Research and Optimization of the Belt Truss Location in High-Rise RCC Structure

Shravan Vijay Mantri, P. Hiwase, Prasad P. Dahale

Abstract*—Rapid improvement in infrastructure to acquire the development of modern civilization is the demand of high-rise structures. As day by day, the height of structures is increasing there is problem with its stiffness which induces lateral stability and sway due to lateral forces, which has to be reduce. One more structural system has been developed to overcome problems related to lateral stability and sway of building. To reduce the lateral deflection due to earthquake or wind forces, one of the most efficient and economical structural system used to knock out these challenges is the use of belt truss and outrigger truss. It is commonly used to control the excessive drift due to lateral load, so that during minor or major earthquake, the risk of structural and non-structural damage can reduce to sufficient amount. The objective of this thesis is to optimize the location of belt truss to control the deflection or sway of building. Here, Belt truss can be shear wall, hollow steel sections, braced sections and many more. In this paper, we are going to compare the results due to different locations of shear wall and X-braced section. Structure is located in earthquake zone IV(India) on Hard rock strata. Different results to be compared are Lateral Deflection, story drift. Study provides comparison between the two, by analyzing and designing the G+24 irregular residential structure. By using belt truss at ideal location, overall lateral deflection reduces by 22%. And this ideal location is obtained when the belt truss is applied at 13th & 14th floors simultaneously. From this location of belt truss, we can conclude that the lateral deflection of the high-rise structure can be reduce by applying the belt truss in the middle floors.

***Key words*— Belt truss, Lateral deflection, Storey drift, High-rise structures.**

I. INTRODUCTION

Growth in structural system and high strength material creating influence on rapid development of tall buildings and it is also need of growing population and infrastructures in metro cities. The development in concrete technology over the twenty-first century covering structural system, analysis, construction techniques and materials, made it possible to build tall structure. There are many design objectives for structural engineers to control the design of high-rise buildings such as safety, serviceability, durability, functionality, economic effectiveness, structural integrity and resistance to accidental actions. But, the main factors that will undermine the design are the building drift due to lateral loads and prevention of progressive collapse attributed to the accidental loads resulting in column loss. When the lateral load acts on the building, the bending of the core revolves the outrigger arm, which is connected to the core of structure and brings compression and tension on columns.

Structural system for multi-storied storied buildings:

There are two categories of structural system i.e. interior structures and exterior structures. When the major part of lateral load resisting structure is located in inner part of the building it is called interior structure and if major part of the lateral load resisting system is located on perimeter of building is called as exterior structure. One of the most effective techniques to reduce the lateral drift, that are likely applied in the design of high rise structure is the use of outrigger truss and belt truss. Interior structure consists of belt truss, while exterior structure is for outrigger truss. Advantage of core-outrigger truss are that spacing of exterior column spacing can easily meet functional and aesthetic requirements and the building's exterior framing can meet simple beam-column framing without any rigid frame connections. But there are some problems with outrigger truss that are:

a) area occupied by truss mainly diagonal can create a floor to floor spacing problem
b) architectural aspect
c) connection to core, especially when shear walls are used.

To overcome this problem belt truss as a virtual outrigger truss is used, as it is connected on periphery of structure.

II. Objective and details of present study

The main objective of present study is to study the use belt truss as a virtual outrigger truss placed at different location, to control the deflection of multi-storied building against lateral loads acting through seismic load and wind load. The study is restricted to reinforced cement concrete multi-storied structure. The analyzed model in study is real structure

