the column was taken as from 1st and 2nd storey 800 x 800mm, from 3rd to 5th storey 700 x 700mm, from 6th to 10th storey 600 x 600 mm, from 11th to15th storey 500 x 500mm and from 16th to 30th storey 400 x 400mm. The size of beam 230 x 450mm and for outrigger beam 300 x 300 mm with belt truss was used. Slab thickness was kept 150mm and shear wall thickness is 300mm. Vertical and horizontal loads were calculated as per recommendations of IS 456, IS-1893 (Part 1) and IS-875 (Part 3). First of all comparison of performance of symmetrical and asymmetrical core building with their corresponding bare frame was drawn, then analysis was carried out on different configurations of outriggers and belt truss such as X, K, V and Hexagrid type bracing in the best displacement controlled model. The design dead load on floor slab was taken as 1kN/m² and live load acting on the floor slab was taken as 3kN/m². Mass source definition: dead load=1, floor finish=1 and live load=0.25. The design lateral load due to wind for analysis of building was calculated as per basic wind speed equals to 50 m/sec, terrain category: 3, class: B, Diaphragms: rigid as per IS: 875 (Part 3)-1987. The design earthquake load was calculated for seismic zone V-0.36, importance factor-1, medium type of soil, reduction factor-5 as per IS: 1893 (Part 1)-2002. ETABS software was used for modeling and analysis purpose, static earthquake analysis was done. Different parameters such as maximum storey displacement, maximum storey drift, storey shear was computed and tabulated separately for symmetrical and asymmetrical core buildings. The load combination of 1.2(DL+LL+FF+EQ) were tabulated.
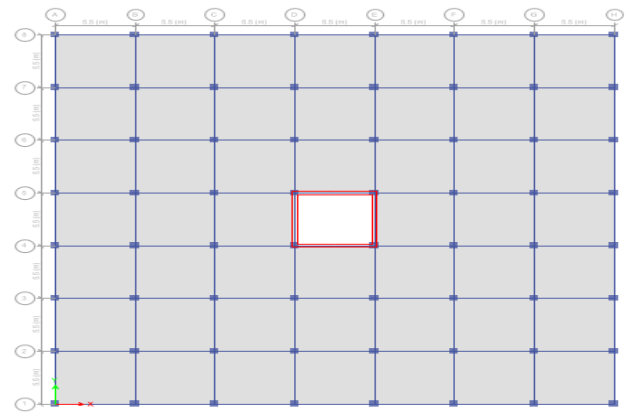


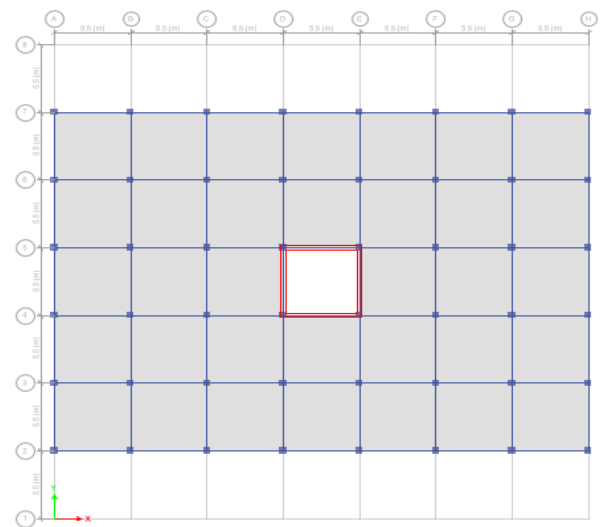Fig-1: Symmetrical core building plan from base to 10th storey



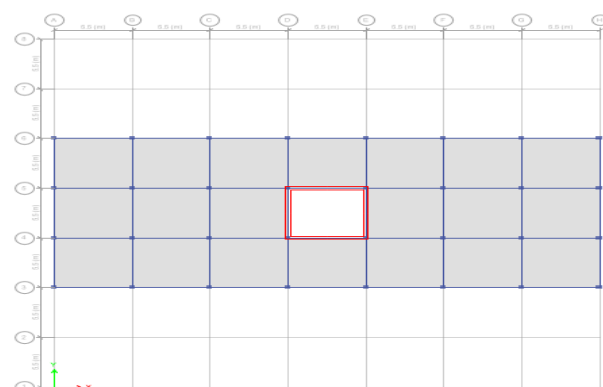Fig-2: Symmetrical core building plan from 11th to 20th storey



