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# WIND ANALYSIS FOR RC BUILDING USING BELT TRUSS

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**Abstract** -*In today's modern era it has become need to undertake development in tall structure to accommodate the present population, as the cities are growing fast and land availability is becoming lesser for human beings ,so there is need for the development of tall structures. Due to wind and lateral loads the lateral stability and sway will occur. To overcome this problem the Belt Truss as Virtual Outrigger are kept at the different storeys of the building to reduce the displacement of the building. The present work is to study the Optimum location of Belt Truss placed at different location subjected to wind loads. The Belt Trusses are placed at the interval of 4storey, 5storey. The Storey Drift and Displacement have compared between with and without Belt Truss system as per varying location. Loads are considered as per Indian Standards IS: 875(Part-1)-1987, IS: 875(Part-2)-1987, IS: 875(Part-3)-1987 and IS: 1893(Part-1)-2002. The Modelling and the Analysis is performed using the finite element software ETABS 15.2.2.*

**Key Words:** Belt Truss, Virtual Outrigger, Storey Drift, Displacement, Lateral loads and Optimum location.

## 1. INTRODUCTION

Tall building development has been rapidly increasing worldwide introducing new challenges that need to be met through engineering judgment. In modern tall buildings, lateral loads induced by wind or earthquake are often resisted by a system of coupled shear walls. But when the building increases in height, the stiffness of the structure becomes more important and introduction of lateral load resisting system is used to provide sufficient lateral stiffness to the structure. The lateral load resisting system effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. The Belt Truss, Outriggers are the structural systems that are used for the tall buildings in order to minimize the displacement. Here we are using the Belt Truss as the Virtual Outrigger.

### 1.1 Outrigger

Outriggers are rigid horizontal structure i.e. truss or beam which connect core wall and outer column of building to improve building strength and overturning stiffness. A structural system for a tall building that uses a central core of concrete, with massive concrete beams that provides stability against the wind loads. It comprises of a main concrete core connected to exterior columns by relatively stiff horizontal members such as bracings. These bracings are termed as the outriggers, classified as

1. Conventional Outrigger.
2. Virtual Outrigger.

### 1.2 Belt Truss

It connects the outer perimeter column of a building and offers a wider perimeter to resist the lateral deflection of a building. In order to provide the stiffness to the building a Belt Truss can be used as the Virtual Outrigger. Belt Truss connects all perimeter columns of building in the form of truss in steel buildings and in the form of rigid concrete wall in the RC structures. In tall buildings Belt Truss can be used to control deflection due to lateral loads and enhance stiffness of the structure.

### 1.3 Belt Truss used as Virtual Outrigger

In order to mobilize the additional axial stiffness of several columns and provide for torsional stiffness, a belt truss can be used at the outrigger levels. As building increases in height shortening of column is the main problem in construction practices, Belt Truss is very much effective in the control of settlement of columns. The Belt Trusses also help in minimizing differential elongation and shortening of columns. Behavior of Outrigger with Belt Truss proven to be more effective when compare to the Outrigger without Belt truss. The exterior columns and Belt truss system resist the rotation of central shear core and decrease the lateral deformation as well as bending moment at base of the structure. The belt truss tied the peripheral column of building while the Outriggers engage them with main or central shear wall. Therefore; exterior columns restrained the core wall from free rotation through outrigger arms. Effectiveness of Outrigger and Belt Truss can be affected by the various factors like position of Outrigger and Belt Truss, number of outrigger, geometry of building, types of core i.e. concrete or steel and floor to floor height.

The use of Outrigger and Belt Truss system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load.