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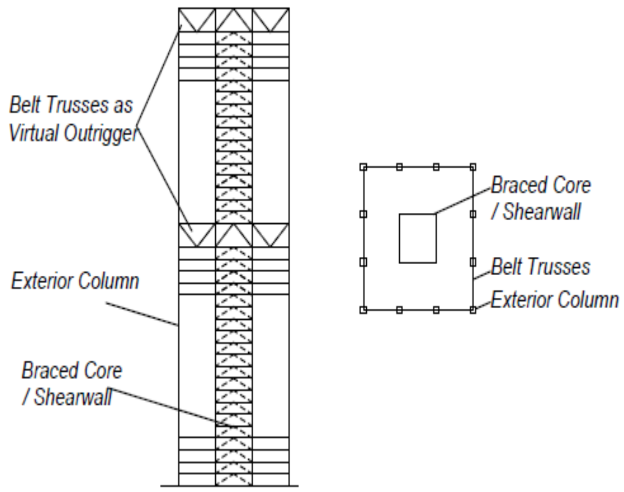

Fig.1 Outrigger and belt truss

implementing in Mumbai with 24 stories. Dimension of plan along X, Y axis is 33.810 m & 21.4 m while elevation of building is 80.2 m excluding foundation. The shape of building is irregular structure. Plan and 3D model of building is shown in fig 2 & fig 3.

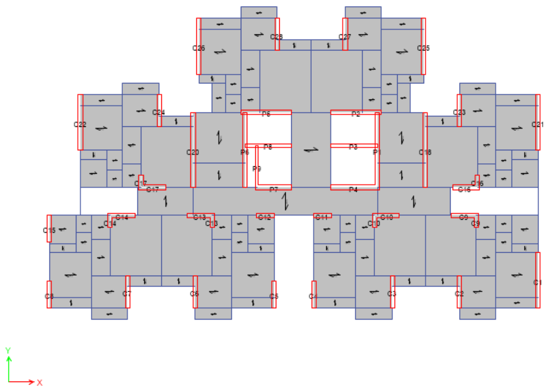

Fig.2. Plan of building at 13th floor

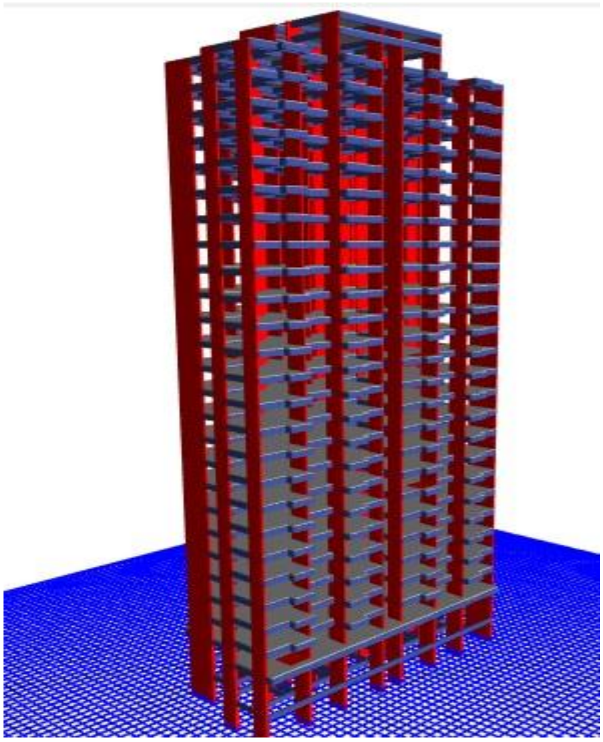

Fig.3. 3D model of structure

Structural data

Plan dimension	33.810m, 21.4m
Total height of building	80.2m
Height of each storey	2.9m
Height of parapet	1m
Grade of concrete	M35 , M40
Density of concrete	25 KN/m^3
Grade of steel	Fe 500
Type of Beam	Size of Beams
B1	150mmX300mm
B2	150mmX600mm
B3	150mmX700mm
B4	230mmX600mm
B5	230mmX700mm
Thickness of Shear Wall	150mm, 230mm 380mm, 430mm
Thickness of Slab	125mm, 140mm
Thickness of Wall	150mm- internal wall 230mm- external wall
Seismic Zone	IV
Wind Speed	44 m/s
Soil Condition	Medium soil
Importance factor	1
Zone factor	0.24
Terrain category	3
Damping ratio	5%
Loadings-	
Dead load:	
a. Terrace floor finish	3.5 KN/m^2
b. Toilet floor finish	1.5 KN/m^2
c. Sunk load floor finish	3.7 KN/m^2
d. Passages floor finish	1.5 KN/m^2