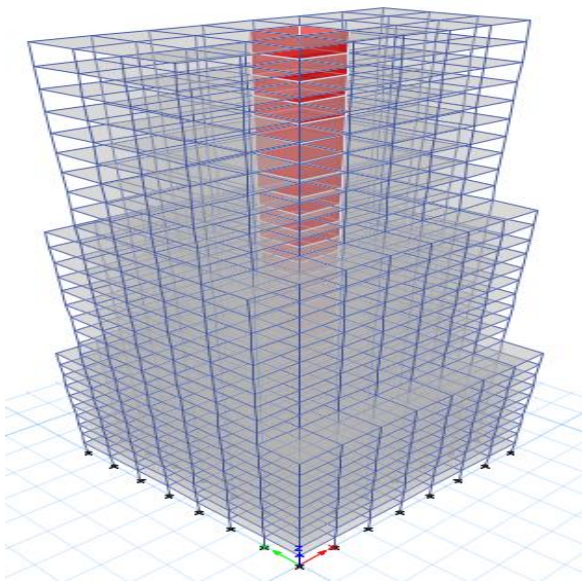Fig-3: Symmetrical core building plan from 21st to 30th storey
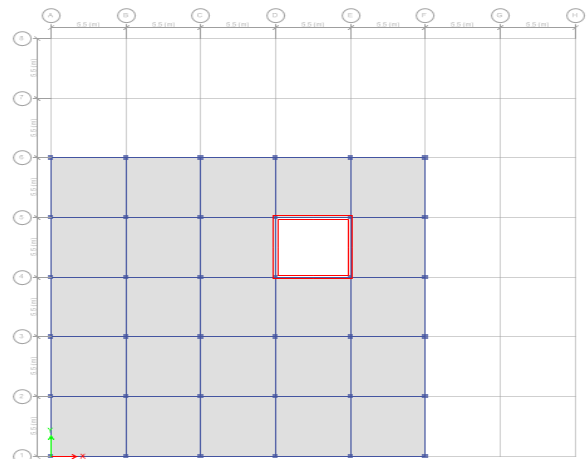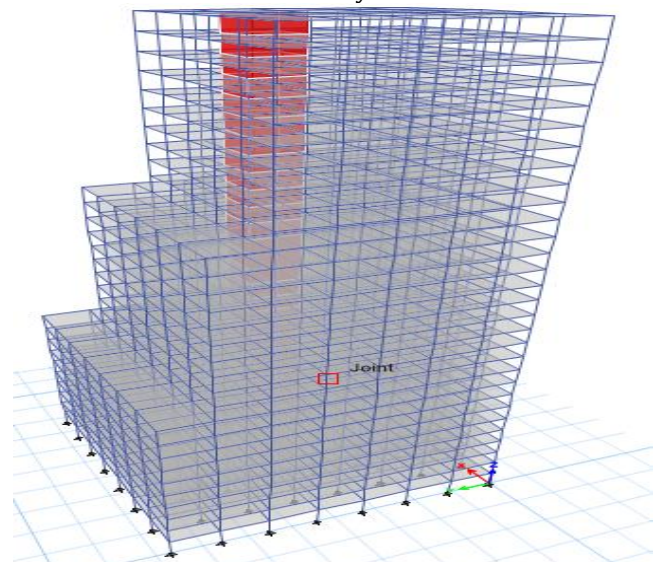
Fig-4: 3D view of symmetrical core buiding



Fig-5: Asymmetrical core building plan from base to 10th storey



Fig-6: Asymmetrical core building plan from 11th to 20th storey
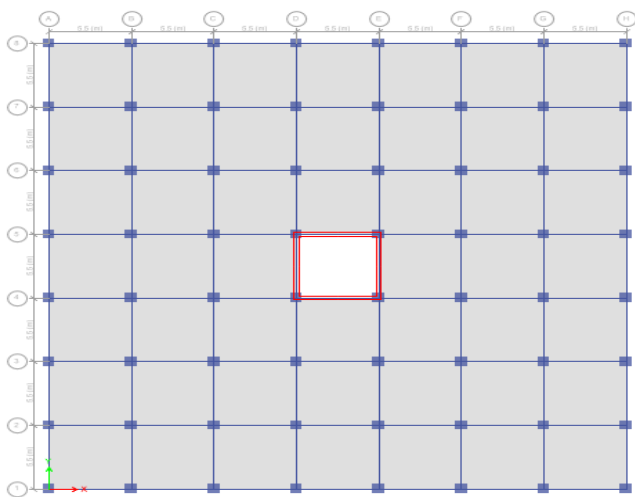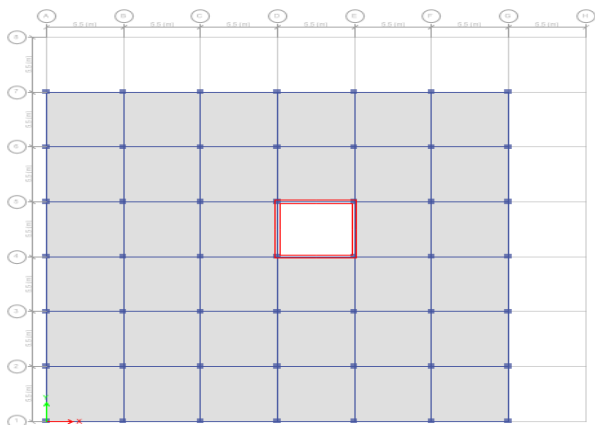


