Study on position of outrigger system in tall structure

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***Abstract*-The design of high-rise building is more often affected by its serviceability rather than the strength of the building. Structural engineers always endeavoring to overcome difficulties of controlling lateral deflection and story drifts additionally self-weight of structure imposed on foundation. One of the most efficient solution is the use of outrigger and belt truss system in composite structure that can solve the described issues in Tall structures. This thesis investigates deflection control by effective utilization of belt truss and outrigger system for 40-storey, 60-storey and 80-storey composite building subjected to Gravity and Earthquake loads. A 3D F.E.M. models have been arranged and analysis have been performed for Different location of outrigger System. Reduction in lateral deflections is compared to a model without Outrigger system. Previous study also shows that outriggers are also capable of reducing the inter story drifts in composite buildings. At the end of Analysis, we found that, by using outrigger and belt truss deflection is reduced, Time period also get reduce which leads to increase in natural frequency of the structure. Graphical representations for Deflection are shown for all different heights of models which are 40-Storey, 60-Storey and 80-Storey.**

Keywords – Lateral deflection; Outrigger; Storey Drift; Time Period; Natural Frequency

I. INTRODUCTION

Structural designing is field of building sciences, identified with configuration, development and support of structures, dams, bridges, tunnels, thruways and different structures by the utilization of physical laws, numerical comparisons and hypotheses of mechanics. Structural Designers use the accessible assets (skill, materials, labour) to finish the task in the given time compass keeping in perspective the time, use, natural issues and physical perils of the venture.

A 'tall building' or 'elevated structure' is a building whose tallness makes distinctive conditions in the configuration, development and use than those that exist in like manner structures of certain area and period.The tallness of a building is a matter of a man's or group's recognition in this way, a specific meaning of a tall building can't be all around connected. Tall building structures outline requires unique basic courses of action, on the off chance that they are subjected to apparent sidelong loads, for example, high wind weights and tremor loading. Design of high rise building has its challenges. Different structural systems have been developed to control the lateral displacement of high rise buildings. There are many Structural systems which have been adopted in Tall structure with variation in Height.

Tall structures are totally refined engineering projects. Due to the complexity of the constructions, probably the most developed engineering design procedures are needed in tall structures. To strengthen these strategies, new and current research and empirical reviews need to be documented in a usable and accessible form.In 1969 Fazlur Khan classified structural systems for tall constructions with regards to their heights with considerations for efficiency in the form of “Heights for Structural System” diagrams (Khan, 1969). This marked the establishing of a new technology of skyscraperrevolution in terms of more than one structural techniques. Later, he upgraded these diagrams by way of modifications (Khan, 1972, 1973).

II. SCOPE OF WORK

Project work is limited to the study of the overall performance of outrigger-braced composite structure with RCC frame, Shear Core and Steel truss outrigger beam as well as Belt Truss. Additionally, the slab stiffness contribution is taken into account, as it is an important element in contributing to the lateral stiffness of a structure. Analytical Study on multi story composite structure with Single Level of Outrigger and Belt Truss for Gravity and Seismic loading for 180 m building situated in Ahmadabad (ZONE-III) using SAP2000‘15 software. In this Study some parameters kept constant likewise condition of Foundation, Number of Level of Outrigger, and Axial rigidity of Columns and Flexural Rigidity of Outrigger Members.

III. LOADINGS

Load acting on the tall buildings can be classified into two type they are load due to gravity and lateral load due to the earthquake.

A) GRAVITY LOAD

The loads acting vertically downward due to the action of the gravitational force are called gravity loads. This is classified as self-weight of structure and the live load in the structure.
The self-weight of the structure is the overall weight of the structural elements such as,
a) Slab weight- The slab is 115 mm thick and no change of the thickness in models and throught out the height of the structure.
b) Beams-The size of the beam is 300 x 600 mm which is same for all models
c) Column- The cross sectional dimension of the column depend upon the plan layout, Height of the structure and Load it carries. Thus, the software calculates load as per its cross-section.
d) Super imposed dead load this comprises of the floor finish and Wall load which is 1.5 kN/m^2 and 6 kN/m respectively.
e) Live load (LL) The live load comprises the self-weight of humans and they are highly variable. As per IS-875(part-II) code suggests to take 4 kN/m2 for office buildings.