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e.	Stair case floor finish	1.5 KN/m^2
f.	Balconies floor finish	1.5 KN/m^2
g.	Floor finish	1.5 KN/m^2
h.	125 mm slab	3.125 KN/m^2
i.	140 mm slab	3.5 KN/m^2
j.	External wall	3.8 KN/m
k.	Internal wall	2.48 KN/m
Live load:		
a.	Terrace	2 KN/m^2
b.	Toilet	2 KN/m^2
c.	Passages	3 KN/m^2
d.	Stair case	4 KN/m^2
e.	Balconies	2 KN/m^2
f.	Lift machine	20 KN/m^2
g.	Water tank	10 KN/m^2
h.	125 mm slab	2 KN/m^2
i.	140 mm slab	2 KN/m^2
j.	Refuge floor	4 KN/m^2

III. ANALYSIS

The building is a R.C.C shear walls and beam slab frame structure. After preliminary sizing of various structural members, a computer model of the structural frame of the building will be generated for carrying out computer analysis for the effects of vertical and lateral load that are likely to be imposed on the structure. The building structure will be analyzed using the ETABS.15.2.0 software. For the design of R.C.C. elements, the Limit State Method will be used as per IS 456-2000. Materials of construction will be predominantly concrete with consideration for strength and durability. The minimum grade of concrete is suggested as M: 30. High Yield Strength Deformed bars conforming to Fy= 500MPa. Covers to reinforcement shall be in accordance with IS: 456:2000. Geometrical dimensions, member properties and member node connectivity including eccentricities will be modeled in the analysis problem. Variation in material grades, if present, will also be considered. The seismic loads will be derived from the results of dynamic analysis of the structure in accordance with the relevant code of practice. The permissible values of the load factors and stresses will be utilized within the purview of the Indian Standards.

The computer analysis will evaluate individual internal member forces, reactions at foundation level and deflection pattern of the entire structure and in the individual members. This data will then be used to verify adequacy of the member sizes adopted and after further iterations arrive at the most appropriate design of the structural members. Some re-runs of the analysis program might be required for arriving at the optimum structural space frame characteristics that satisfy the strength and stability criteria in all respects.

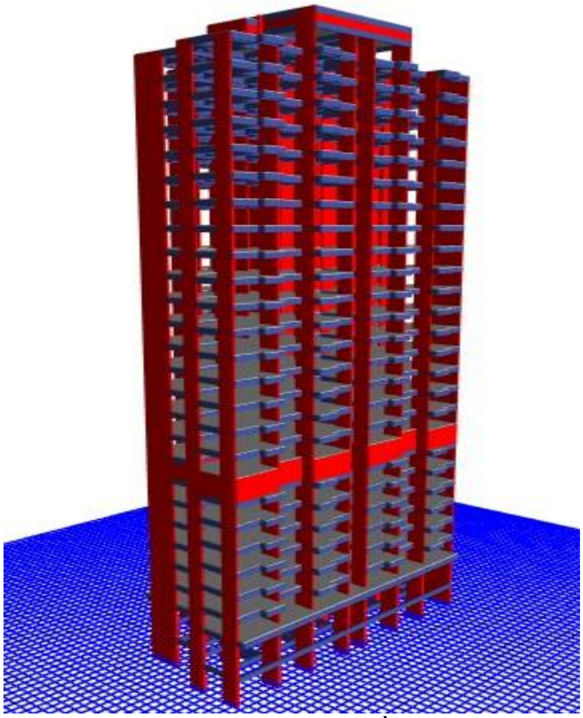

Fig. 4. Shear wall at 8th floor

Space frame analysis will be carried out for gravity loads, wind loads and seismic loads.