Fig-7: Asymmetrical core building plan from 21st to 30th storey



Fig-8: 3D view of asymmetrical core building

## 2.2 Models adopted for positioning of outriggers and belt truss for study

Several positions where adopted to study the effect of outriggers and belt truss system in the 30 storey symmetrical and asymmetrical core buildings. The adopted cases for study in 30 storey building are as follows:

**Case 1**: Both axis symmetrical in 30 storey building

**Case 2**: Both axis asymmetrical in 30 storey building

**Case 3**: Different configurations of outrigger and belt truss in symmetrical core building

**Case 4**: Different configurations of outrigger and belt truss in asymmetrical core building

Table-1: Details of case 1& 2 building

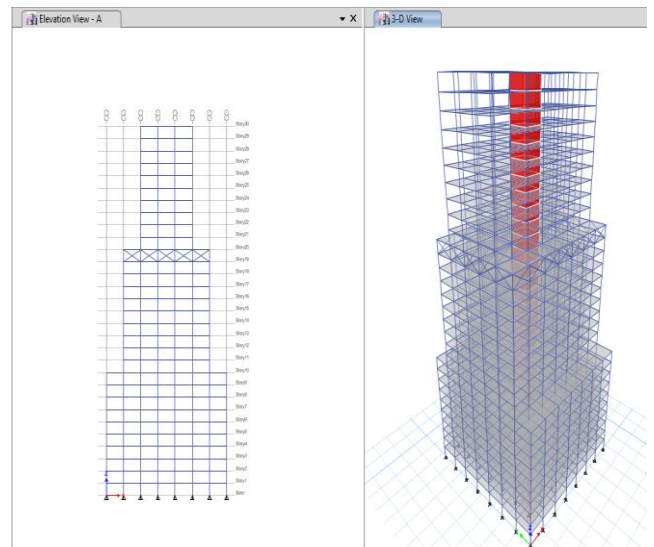| | BARE FRAME | No outrigger and belt truss system |
|---|---|---|
| CASE 1 & CASE 2 | OT n BT @ 30 | Outrigger and belt truss at 30th floor |
| | OT n BT @20 | Outrigger and belt truss at 20th floor |
| | OT n BT @10 | Outrigger and belt truss at 10th floor |
| | OT n BT @ 20 n 25 | Outrigger and belt truss at 20th and 25th floor |



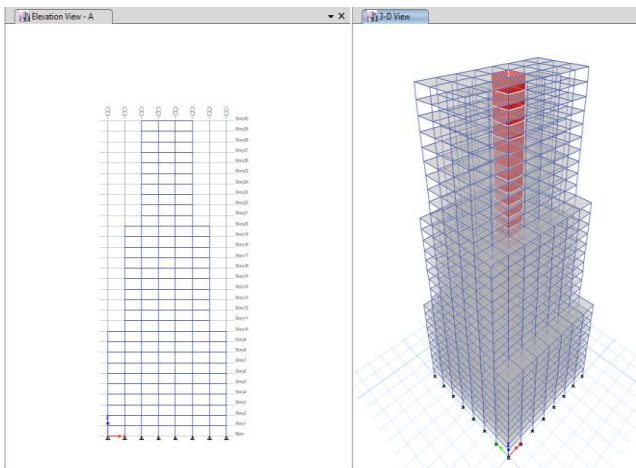Fig-11: Modelling of symmetrical core building with outrigger n belt truss @ 20th storey



Fig-9: Modelling of bare frame at symmetrical core building
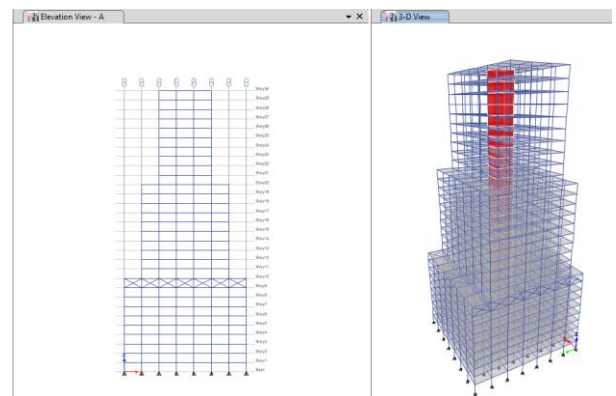


