PARAMETRIC STUDY ON MULTI-STOREY RC BUILDING WITH BELT TRUSS SYSTEM

With Inner Shear Core and outer Shear Wall

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Abstract : ***Due to the advances in structural systems nowadays building became light weight, and slenderness is increased. Which is the reason why the lateral loads are required to be considered. These lateral loads are wind and earthquake load. For resistance of this lateral loads in tall buildings, identification of proper structural system is must. For lateral resistance of tall buildings, there are many structural systems. In tall buildings, the stiffness of the building becomes more important. Thus, the belt truss outrigger system is used in tall building to provide sufficient lateral stiffness. Outrigger and belt truss system is one of the structural system which controls the excessive drift due to lateral load. The risk of structural and non-structural damage can be lowered during wind or earthquake load by using this system. Outriggers in the building results in less usable space on particular floors. In this research work the behaviour of building having 2 belt trusses with outrigger system and building having 3 belt trusses with outer shear wall are studied for 30, 40 and 50 storey RC buildings.***

Key Words - Belt Truss System, Outriggers, Tall Building, Optimum Position, Outer Shear Wall

I. INTRODUCTION

From the establishment of civilization, tall towers and buildings have enthralled mankind. Contemporary tall buildings begin to development in the 1880 has mostly for commercial and residential building purposes [1]. Due to quick increment of population and for it limited space available tends to increase tall buildings. Tall buildings are generally built based on commercial or residential purposes. Vertical, horizontal or torsion type of loads give various effects on building. The primary function of the structural elements is to resist the gravity loading from the weight of the building and its contents and secondary function of the vertical structural elements is to resist the wind and earthquakes whose magnitude will be varied from the epicenter to epicentral distance whose magnitude obtained in the IS 1893 2002 code book [1]. As height of structure increases its displacement, story shear, story drift of the building decreases. To restrain those parameter in the building under seismic and wind load, suitable method to be taken to reduce those effect [1]. The design of tall and slender structures is controlled by three governing factors, strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loading, such as wind [2]. By the advances in structural design/systems and high strength materials, building weight has reduced, in turn increasing the slenderness, which necessitates taking into account majorly the lateral loads such as wind and earthquake [3]. Specifically, for the tall buildings, as the slenderness, and flexibility increases, buildings are severely affected from the lateral loads resulting from wind and earthquake [3].

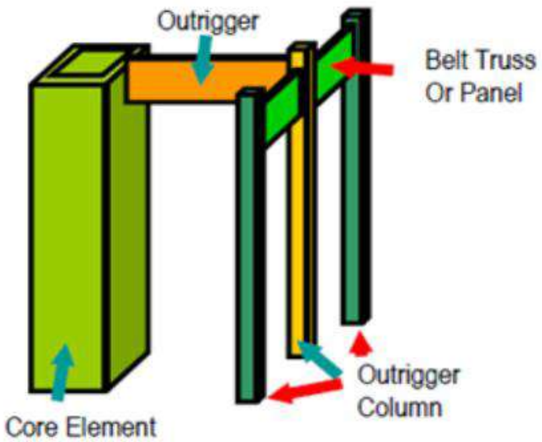


Figure 1.1 Outrigger and belt truss [2]

Hence, it becomes more necessary to identify the proper structural system for resisting the lateral loads depending upon the height of the building [3]. There are many structural systems that can be used for the lateral resistance of tall buildings like Braced frame systems, Rigid frame systems, Outrigger systems, Shear-walled frame systems [3]. Figure 1.1 shows the outrigger and belt truss system.

During the last few decades several buildings have been built utilizing belt truss and outrigger system for the lateral loads transfer (throughout the world) [4]. The efficiency of the building structure may be improved by the use of horizontal belt trusses that tie the frame to the core (Schueller 1977) [5].

II. OUTRIGGER AND BELT TRUSS

Outrigger systems are modified form of braced frame and shear-walled frame systems [7]. To brace medium high-rise structures, general method is bracing around the core and stair wells [8]. In conditions with restriction using this method (buildings higher than 150 meter), lateral bracing system is employed as an effective solution [8]. This system consists of joined shear walls with outriggers that are able to restrain inter-storey drift under wind and earthquake loads and also decrease moment of core element and its dimension [8]. Outrigger beams are connected directly to shear walls or braced frames at the core element and external columns which are tied by peripheral truss in that level (Figure 1.1).