B) LATERAL LOAD

Lateral load due to the earthquake. The structure is considered in the Ahmedabad region since most of the tall structure in Gujarat is in Ahmedabad. The earthquake loads are calculated according to the IS 1893(PART 1) – 2002 the details of the loading and clauses of the codes are specified in table 1.

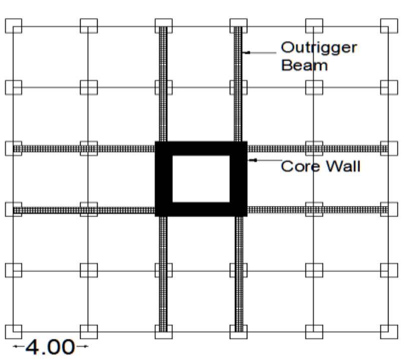
Table1: Earthquake loading details as per IS1893 (PART 1) – 2002

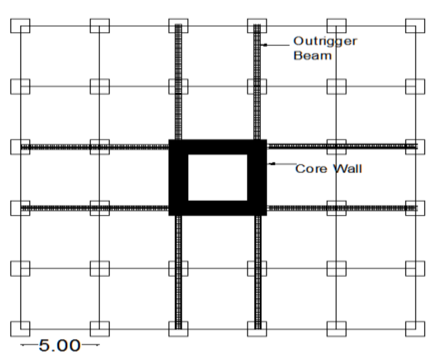
Earthquake Zone	3
Importance factor	1
Response Reduction factor	5 (SMRF with shear wall)
Soil Type	I (hard and Rocky)
Fundamental Time Period	For 40-Storey = 2.72 sec
	For 40-Storey = 3.69 sec
	For 40-Storey = 4.57 sec

IV. ASPECT RATIO

The height limits have been shown in the introductory part of thisthesis therefore presumptive based on Literatures and the predictionwithin an acceptable range of aspect ratios of the buildings, say about 6to 8 can be taken. So, for this study aspect ratios are taken as 6, 7 and 8.
For Aspect Ratio = 6, Building Height is 120 m and Plan Dimension are20 m X 20 m
For Aspect Ratio = 7, Building Height is 180 m and Plan Dimension are25 m X 25 m
For Aspect Ratio = 8, Building Height is 240 m and Plan Dimension are30 m X 30 m

V. LAYOUT OF BUILDING PLAN





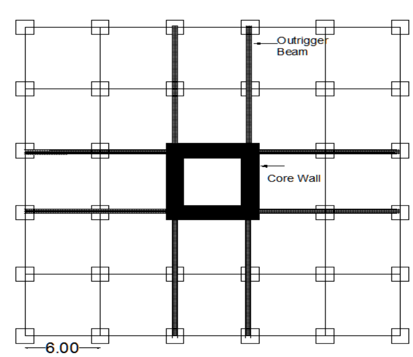


Figure 1 Building Plan 40-Storey
20 m x x20 m

Figure 2 Building Plan 60-Storey
25 m x 25 m

Figure 3 Building Plan 80-Storey
30 m x 30 m

The models considered for this study are 120m, 180m and 240m high rise composite building frames. The building represents a 40-storey.60-storey and 80-storey office building respectively. The Plan area of the Structure is 20 m x 20 m, 25 m x 25 m and 30 m x 30 m with columns spaced at 4 m, 5 m and 6 m from center to center respectively. The height of each Storey is 3.00m and all the floors are considered as Typical Floors. The location of the building is assumed to be at Ahmedabad.

VI. OUTRIGGER ARRANGEMENTS IN MODEL

Table 2: Model Arrangements

	Model Title	Model Arrangement
Outrigger Placement	**40-Storey (Aspect Ratio = 6)**	
	40-1	Without Outrigger
	40-2	Outrigger at Top
	40-3	Outrigger at Mid Height
	40-4	Outrigger at Top and Mid Height
	60-Storey (Aspect Ratio = 7)	
	60-1	Without Outrigger
	60-2	Outrigger at Top
	60-3	Outrigger at Mid Height
	60-4	Outrigger at Top & Mid Height
	60-5	Outrigger at Top and 2/3 Height
	60-6	Outrigger at 1/2 Height, 2/3 Height
	60-7	Outrigger at Top, 1/2 Height and 2/3 Height
	80-Storey (Aspect Ratio = 8)	
	80-1	Without Outrigger
	80-2	Outrigger at Top
	80-3	Outrigger at Mid Height
	80-4	Outrigger at Top & Mid Height
	80-5	Outrigger at Top and 2/3 Height
	80-6	Outrigger at 1/2 Height, 2/3 Height
	80-7	Outrigger at Top, 1/2 Height and 2/3 Height