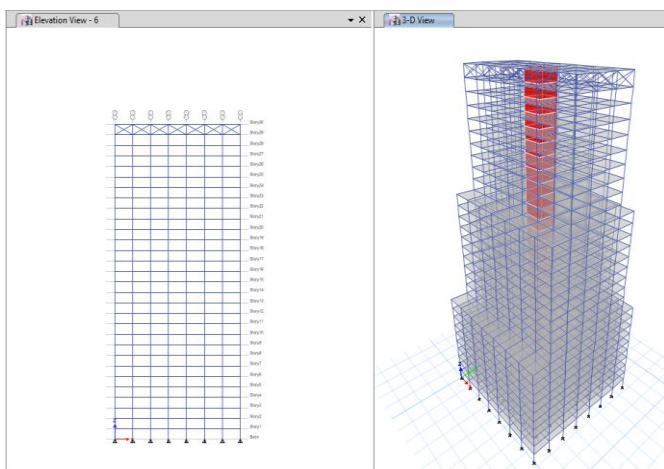Fig-12: Modelling of symmetrical core building with outrigger n belt truss @ 10th storey



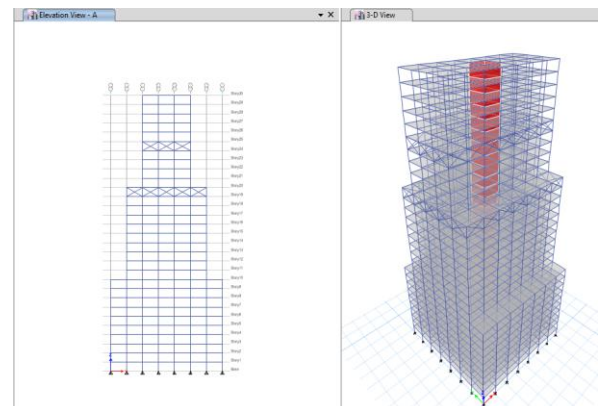Fig-10: Modelling of symmetrical core building with outrigger n belt truss @ 30th storey



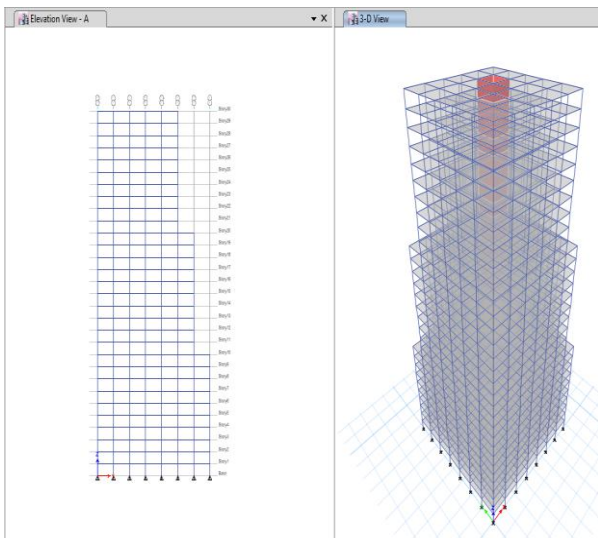Fig-13: Modelling of symmetrical core building with outrigger n belt truss @ 20th n 25th storey

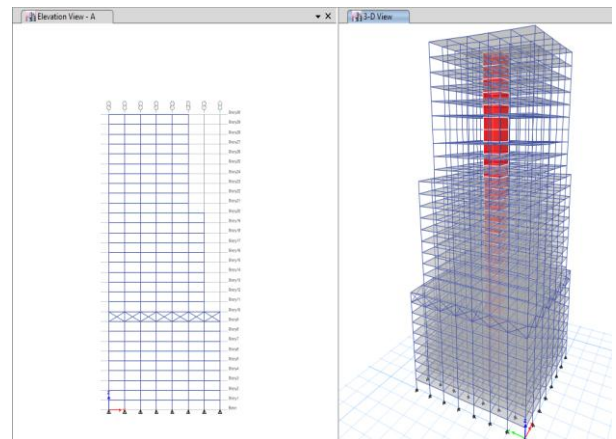Fig-14: Modelling of bare frame at asymmetrical core building



Fig-15: Modelling of asymmetrical core building with outrigger n belt truss @ 30th storey



Fig-16: Modelling of asymmetrical core building with outrigger n belt truss @ 20th storey
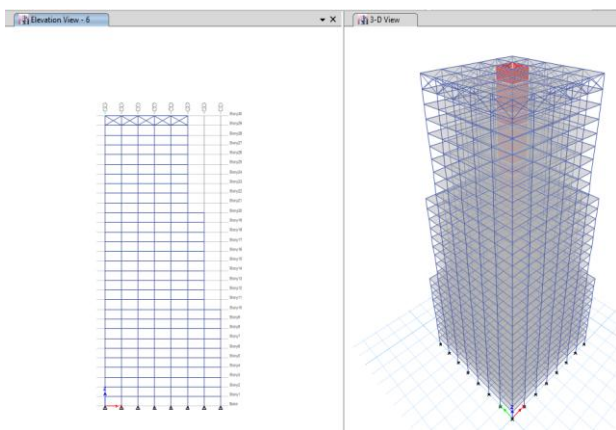