When the lateral load acts on the structure, the bending of the core rotates the stiff outrigger arms, which is connected to the core and induces tension and compression in the columns and forced double curvature increase its flexural stiffness [8] (Figure 2.1).

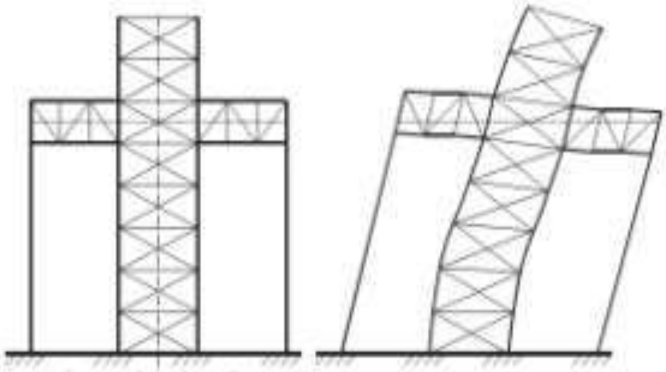


Figure 2.1 Performance of outrigger system against lateral load [8]

III. PROBLEM WITH OUTRIGGER AND BELT TRUSS SYSTEM

There are several problems associated with the use of outriggers, problems that limit the applicability concept in the real world [9].

a) The space occupied by the outrigger trusses places constraints on the use of the floors at which the outriggers are located. Even in the mechanical equipment floors, the presence of outrigger truss members can be a major problem.

b) Architectural and functional constraints may prevent placement of large outrigger columns where they could most conveniently be engaged by outrigger trusses extending out from the core.

IV. LITERATURE SURVEY

In 2017 Y.B. Meshram[3] conducted the analysis on g+20,30,40 multi storey steel building having bar belt truss system against earthquake and wind loads. In it, it is observed that X type of belt truss system is suitable for all type of models in that study. It is concluded that shear wall provision is effective for 20 storey building. For 30 and 40 storey building X type belt truss outrigger system is more effective.

N. Herath[10] aimed to derive the optimum outrigger location in tall buildings under earthquake masses in 2009. They concluded that the optimum location of the structure is between 0.44-0.48 times its height.

V.K.Gowda[1] conducted a comparative study on different type of belt trusses and derive which of it provide more economical for human beings under different seismic zone criteria with and without shear core for building. He concluded that the concrete belt truss is more efficient in reducing the lateral displacement and storey drift for the concrete building. We should not use steel type of belt truss to the concrete building which gives negligible results.

Shivacharan K[2] studied the use of outrigger and belt truss placed at different location subjected to wind and earthquake load. In it, it is concluded that the optimum location of the outrigger is between 0.5 times of buildings height.

PMB Rajkiran[6] studied optimum location of outrigger, its behaviour and efficiency of every outrigger when three outriggers are used in the building. In it, it is concluded that using second outrigger with cap truss gives the reduction of 18.55% and 23.01% with and without belt truss. The optimum location of second outrigger is middle height of the building.

V. OBJECTIVE OF THE STUDY

Following are the main objectives of the present study:

a) To analyse 30, 40 and 50 storey RC building with outrigger belt truss having shear core.

b) To analyse 30, 40 and 50 storey RC building having outer shear wall connected with belt truss.

c) To analyse the models by equivalent static and response spectrum method as per IS 1893 – 2002.

d) To analyse displacement, story drift, base shear and time period for different height of building.

VI. STRUCTURAL MODEL

Here 30, 40 and 50 storey RC buildings having bar belt truss system with a plan size of 38.5m x38.5m is taken for study. Figure 6.1 and 6.2 shows the plan of building having shear core and with outer shear wall respectively. There are 7 bays of 5.5m in both side. The height of each storey is 3m. Shear walls are 300mm thick. Other data are given in table 6.1. Surat city of India is taken as building location. Here total 3 models for each height of the buildings are created using ETABS 2016 software. These three models are as follow.