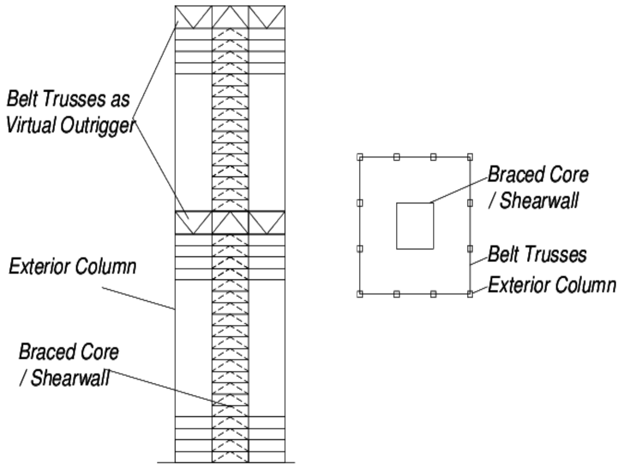


Fig.1 Belt Truss as Virtual Outrigger

Belt trusses used as virtual outriggers offer many of the benefits of the outrigger concept, while avoiding most of the problems associated with conventional outriggers.

- Connection difficulty between outrigger and core is eliminated.
- There are no diagonal trusses extending from the core to the exterior of the building.
- There would not be the effect of differential shortening of core and outer column on floor diaphragm since they are stiff in their own plane and flexible in vertical plane.
- The need to locate outrigger columns where they can be conveniently engaged by trusses extending from the core is eliminated.

### 1.4 Objectives of the study

- To study the behavior of tall buildings with Belt Truss as Virtual Outrigger for lateral loads
- To arrive the optimum location Belt truss as Virtual Outrigger in the structure.
- To show comparison between with and without Belt Truss.

### 1.5 Scope of study

In order to reduce the lateral displacement and Storey Drift and to provide stiffness to the building we are providing Stiffen Girder i.e., Belt Truss at different storey levels of the building by using ETABS structural software.

## 2. Literature Review

**Prajyot A.Kakde & Ravindra Desaidone**: They concluded that the Outrigger system is found to be efficient in controlling the lateral loads and has proved to be economical. Steel Outrigger is found to be efficient in reduction of displacement ass compared to Concrete Outrigger. Storey drift and Base shear of Steel Outrigger is found to be less in comparison to Concrete Outrigger. They finally concluded that Steel Outrigger and Belt Truss system is found to be efficient in comparison to Concrete Outrigger and Belt Truss.

**Vasudev M.V & Vinay pai S:** They concluded that providing Belt Truss at the location of Outriggers reduces the Inter-storey drift by 51% and deflection at the top by 15% to 18% as compared to models with Outriggers alone. Even though when Outrigger and Belt Truss placed at the top of the structure as a cap truss is not efficient, maximum reduction of Inter-storey drift was found. Similarly if 4 Outriggers are to be used in a symmetrical structure, optimum locations can be found by subdividing the structure into 5 equal parts.

**Shivacharan K, Chandrakala.S S, Karthik N M**: They had taken a building and kept the Outriggers at top of building and 0.67height of the building and 0.5height of the building from this the Optimum position of the outrigger is found based on the decrease in the deflection and drifts. It is observed that 28.58% and 27% of the deflection and the drift is controlled by providing one position Outrigger at 0.67 height.37.7%and 36.11% of the deflection and drift is controlled by providing Outrigger and Belt Truss at 0.67 and 0.5 height.12.78% and 11.5% of the deflection and drift is controlled by comparing the first position Outrigger system and second position of Outrigger system of the building.

### 3. METHODOLOGY

- DRAWING UP THE PLAN
  - The plan is developed in AutoCAD software.
- MODELING IN ETABS Software
  - The models have to be modeled.
- CONSIDERING LOADS
  - The loads have been considered based on manual calculations as per IS codes.
- ANALYSIS
  - Analysis of RCC framed structure after assigning the loads and then the Displacements, Storey Drifts, Stiffness, Base Shear are taken from the Software.
- GEOMETRIC PARAMETERS
  - Beam = 300 x 600 mm
  - Column = 1200 x 1200 mm
  - Depth of Slab = 150 mm

### 4.MODELING AND ANALYSIS

In the present study the wind analysis and lateral load analysis for the RC frame building with the provision of introduction of Belt Truss are done

### 4.1 Method of Modelling

The ETABS software is utilized to create 3D model and to carry out the analysis.