Fig-17: Modelling of asymmetrical core building with outrigger n belt truss @ 10th storey



Fig-18: Modelling of asymmetrical core building with outrigger n belt truss @ 20th n 25th storey
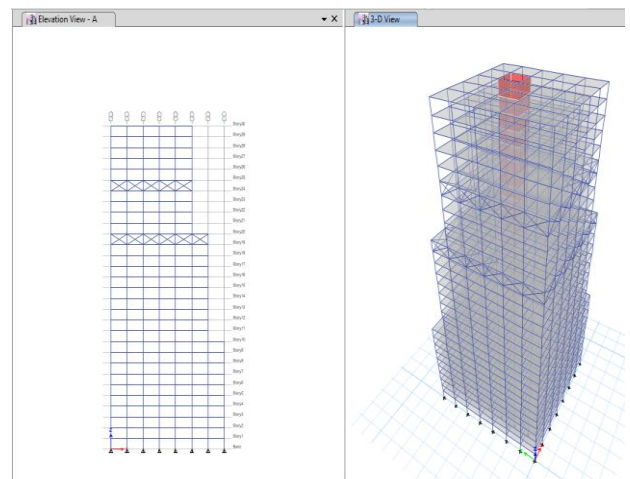
Table-2: Details of case 3 & 4 building

| | V | Outrigger and belt truss at 20th and 25th floor |
|---|---|---|
| CASE 3 | K | Outrigger and belt truss at 20th and 25th floor |
| & | X | Outrigger and belt truss at 20th and 25th floor |
| CASE 4 | Hexagrid | Outrigger and belt truss at 20th and 25th floor |

Fig-19: Modelling of symmetrical core building with V type outrigger n belt truss @ 20th n 25th storey



Fig-20: Modelling of symmetrical core building with K type outrigger n belt truss @ 20th n 25th storey



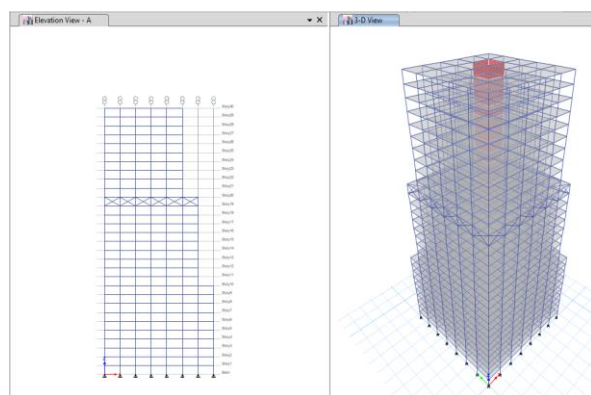Fig-21: Modelling of symmetrical core building with X type outrigger n belt truss @ 20th n 25th storey



Fig-22: Modelling of symmetrical core building with hexagrid type outrigger n belt truss @ 20th n 25th storey



Fig-23: Modelling of asymmetrical core building with V type outrigger n belt truss @ 20th n 25th storey