Model I: Building having shear core with 2 belt trusses connected by outriggers.

Model II: Building having outer shear wall connected with 2 belt trusses.

Model III: Building having outer shear wall connected with 3 belt trusses.

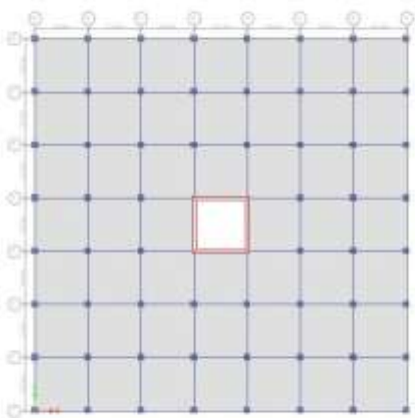


Figure 6.1 Plan of building with shear core

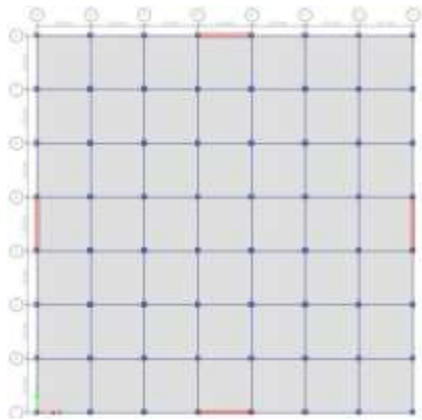
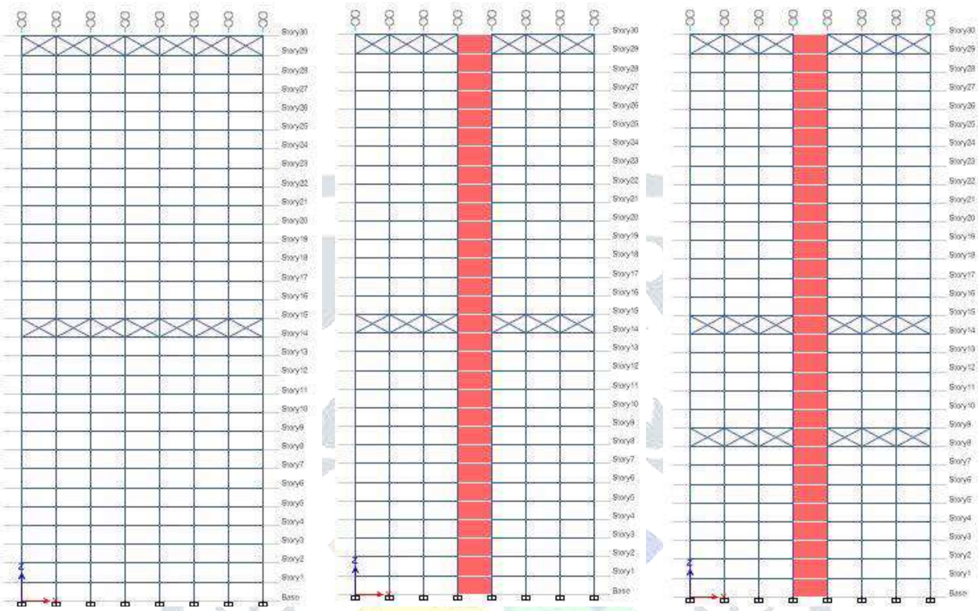