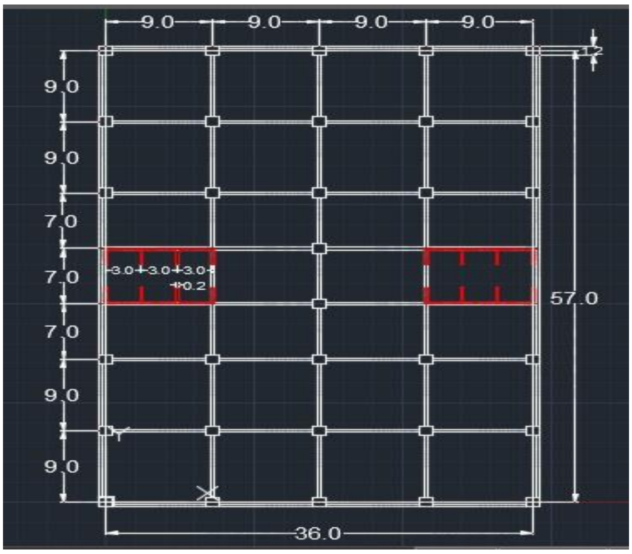


Fig.2 Plan in AUTO CAD

### 4.2 Plan Dimensions

- No of storeys – G+23.
- Height of the building is 106m from ground surface.
- Thickness of the slab is 150mm.
- Below the ground the 3 parking floors with height of 14m.
- Plan dimensions 36mx57m.
- Beam size- 300x600mm.
- Thickness of RC shear wall -200mm.
- Column size-1200x1200mm.
- Basic wind speed-50m/s.
- Belt Truss-230x300mm.
- Bays in X-direction -4.
- Bays in Y direction-8.
- Width in X direction 9m.
- Width in Y direction 9m.
- Bottom storey height 5m.
- Storey height 4.5m.

### 4.3 Models

- Model 1: without Belt Truss.
- Model 2: with the Belt Truss at the every 5 storey interval.
- Model 3: with the Belt Truss at the every 4 storey interval.

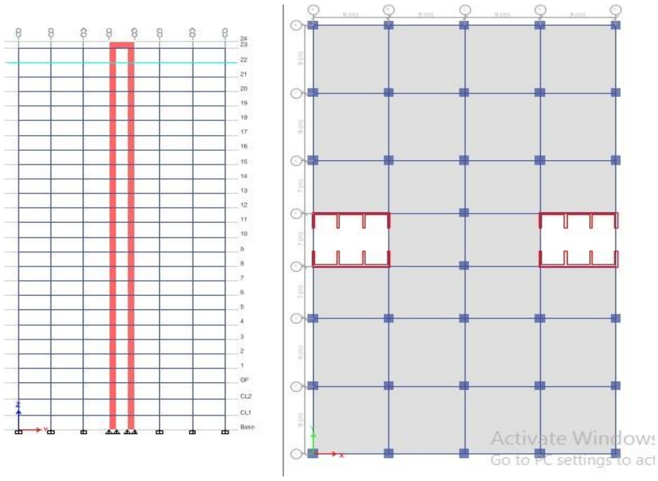

Fig.3 Model-I without Belt Truss in building

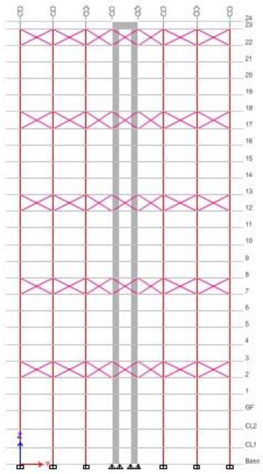

Fig.4 Belt Truss at 5 storey Interval Model-II

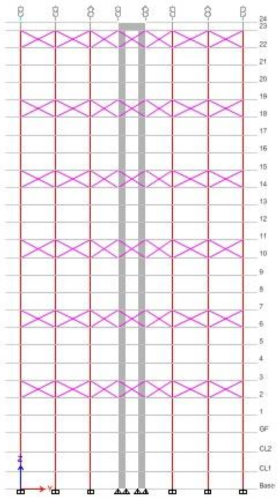

Fig.5 Belt Truss at 4 storey interval Model-III

### 4.5 Load considerations

**Dead load-** The dead is taken as self-Weight of the members -1 as per IS 875(part - 1)-1987.

**Imposed load-** The live load is taken as the 4kN\m$^2$ and the Floor load as the 2 kN\m$^2$ as per IS 875(part - 2)-1987.