Fig-24: Modelling of asymmetrical core building with K type outrigger n belt truss @ 20th n 25th storey
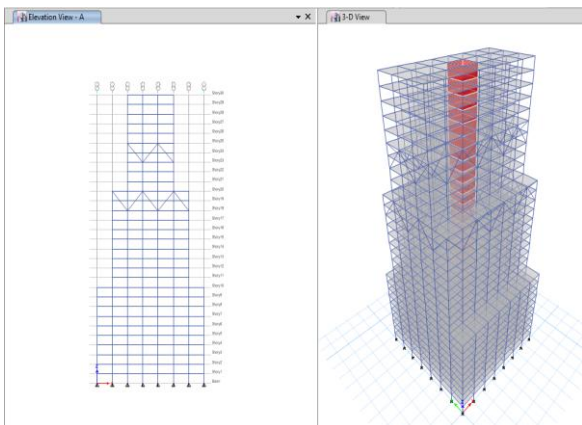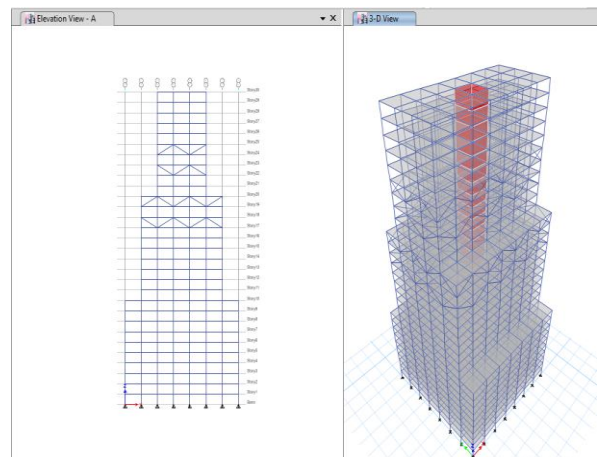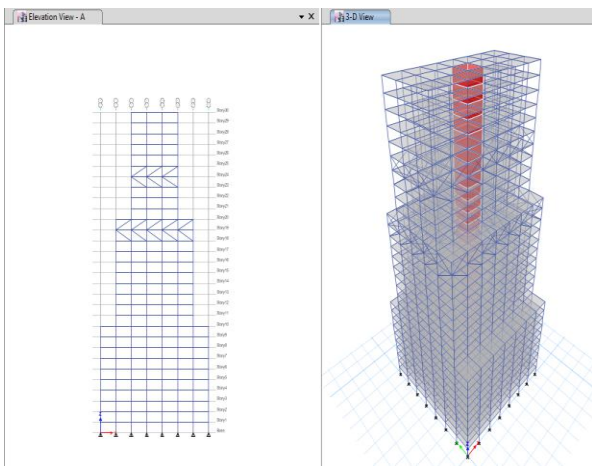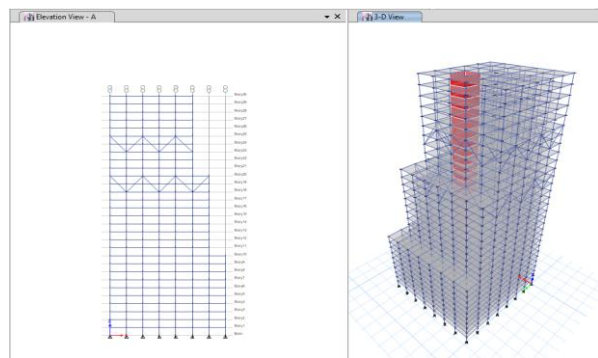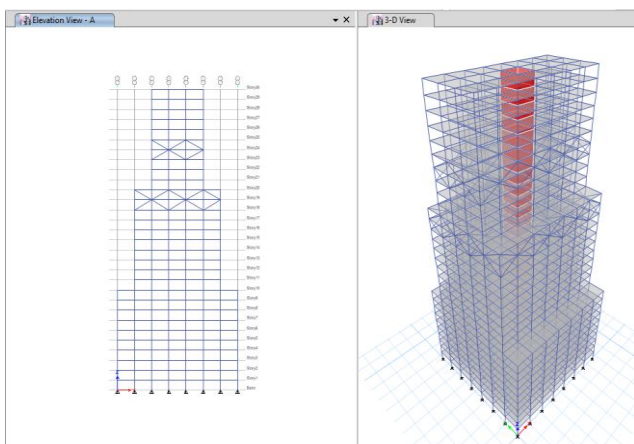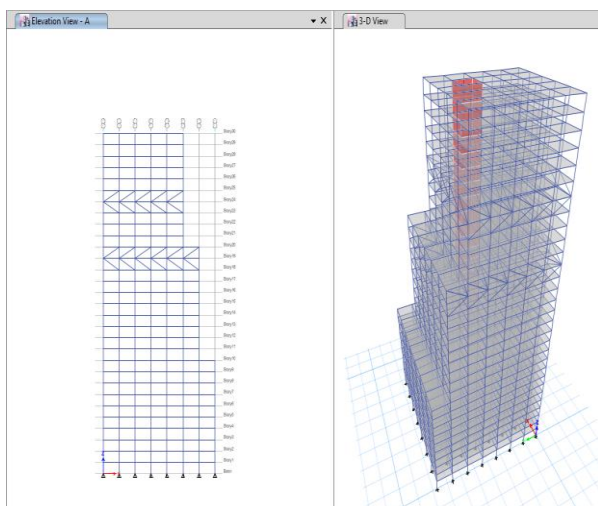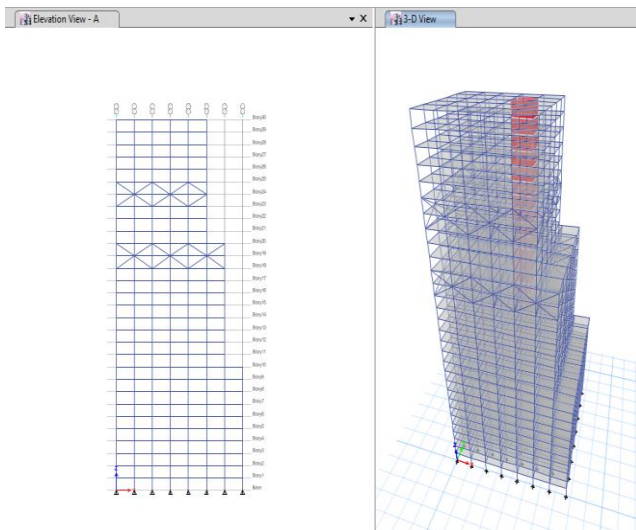
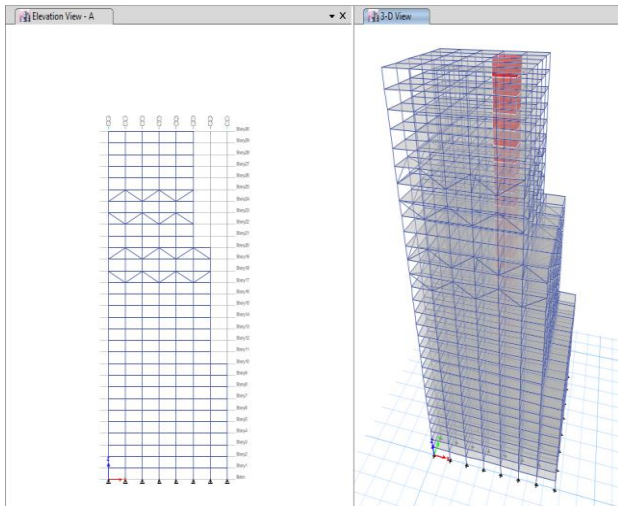Fig-25: Modelling of asymmetrical core building with X type outrigger n belt truss @ 20th n 25th storey