In the present study total 17 models are studied are:

Sr. No.	Structure	R. S. in X (mm)	R. S. in Y (mm)	Wind in X (mm)	Wind In Y (mm)
1.	Without belt truss	44	39.8	52.957	104.67
WITH BELT TRUSS AS SHEAR WALL					
2.	At 8th floor	37.44	32.9	45.65	96.73
3.	At 12th floor	36.6	31.6	44.32	94
4.	At 8th and 16th floor	35.89	30.4	43.87	91.56
5.	At 12th and terrace floor	35.3	31.53	43.02	94.15
	Simultaneously at two floors				
6.	At 8th and 9th floor	34.26	32.05	42.13	95.38
7.	At 13th and 14th floor	36.3	31.92	41.29	95.75
8.	At 8,9th and 16,17th floor	32.76	26.02	40.89	87.63
9.	At 12,13th and 24, terrace floor	30.87	29.85	38.73	89.23
WITH BELT TRUSS AS X-BRACE					
10.	At 8th floor	38.15	34.62	46.18	97.98
11.	At 12th floor	37.9	33.62	45.69	96.32
12.	At 8th and 16th floor	30.2	29.3	39.16	90.15

13.	At 12th and terrace floor	31.1	30.15	41.12	91.23
	Simultaneously at two floors				
14.	At 8th and 9th floor	34.82	32.7	42.63	96.01
15.	At 12th and 13th floor	34.24	32.9	42.48	95.76
16.	At 8,9th and 16,17th floor	29.32	27.45	38.32	89
17.	At 12,13th and 24, terrace floor	32.8	30.85	40.78	91.56

Figure 4 shows shear wall at 8th floor and figure 5 shows X-brace at 8th floor.

IV. LOAD COMBINATION

The results obtained from the computer analysis in the form of member forces and reactions will be used for design the structural members. Following load combinations of the member forces will be considered for arriving at the design forces.

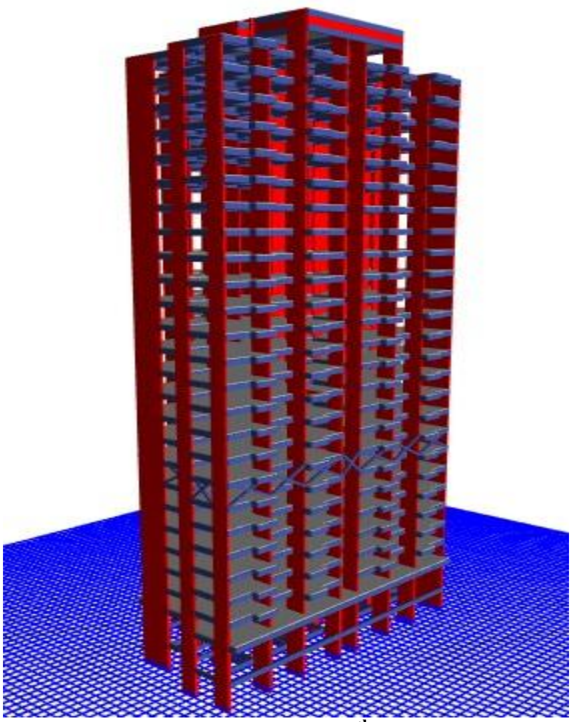

Fig. 5. X-brace at 8th floor

Load combinations:
1.5 Dead + 1.5 Live
1.5 Dead ± 1.5 Wx/Wy/EQx/EQy
1.2 Dead + 1.2 Live ± 1.2 Wx/Wy/EQx/EQy
0.9 Dead ± 1.5 Wx/Wy/EQx/EQy
Suffixes x and y in the above table indicate the direction in which the force is applied.

All members will be designed for the largest value of the design forces obtained due to positive as well as negative values of reversible forces (Wind and Earthquake).