Figure 6.2 Plan of building with outer shear wall

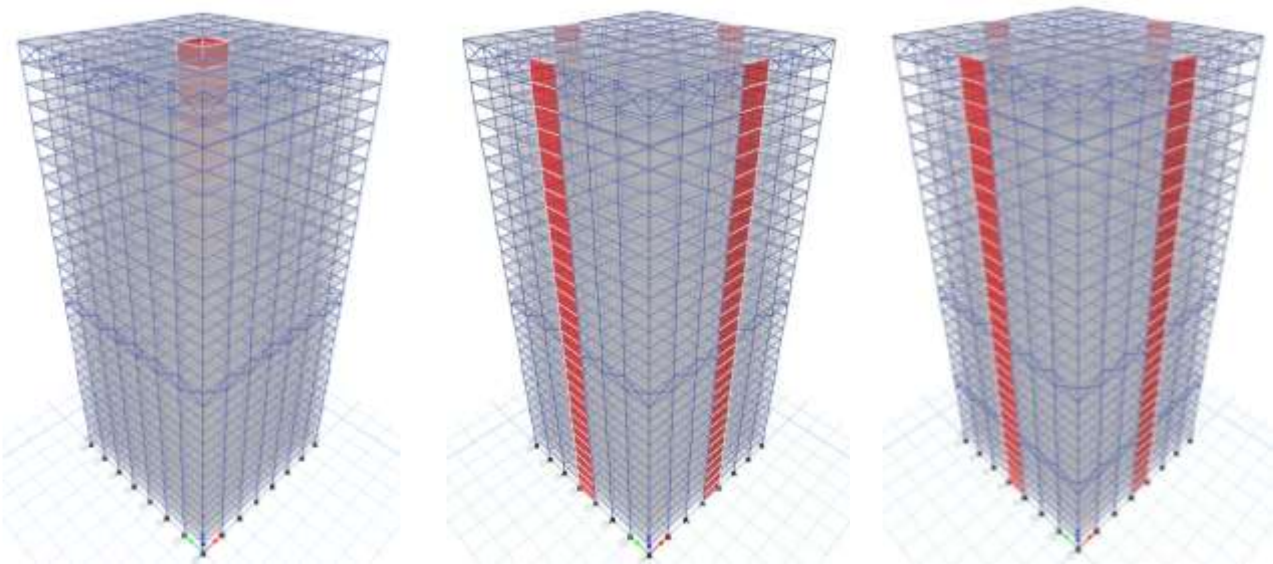


(a) (b) (c)

Figure 6.3 Elevation (a) Model I (b) Model II (c) Model III

Table 6.1 Data for analysis of RCC structure

Sr. No.	Name	30 Storey	40 Storey	50 Storey
1	Plan Dimension	38.5m x 38.5m	38.5m x 38.5m	38.5m x 38.5m
2	Height	90 m	120 m	150 m
3	Height of each story	3 m	3 m	3 m
4	Beam Size	380mmx680mm	380mmx680mm	380mmx680mm
5	Column Size	600mmx600mm	680mmx680mm	760mmx760mm
6	Braces Size	380mmx680mm	380mmx680mm	380mmx680mm
7	Thickness of Shear wall	300 mm	300 mm	300mm
8	Thickness of Slab	150 mm	150 mm	150 mm
9	Grade of Concrete	M40	M40	M40
10	Grade of Reinforcement Steel	Fe500	Fe500	Fe500
11	Seismic Zone	III	III	III
12	Wind Speed	39 m/s	39 m/s	39 m/s
13	Importance Factor	1.5	1.5	1.5
14	Zone Factor	0.16	0.16	0.16
15	Damping Ratio	5%	5%	5%
16	Soil Condition	Medium	Medium	Medium
17	Floor Finish	1 kN/m^2	1 kN/m^2	1 kN/m^2
18	Live Load at all Floor	4 kN/m^2	4 kN/m^2	4 kN/m^2
19	Density of Concrete	25 kN/m^3	25 kN/m^3	25 kN/m^3
20	Density of Brick	20 kN/m^3	20 kN/m^3	20 N/m^3



(a) (b) (c)

Figure 6.4 3D model (a) Model I (b) Model II (c) Model III

VII. Analysis of models

The structure is analyzed as per the loading combinations provided in IS: 456-2000. The following load combinations are used to determine the maximum lateral deflection in the structure.

i) DL+LL
ii) DL+LL±WL(x or y)
iii) DL+LL±EL(x or y)
iv) DL±WL(x or y)
v) DL±EL(x or y)

The structure with above mentioned specifications and assumptions is analyzed using the program ETABS and maximum story displacement, maximum story drift, base shear and time period are calculated for both Wind & Earthquake loading.

VIII. RESULTS AND DISCUSSION

8.1 Belt Truss Location

Here 1st and 2nd belt truss location is derived from the conclusions of different research papers, but 3rd belt truss location is derived by try and error method.