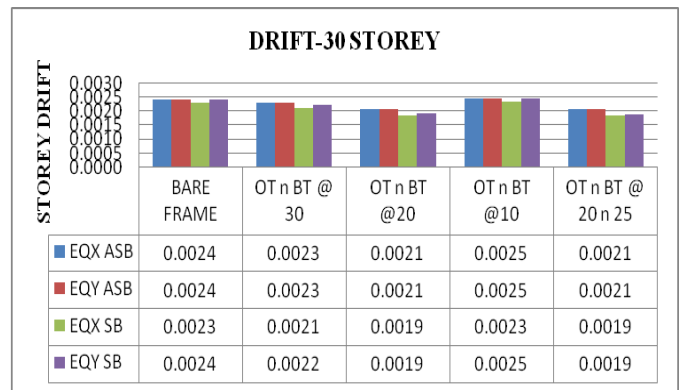Fig-26: Modelling of asymmetrical core building with hexagrid type outrigger n belt truss @ 20th n 25th storey

## 3. RESULT AND DISCUSSION

By analyzing the different models in ETABS from static earthquake analysis following results were achieved.



**DISPLACEMENT- 30 STOREY**

| | BARE FRAME | OT n BT @ 30 | OT n BT @ 20 | OT n BT @ 10 | OT n BT @ 20 n 25 |
|---|---|---|---|---|---|
| EQX ASB | 175.0 | 150.3 | 143.0 | 163.8 | 126.1 |
| EQY ASB | 175.0 | 150.3 | 143.0 | 163.8 | 126.1 |
| EQX SB | 164.0 | 138.8 | 129.1 | 152.2 | 111.0 |
| EQY SB | 169.5 | 152.8 | 136.7 | 157.0 | 124.2 |

Fig-27: Comparison of storey displacement in case 1 n case 2



**DRIFT-30 STOREY**

| | BARE FRAME | OT n BT @ 30 | OT n BT @20 | OT n BT @10 | OT n BT @ 20 n 25 |
|---|---|---|---|---|---|
| EQX ASB | 0.0024 | 0.0023 | 0.0021 | 0.0025 | 0.0021 |
| EQY ASB | 0.0024 | 0.0023 | 0.0021 | 0.0025 | 0.0021 |
| EQX SB | 0.0023 | 0.0021 | 0.0019 | 0.0023 | 0.0019 |
| EQY SB | 0.0024 | 0.0022 | 0.0019 | 0.0025 | 0.0019 |

Fig-28: Comparison of storey drift in case 1 n case 2



**SHEAR-30 STOREY**

| | BARE FRAME | OT n BT @ 30 | OT n BT @20 | OT n BT @10 | OT n BT @ 20 n 25 |
|---|---|---|---|---|---|
| EQX ASB | 6970.1 | 7324.2 | 8016.5 | 8015.6 | 8318.9 |
| EQY ASB | 6970.1 | 7324.2 | 8016.5 | 8015.6 | 8318.9 |
| EQX SB | 7045.5 | 7461.9 | 8154.6 | 8120.0 | 8486.8 |
| EQY SB | 6931.3 | 7192.9 | 7935.8 | 7996.5 | 8166.3 |
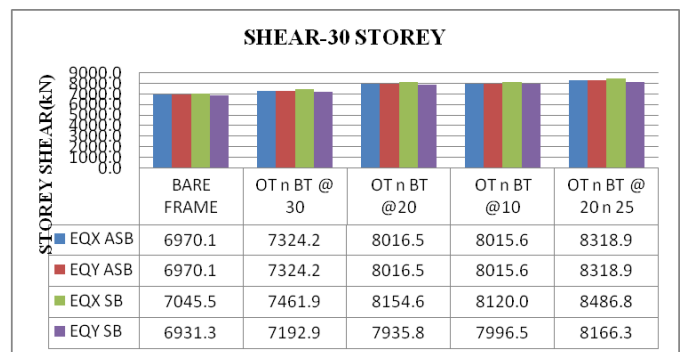
Fig-29: Comparison of storey shear in case 1 n case 2