V. RESULT AND DISCUSSION

In present study the different parametric studied are lateral storey displacements and storey drift using ETABS.

Followings graphs represents values without belt truss, with belt truss as shear wall and x-bracing.

A. Lateral Displacement:

From the figures 6 and 7 it is observed that lateral displacement for response specturm method is reduced by 21% in X direction and 18% in Y direction,by applying shear and X bracing as belt truss system.

From the figures 8 and 9 it is observed that lateral displacement for wind analysis is reduced by 16% in X direction and 23% in Y direction,by applying shear and X bracing as belt truss system.

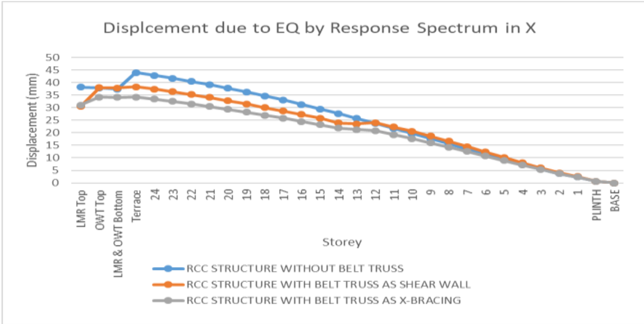

Fig.6. Lateral displacement for Response spectrum in X-direction

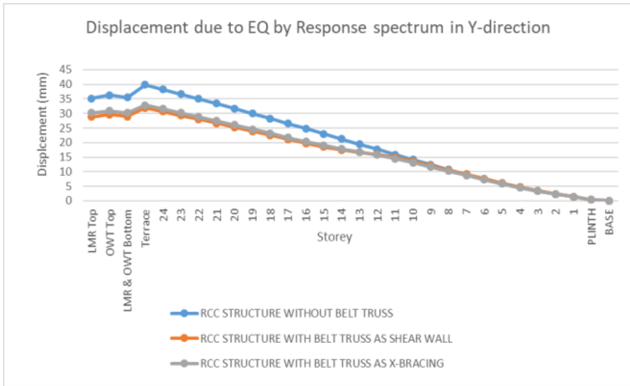

Fig.7. Lateral displacement for response spectrum in Y-direction.

B. Storey drift:

By applying shear and X bracing as belt truss system, it is observed that drift for response specturm method is reduced by 48% in X direction and 42% in Y direction for partocular floor's as shown in figures 10 and 11.

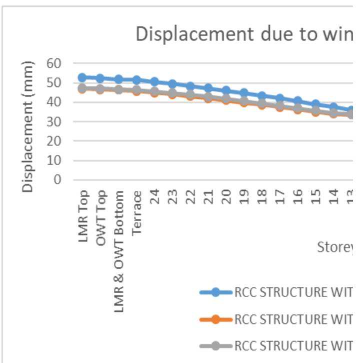

Fig.8. Lateral displacement for wind in X-direction

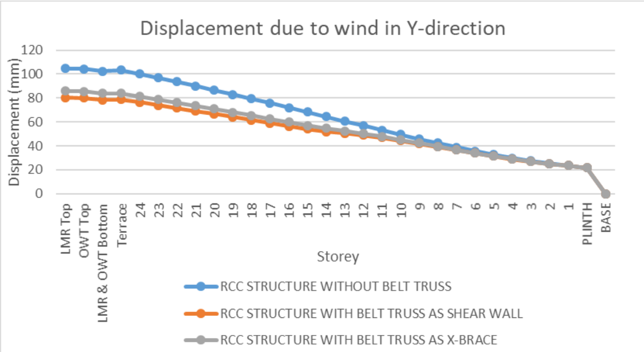

Fig.9. Lateral displacement for wind in Y-direction

By applying shear and X bracing as belt truss system, it is observed that drift for wind analysis is reduced by 44% in X direction and 49% in Y direction for particular floor's as shown in figures 12 and 13.