**Wind loads-** Calculated from IS 875(Part-3)-1987.

From clause 5.4
$P_z = 0.6 V_Z^2$
$P_z$ =design wind velocity in N/m$^2$ at height Z.
$V_Z$ =design wind velocity in m/s at height Z.
From clause 5.3
$V_Z = V_b K_1 K_2 K_3$
$K_1$ =probability factor (risk co-efficient) from Clause 5.3.1.
$K_2$ =terrain, height and structure size factor from Clause 5.3.2
$K_3$ =topography factor 5.3.3
$V_b$ =basic wind speed

From appendix –A: The basic wind speed is 50m/s for Vijayawada.

$K_1$=1m/s from table -1 of IS: 875 part-III

- The category of our building is 2 from clause 5.3.2.1(b).
- The class of the building is C from (pg-11) so, from the table 2 the value of $k_2$ =1.19.
- The value of $k_3$=1 from clause 5.3.3.1(because the site upwind slope. And also from appendix C.

$V_z$ =50x1x1.19x1 =59.5m/s.
Pz =0.6*59.5 =2.124kN/m².
Wind speed at heights of $P_z$=0.6[50*A] $^2$
The value of A is taken from the table -2.
When A=10; $P_Z$ = 0.6(50 x 10)² = 1.297 KN/m².
A=20; $P_Z$ =1.5kN/m².
A=30; $P_Z$ =1.62kN/m².
A=50; $P_Z$ =1.815kN/m².
A=100; $P_Z$ =2.05kN/m².
A=106; $P_Z$ =2.124kN/m².

The external pressure co-efficient are calculated from table -4, pg-14.

Here 3/2 < h/w < 6 ≈ 3/20 < 106/57 < 6 ≈ 1.5.
Then 1 < l/w ≤ 3/2 1 < 36/57 ≤ 3/2 ≈1.
The $C_{pe}$ at Wind ward 0° = 0.87, at Wind ward at 90⁰ = 0.8.
Leeward ward 0° = -0.25, at Leeward ward at 90⁰= -0.25.
**Floor Finish**: 1kN/m²
**Wall load**: 15kN/m²

**Load Combinations considered**

| S.No | FACTOR | LOAD COMBINATION |
|---|---|---|
| 1. | 1.5 | (DEAD + WALL + F.F) |
| 2. | 1.5 | (DEAD + LIVE + WALL + F.F) |
| 3. | 1.2 | (DEAD + LIVE + WALL + F.F + WINDX) |
| 4. | 1.2 | (DEAD + LIVE + WALL + F.F - WINDX) |
| 5. | 1.2 | (DEAD + LIVE + WALL + F.F + WINDY) |
| 6. | 1.2 | (DEAD + LIVE + WALL + F.F - WINDY) |
| 7. | 1.5 | (DEAD + WALL + F.F + WINDX) |
| 8. | 1.5 | (DEAD + WALL + F.F - WINDX) |
| 9. | 1.5 | (DEAD + WALL + F.F + WINDY) |
| 10. | 1.5 | (DEAD + WALL + F.F - WINDY) |
| 11. | 0.9 | (DEAD + WALL + F.F) + 1.5 WINDX |
| 12. | 0.9 | (DEAD + WALL + F.F) - 1.5 WINDX |
| 13. | 0.9 | (DEAD + WALL + F.F) + 1.5 WINDY |
| 14. | 0.9 | (DEAD + WALL + F.F) - 1.5WINDY |