**DISPLACEMENT-30 STOREY**

| | V type | K type | X type | Hexagrid type |
|---|---|---|---|---|
| EQX ASB | 125.1 | 124.6 | 124.0 | 123.2 |
| EQY ASB | 133.8 | 133.5 | 132.9 | 132.6 |
| EQX SB | 139.0 | 138.6 | 138.3 | 137.6 |
| EQY SB | 139.0 | 138.6 | 138.3 | 137.6 |
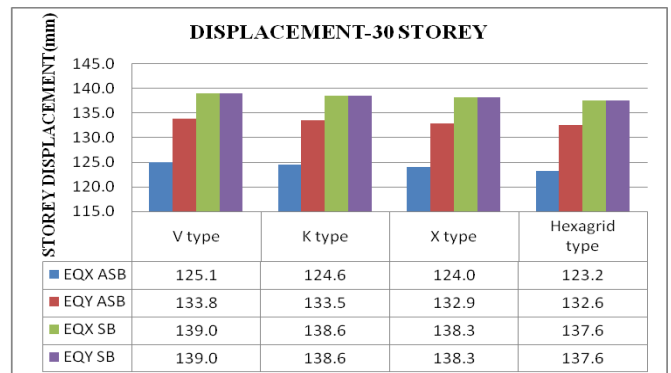
Fig-30: Comparison of storey displacement in case 3 n case 4



**DRIFT-30 STOREY**

| | V type | K type | X type | Hexagrid type |
|---|---|---|---|---|
| EQX ASB | 0.0018 | 0.0018 | 0.0018 | 0.0018 |
| EQY ASB | 0.0019 | 0.0019 | 0.0019 | 0.0018 |
| EQX SB | 0.0021 | 0.0021 | 0.0021 | 0.0020 |
| EQY SB | 0.0021 | 0.0021 | 0.0021 | 0.0020 |

Fig-31: Comparison of storey drift in case 3 n case 4

Fig-32: Comparison of storey shear in case 3 n case 4

## 4. CONCLUSIONS

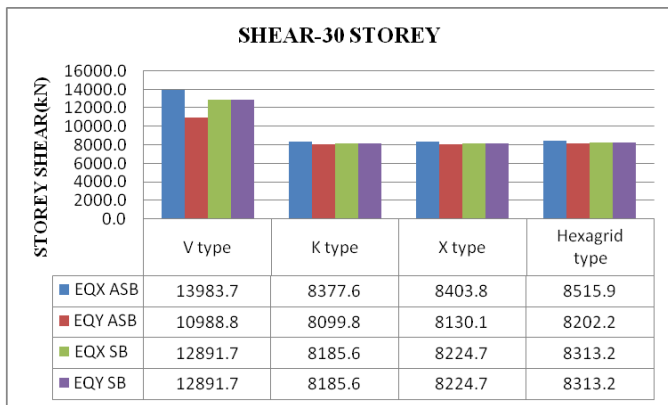The following conclusions are made from the present study:

1. The behavior of outrigger with belt truss system is studied in symmetrical and asymmetrical core building. It is studied that the outrigger with belt truss system is effective in controlling displacement, drift, shear of the building and makes the structural form efficient under lateral load.

2. The displacement is reduced by 15.4%, 7.19% and 32.32% by placing outrigger and belt truss at 30th position, 10th position and 20th & 25th position respectively under earthquake combination behavior compared with bare frame in case of symmetrical core building.

3. The displacement is reduced by 14.11%, 6.4% and 27.9% by placing outrigger and belt truss at 30th position, 10th position and 20th & 25th position respectively under earthquake combination behavior compared with bare frame in case of asymmetrical core building.

4. The maximum drift is reduced by 8.69% and 17.39% by placing outrigger and belt truss at 30th position, 20th position and 20th & 25th position respectively under earthquake combination behavior compared with bare frame in case of symmetrical core building.

5. The maximum drift is reduced by 4%, 8% and 16% by placing outrigger and belt truss at bare frame, 30th position, 20th position and 20th & 25th position respectively under earthquake combination behavior compared with bare frame in case of asymmetrical core building.

6. Increase in base shear from 3.91% to 13.6% is observed as increase in stiffness is occurred by various outrigger positions in symmetrical core building.

7. Increase in base shear from 3.64% to 13.05% is observed as increase in stiffness is occurred by various outrigger positions in asymmetrical core building.

8. The type of configurations affects the efficiency of the building which is represented by lateral displacement and storey drifts. It also concluded that Hexagrid bracing is found best in symmetrical and asymmetrical core building.

9. In all the cases, optimum location of outrigger is between 0.5 time its height.

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