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Comparative Analysis on Wind and Seismic Behaviour of Tall Structure Building with Outrigger System

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***Abstract:** With the ongoing trend of urban densification, the development of high-rise structures has been widely adopted as a solution to limited land availability. Structural performance under lateral forces such as wind and earthquakes has been regarded as a primary concern in the design of these tall buildings. To address this, outrigger systems have been employed as an effective method to enhance lateral stiffness and control structural displacement. In recent studies, shear walls have been proposed to function as outrigger elements, offering a more integrated and efficient approach to resisting lateral loads. In this research work, it has necessary to compute the outrigger shear wall should be applied at different floor level with a view of comparative analysis of seismic and wind effects which has not been observe yet. Simulations are conducted using an analysis software to assess the response of the selected tall structure (G+79). Different models have generated and comparative analysis has conducted to show the effects of wind and seismic forces and there intensity for that, one case without outrigger and five cases of with outrigger has applied over the structure. The response of the structure to see the performance including displacement, base shear and fundamental time period of entire structure has plotted in graphs and tables to show the percentage variations both horizontal comparative analysis. Finally in conclusion, remarks for each output has inscribe with comparative observations. At last, recommendations has given based on adaptability of the outriggers applications on tall structures based on Taranath's method.*
***Keywords:** Wind load, Gust Factor Method, Seismic Effects, Taranath's Method, Outrigger system, Tall Structure, Fundamental Natural Period*

I. INTRODUCTION

In tall buildings, lateral stiffness improvement and drift control under wind and seismic forces are achieved using the outrigger system, which is a structural mechanism commonly applied. The outer columns are connected to the central core—typically housing stairwells and elevators—through horizontal structural elements known as outriggers, by which the system functions. Lateral forces are distributed and overturning moments are reduced by these elements acting like stiff arms. Due to efficient structural behavior, ease of integration, and simplicity, the wall outrigger system has been increasingly recognized among truss-type, belt-type, and hybrid configurations. As outrigger elements, vertical shear walls extending horizontally from the core are used in this configuration. Overturning forces are resisted more effectively, and lateral load sharing is enabled by these walls engaging the perimeter columns. Mechanical and usable spaces are often uninterrupted because deep truss structures are avoided in wall outrigger systems, making them advantageous in architectural and structural coordination. Interior layouts are made more adaptable by aligning wall outriggers with service shafts or partition walls. Due to monolithic behavior and material continuity, wall outriggers offer considerable benefits in reinforced concrete high-rise buildings, although they are less flexible than steel truss outriggers for long-span axial force transfer. Drift and moment demand on the core can be significantly reduced when wall outriggers are placed at one-third or two-thirds of the building height. Interaction with perimeter framing or belt walls, proper detailing, and stiffness balancing are factors upon which their performance depends. Especially in regions sensitive to seismic and wind activity, lateral load control in reinforced concrete tall buildings is efficiently supported by wall outriggers, which provide a practical structural solution.

II. RESEARCH OBJECTIVES

Following heads shows the point of comparison of result parameters between various models during earthquake forces and wind forces for tall structure cases. They are divided into two different sections:-

A. Section I: Obtaining Results for all individual case

1) To determine the maximum displacement obtained for both X and Y direction for all tall structure cases.
2) To examine the base shear obtained for both X and Y direction for all tall structure cases.
3) To examine the time period of entire structure to show the stiffness for all tall structure cases.

B. Section II: Discussion on comparative analysis of effect of wall outrigger usage on entire structure with seismic and wind cases

1) Maximum Displacement in X direction
   a) To conduct a cumulative percentage wise comparative analysis of effect of using outrigger system on Maximum Displacement in X direction for seismic and wind cases.
   b) Comparison on Maximum Displacement in X direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method.
2) Maximum Displacement in X direction
   a) To conduct a cumulative percentage wise comparative analysis of effect of using outrigger system on Maximum Displacement in Y direction for seismic and wind cases.
   b) Comparison on Maximum Displacement in Y direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method.
3) Base Shear in X direction
   a) To conduct a cumulative percentage wise comparative analysis of effect of using outrigger system on Base Shear in X direction for seismic and wind cases.
   b) Comparison on Base Shear in X direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method.
4) Base Shear in Y direction
   a) To conduct a cumulative percentage wise comparative analysis of effect of using outrigger system on Base Shear in Y direction for seismic and wind cases.
   b) Comparison on Base Shear in Y direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method.
5) Fundamental Time Period
   a) To conduct a cumulative percentage wise comparative analysis of effect of using outrigger system on Fundamental Time Period for seismic and wind cases.
   b) Comparison on Fundamental Time Period for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method.