## 5 RESULTS

### 5.1 Maximum storey displacements

Table 5.1 Maximum top storey displacement

| Model | Displacement, mm | | Decrease in percentage, % | |
|---|---|---|---|---|
| | Wind X | Wind Y | Wind X | Wind Y |
| 1 | 223.69 | 166.06 | - | - |
| 2 | 131.04 | 83.31 | 41.41 | 49.83 |
| 3 | 122.07 | 73.82 | 49.83 | 55.54 |

### 5.2 Maximum storey drifts

Table 5.2 Maximum storey drifts

| S.No | Model | Storey Drift | | Decrease in percentage (%) | |
|---|---|---|---|---|---|
| | | Wind X | Wind Y | Wind X | Wind Y |
| 1 | Without Belt Truss | 0.00229 | 0.00196 | - | - |
| 2 | With Belt truss at 5 storey interval | 0.00141 | 0.00115 | 38.42 | 41.32 |
| 3 | With Belt Truss at 4 storey interval | 0.00138 | 0.00113 | 39.73 | 42.34 |

### 5.3 Maximum Stiffness

Table 5.3 Maximum stiffness

| S.No | Model | Stiffness(kN/m) | | Increase in percentage (%) | |
|---|---|---|---|---|---|
| | | Wind X | Wind Y | Wind X | Wind Y |
| 1 | Without Belt Truss | 8.06 | 3.33 | - | - |
| 2 | With Belt Truss at 5 storey interval | 9.96 | 3.88 | 23.57 | 16.511 |
| 3 | With Belt Truss at 4 storey interval | 10.20 | 3.90 | 26.55 | 17.11 |

### 5.4 Base shear

Table 5.4 Base Shear

| S.No | Type of MODEL | Base Shear(kN) |
|---|---|---|
| 1 | Without Belt Truss | 4088 |
| 2 | With Belt Truss at 5 storey interval | 4141.825 |
| 3 | With Belt Truss at every 4 storey interval | 4150 |

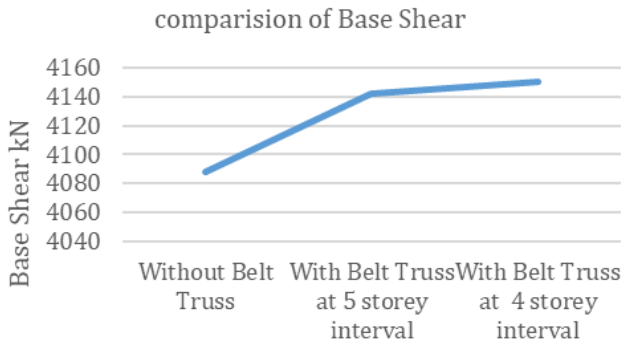


Fig.4 Comparison of Base Shear for tall buildings with and without Belt truss

### 5.5 Comparison

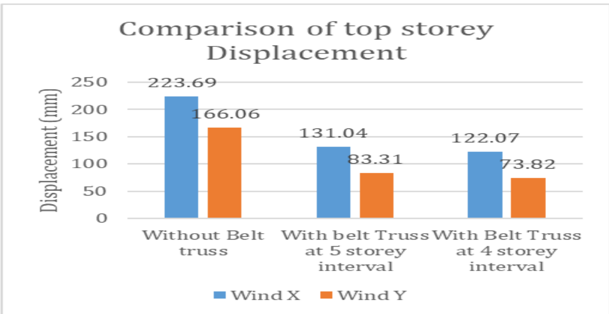


Fig.1 Comparison of Top storey Displacement in wind X and Y directions for tall buildings with and without Belt truss