VII. STRUCTURAL ELEMENT

Reinforced concrete sections are provided for main beams and columns as well as for shear wall. Beams are typically of 4m. 5m, and 6m span with same center to center distance and supported on columns.

Table 3: Structural Elements

No. of Storey	40	60	80
Section	Dimension	Dimension	Dimension
Slab	115 mm thick	115 mm thick	115 mm thick

Beam	300 mm X 600 mm	300 mm X 600 mm	300 mm X 600 mm
Column	900 mm X 900 mm	1200 mm X 1200 mm	1400 mm X 1400 mm
Core Wall	300 mm thick	600 mm thick	900 mm thick
Belt Truss & Outrigger	ISWB-600	ISWB-600	ISWB-600

VIII. METHODOLOGY

This chapter consist of Modelling Process and Analysis of all models and from that all necessary outputs were carried out. Here Steps of Modelling and Application of Load is given.

- Preparing Finite Element Model of Building using SAP 2000 V15
- Modelling Shear wall core.
- Modelling of Outriggers and Belt– Truss
- Dead Load and Live Load are calculated as per IS 875 (part – I and II).
- Earthquake load have been calculated as per IS 1893 (part-I), in which Response Spectrum method is used for calculating Lateral Loads.

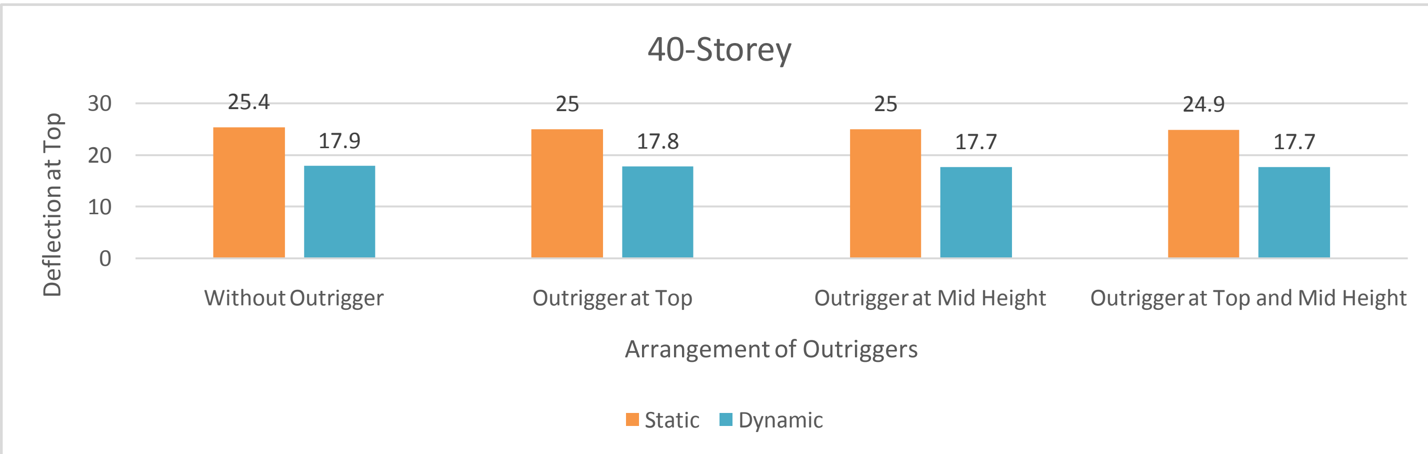
IX. ASSUMPTIONS FOR ANALYSIS

The procedure of analysis is situated on the following assumptions:

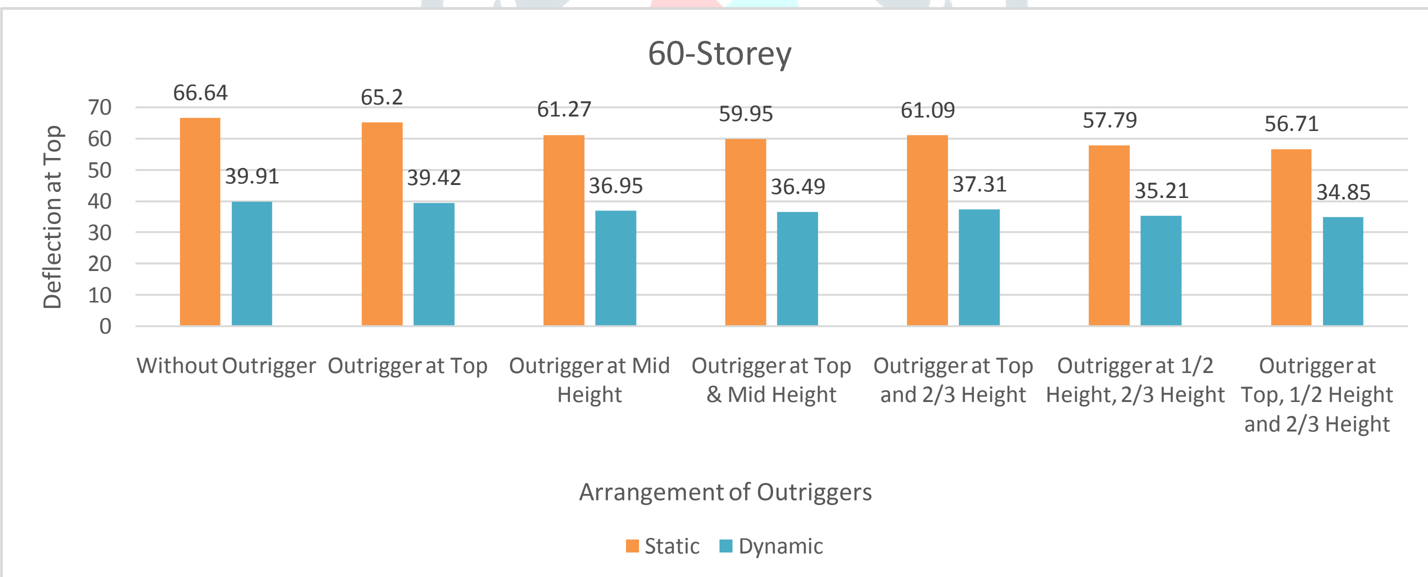
- The structure is linear elastic;
- Only axial forces are induced within the columns;
- The outriggers are rigidly connected to the core;
- The core is rigidly connected to the foundation;
- The sectional properties of the core, columns, and outriggers are uniform during their height.