Table 8.1 Belt truss location

Floor No.	Belt Truss	30 Story	40 Story	50 Story
Model I	1^{st}	30^{th}	40^{th}	50^{th}
	2^{nd}	15^{th}	20^{th}	25^{th}
Model II	1^{st}	30^{th}	40^{th}	50^{th}
	2^{nd}	15^{th}	20^{th}	25^{th}
Model III	1^{st}	30^{th}	40^{th}	50^{th}
	2^{nd}	15^{th}	20^{th}	25^{th}
	3^{rd}	9^{th}	11^{th}	13^{th}

8.2 Maximum Story Displacement

Maximum story displacement results of the 30, 40 and 50 story buildings are as shown in table 8.2.

Table 8.2 Maximum story displacement

Maximum Displacement (mm)	30 Storey	40 Storey	50 Storey
Model I	212.03	332.92	461.62
Model II	238.28	354.31	477.15
Model III	199.98	308.96	426.61

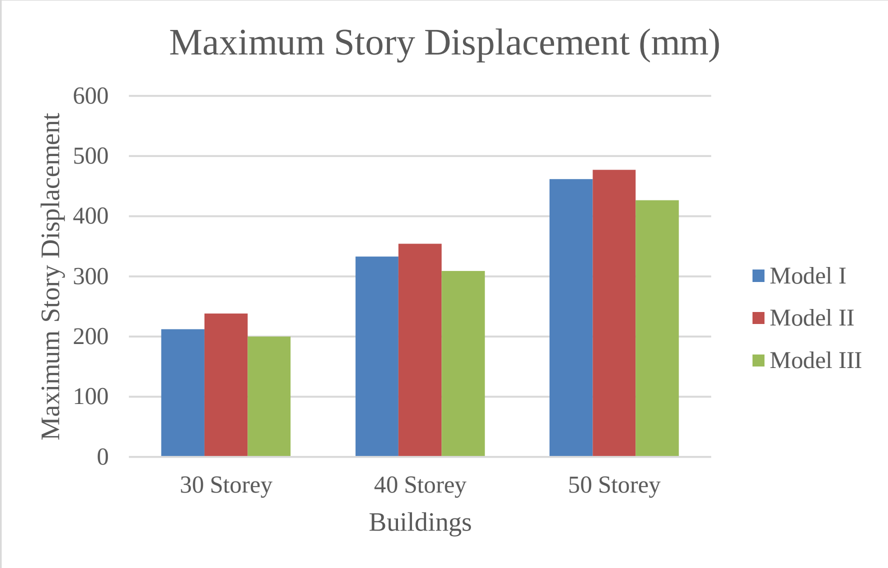


Figure 8.1 Maximum story displacement graph

After analysing data of maximum displacement, we get results as below.

a) For 30 storey reductions in maximum displacement is 5.68%.
b) For 40 storey reductions in maximum displacement is 7.2%.
c) For 50 storey reductions in maximum displacement is 7.57%.

8.3 Maximum Story Drift

Maximum story drift results of the 30, 40 and 50 story buildings are as shown in table 8.3.

Table 8.3 Maximum story drift

Maximum Story Drift (mm)	30 Storey	40 Storey	50 Storey
Model I	3.271	3.83	4.221
Model II	3.829	4.162	4.403
Model III	3.022	3.34	3.687