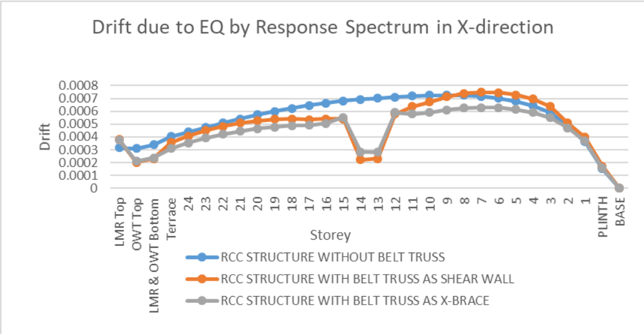

Fig.10. Drift for Response spectrum in X-direction

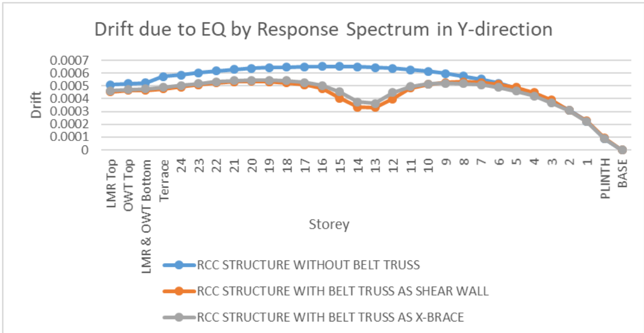

Fig.11. Drift for response spectrum in Y-direction

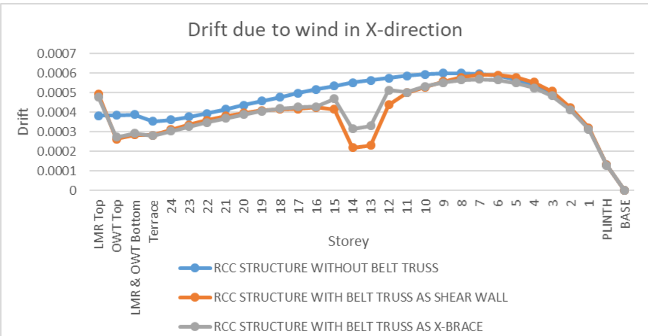

Fig.12. Drift for wind in X-direction

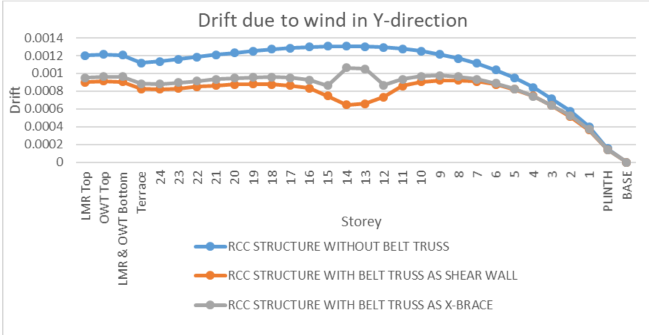

Fig.13. Drift for wind in Y-direction

VI. CONCLUSION

Here, different techniques were proposed for the application of belt truss as an outrigger. As the results were discussed, in the previous section, for G+24 building by applying belt truss at different locations. Thus from the discussion of above observations and results, we come to the following concluding statements as:

1. The use of belt truss structural systems in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load.
2. Results were found to be more less at different location, but the optimum location was observed at 13th and 14th floor.
3. Lateral deflection was reduced by 21% and 18% in Response spectrum method, while in wind it was reduced by 16% and 23% in X and Y direction.
4. Drift at particular floor was reduced by 48% and 42% in Response spectrum method, while in wind it was reduced by 44% and 49% in X and Y direction.
5. Provision of belt truss results in well distribution of design reaction and axial force in perimeter column that will help in column design to maintain same size of column and help to reduce column sizes.

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