Table 4: Results for Deflection at Top

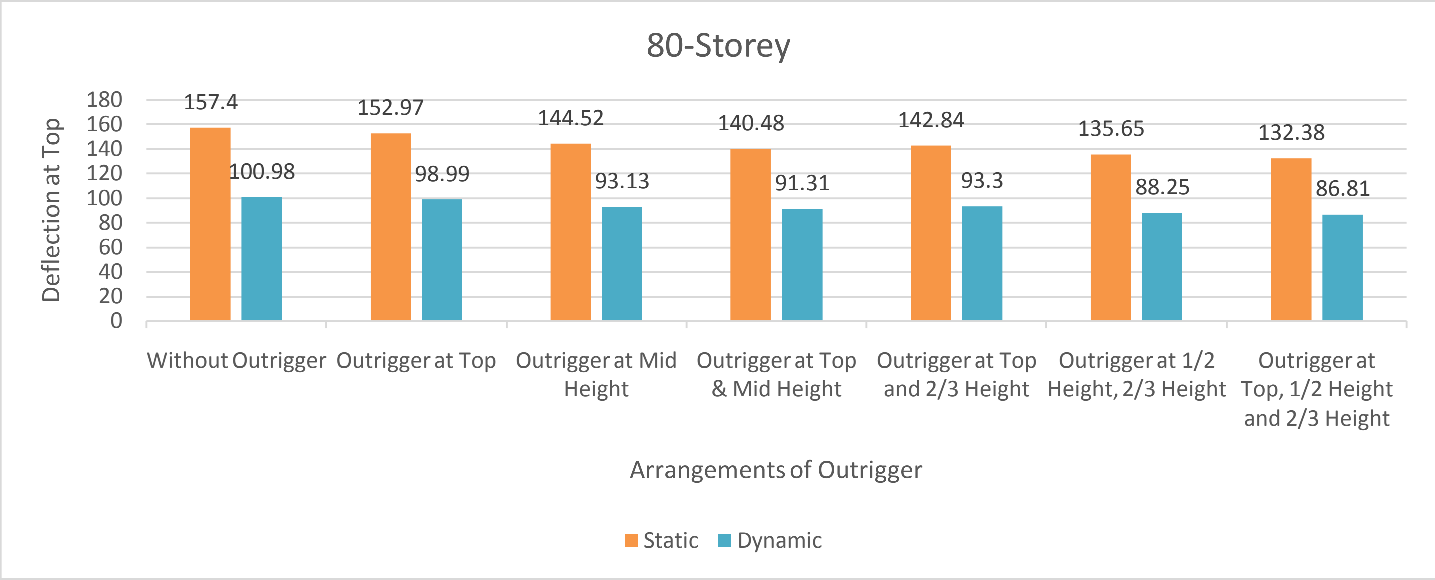
Outrigger Placement	Model Title	Model Arrangement	Deflection at Top (mm)	
			Static	Dynamic
	40-Storey (Aspect Ratio = 6)			
	40-1	Without Outrigger	25.4	17.9
	40-2	Outrigger at Top	25	17.8
	40-3	Outrigger at Mid Height	25	17.7
	40-4	Outrigger at Top and Mid Height	24.9	17.7
	60-Storey (Aspect Ratio = 7)			
	60-1	Without Outrigger	66.64	39.91
	60-2	Outrigger at Top	65.2	39.42
	60-3	Outrigger at Mid Height	61.27	36.95
	60-4	Outrigger at Top & Mid Height	59.95	36.49
	60-5	Outrigger at Top and 2/3 Height	61.09	37.31
	60-6	Outrigger at 1/2 Height, 2/3 Height	57.79	35.21
	60-7	Outrigger at Top, 1/2 Height and 2/3 Height	56.71	34.85
	80-Storey (Aspect Ratio = 8)			
	80-1	Without Outrigger	157.4	100.98
	80-2	Outrigger at Top	152.97	98.99
	80-3	Outrigger at Mid Height	144.52	93.13
	80-4	Outrigger at Top & Mid Height	140.48	91.31
	80-5	Outrigger at Top and 2/3 Height	142.84	93.3
	80-6	Outrigger at 1/2 Height, 2/3 Height	135.65	88.25
	80-7	Outrigger at Top, 1/2 Height and 2/3 Height	132.38	86.81



Graph 1. Deflection for 40-Storey Model



Graph 2. Deflection for 60-Storey Model



Graph 3. Deflection for 80-Storey Model

X. CONCLUSION

Here various models are analyzed by making Finite Element model in the SAP2000 having different aspect ratio including different arrangement of Outrigger and belt truss systems. After analyzing the 18 F.E.M. models in the SAP. Analysis results were carried out in the form of Tables as shown.

- The results are established after careful examination of data from SAP2000. The following results highlight the best fit outrigger for different height of structure.
- Best options for model are selected with respect to the number of outrigger and belt truss and placement of belt truss and outriggers and horizontal forces acting on structure.
- 40-storey is half the height of the 80-storey model at 120 m. This height was selected to establish a comparison and to find out the benefits of outriggers on such a low elevation
- The results of static and dynamic load show similarity in certain models and are completely different in others. The deflection values of static combinations are higher and for dynamic combination this values are lower comparatively.
- It is noted that for 40-storey building no major reduction in deflection is obtained and previous study also shows that outrigger system is beneficial for very tall building.
- Provision of outrigger and belt truss in 60 Storey and 80 Storey models shows the significant changes in the results obtained from the analysis. In the case of 60-storey model maximum deflection at roof is 66.64 mm in the case of static load case and 39.91 mm in dynamic load case. Maximum reduction is fond out in model no. 60-7 for 60 Storey which is 56.71 mm (14.90%). And in model n. 80-7 for 80 Storey which is 132.38 (15.90%).

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