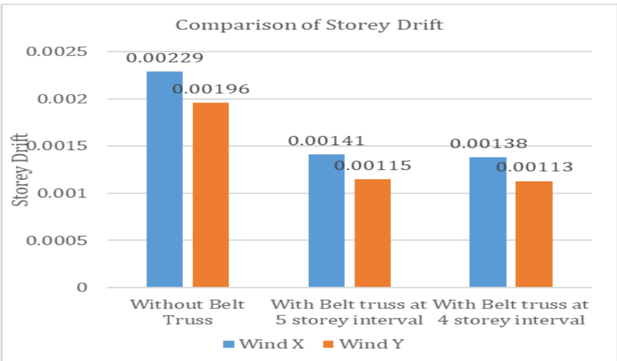


Fig.2 Comparison of Storey Drift in Wind X and Y Directions for tall buildings with and without Belt truss

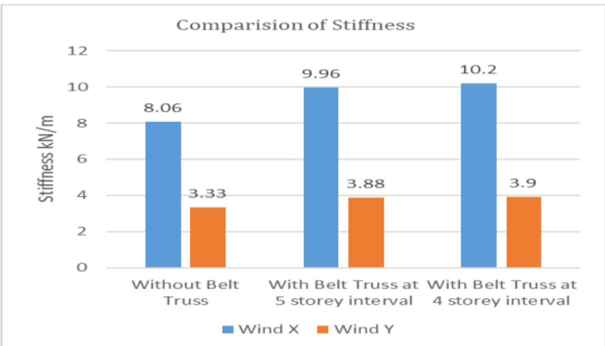


Fig.3 Comparison of Stiffness in Wind X and Y Directions for tall buildings with and without Belt truss

## 6. CONCLUSIONS

### 6.1 Displacements

After performing the analysis and studying the results we came to below conclusions:

1. The top storey displacement by wind analysis without Belt Truss is 223.69mm in the X direction and 166.09mm in the Y direction.

2. The top storey displacement by wind analysis With Belt truss at 5 storey interval is 131.04mm in X direction and 83.31mm in Y direction which has resulted in 41.41% in X direction and 49.83% in Y direction reduction in the displacement.

3. The top storey displacement by wind analysis With Belt truss at 4 storey interval is 122.07mm in X direction and 73.82mm in Y direction which has resulted in 49.83% in X direction and 55.54% in Y direction reduction in the displacement.

### 6.2 Storey Drifts

After performing the analysis and studying the results we came to below conclusions:

1. The Maximum Storey Drift by wind analysis Without Belt truss is 0.00229 in X direction and 0.00196 in Y direction.

2. The Maximum Storey Drift by wind analysis With Belt truss at 5 storey interval is 0.00141 in X direction and 0.00115 in Y direction which has resulted in 38.42% in X direction and 41.32% in Y direction reduction in the Storey Drift.

3. The Maximum Storey Drift by wind analysis With Belt truss at 4 storey interval is 0.00138 in X direction and 0.00113 in Y direction which has resulted in 39.73% in X direction and 42.34% in Y direction reduction in the Storey Drift.

### 6.3 Stiffness

After performing the analysis and studying the results we came to below conclusions:

1. The Maximum Stiffness by wind analysis Belt truss is 8.06kN\m in X direction and 3.33kN\m in Y direction.

2. The Maximum Stiffness by wind analysis With Belt truss at 5 storey interval is 9.96kN\m in X direction and 3.88kN\m in Y direction which has resulted in 23.57% in X direction and 16.51% in Y direction reduction in the Stiffness.

3. The Maximum Stiffness by wind analysis With Belt truss at 4 storey interval is 10.2kN\m in X direction and 3.9kN\m in Y direction which has resulted in 26.55% in X direction and 17.11% in Y direction reduction in the Stiffness.

### 6.4 Base Shear

1. The Base shear for the Tall Building without Belt truss is 4088kN.

2. The Base shear for the Tall Building with Belt truss at 5 storey interval is 4141.825kN.

3. The Base shear for the Tall Building with Belt truss at 4 storey interval is 4150kN.

From the above we would like to conclude that the Optimum position of the Belt truss is providing the BELT TRUSS as VIRTUAL OUTRIGGER at every 4 storey interval. When compared to other the Displacement and Storey Drift is less and Stiffness is more to the building provided with Belt truss at every 4 storey interval. So, the Optimum position of the Stiffen Girder is providing at every 4 storey interval.

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