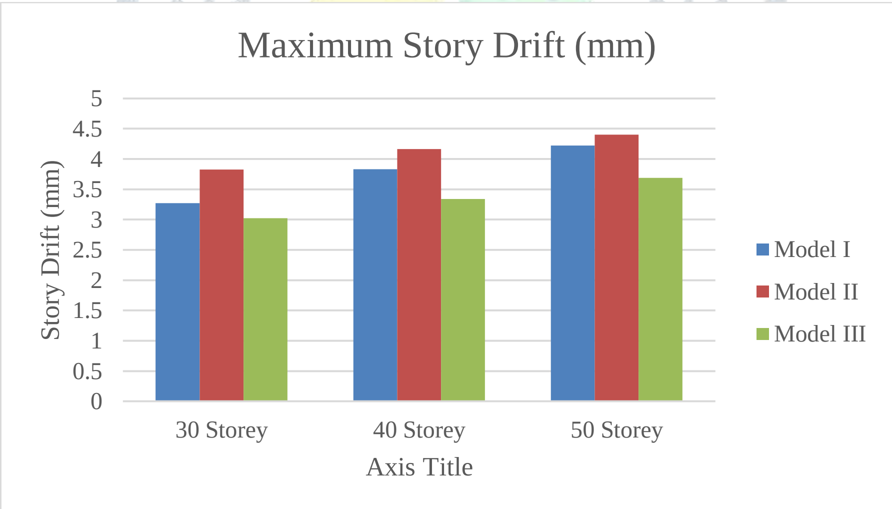


Figure 8.2 Maximum story drift graph

After analysing data of maximum story drift, we get results as below.

a) For 30 storey reductions in maximum story drift is 7.61%.
b) For 40 storey reductions in maximum story drift is 12.79%.
c) For 50 storey reductions in maximum story drift is 12.65%.

8.4 Base Shear

Base shear results of the 30, 40 and 50 story buildings are as shown in table 8.4.

Table 8.4 Base shear

Base Shear (kN)	30 Storey	40 Storey	50 Storey
Model I	22797.75	23306.98	23942.88
Model II	22945.37	23554.32	24272.94
Model III	23042.49	23627.16	24331.21

Figure 8.3 Base shear graph

After analysing data of base shear, we get results as below.

a) For 30 storeys increase in base shear is 1.07%.
b) For 40 storeys increase in base shear is 1.37%.
c) For 50 storeys increase in base shear is 1.62%.

8.5 Time Period

Results of time period of 30, 40 and 50 story buildings are as shown in table 8.5.

Table 8.5 Time period

Time Period (sec)	30 Storey	40 Storey	50 Storey
Model I	4.14	5.90	7.77
Model II	4.39	6.14	7.94
Model III	3.89	5.57	7.33

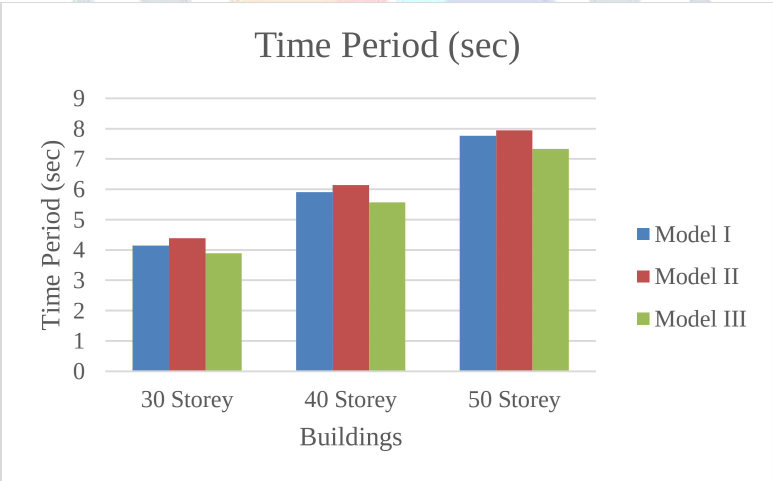


Figure 8.4 Time period graph

After analysing data of time period, we get results as below.

a) For 30 storeys increase in time period is 6.01%.
b) For 40 storeys increase in time period is 5.64%.
c) For 50 storeys increase in time period is 5.68%.
d)

IX. CONCLUSION

Analysis results of 30, 40 and 50 storey RC building are shown in result chapter. The comparison of results of all building models shows that: -

a) The optimum position of the 3rd belt truss in the building is near about 0.275 times of the height of the building.
b) Outer shear wall with 3 belt trusses is more effective than inner shear wall with 2 belt trusses.
c) Displacement reduction in building having outer shear wall with 3 belt trusses is 5.68%, 7.2% and 7.57% respectively for 30, 40 and 50 storeys building in comparison to building having inner shear wall with 2 belt trusses.
d) Providing outer shear wall with belt truss system eliminates the outrigger from the building (In case of inner shear wall).
e) Elimination of outrigger from building, free up the space in the building occupied by them.
f) 3rd belt truss' cost is balanced by elimination of outriggers from the building.

X. References

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