At last the observations and recommendations will be provided.

III.PROCEDURE AND 3D MODELING OF THE STRUCTURE

There are different cases considered in G+79 storey tall structure of same height cases has fixed so that response of the seismic and wind behaviour of the structure by the implementation of with and without wall outrigger member at different floor levels that could be analysed with input parameters taken shown in table 1, table 2 and table 3 shows list of models framed with assigned abbreviation for seismic and wind analysis as mentioned below:-

Table 1: Description of parameters taken for analysis

Parameters	Values used
Building configuration – Tall Structure	G + 79
Building type	Residential apartment
Total constructed plan area	30m x 30m = 900 m^2
Height of building	328 m from ground level
Height of each floor and depth of footing	4 m each and 4 m deep
Beam dimensions	900 mm x 700 mm 750 mm x 500 mm
Shear wall thickness	150 mm

Outrigger wall thickness	150 mm
Slab thickness & Staircase waist slab	155 mm both
Column dimensions	1250 mm x 1250 mm 950 mm x 950 mm 650 mm x 650 mm
Material properties	Concrete (M30) Steel (Fe 500)

Table 2: List of models framed with assigned abbreviation for seismic analysis

S. No.	Models framed for analysis for seismic effects	Abbreviation
1.	G+79 storey Residential Apartment with no outrigger application and considering seismic analysis	TS-SN
2.	G+79 storey Residential Apartment with single outrigger application and considering seismic analysis	TS-SA
3.	G+79 storey Residential Apartment with two outrigger application and considering seismic analysis	TS-SB
4.	G+79 storey Residential Apartment with three outrigger application and considering seismic analysis	TS-SC
5.	G+79 storey Residential Apartment with four outrigger application and considering seismic analysis	TS-SD
6.	G+79 storey Residential Apartment with five outrigger application and considering seismic analysis	TS-SE

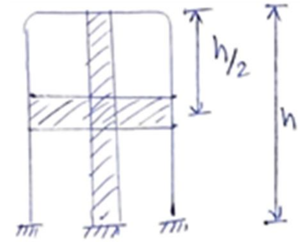
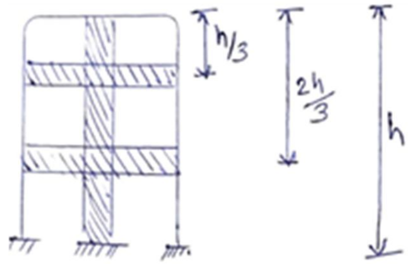
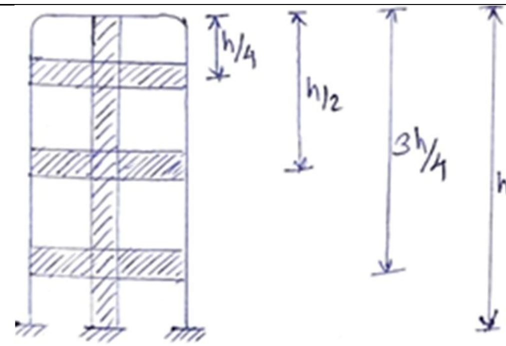
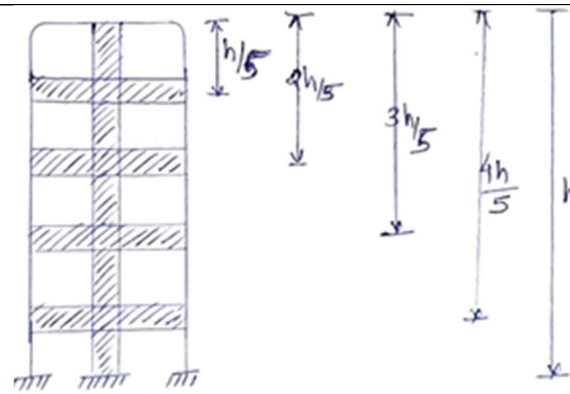
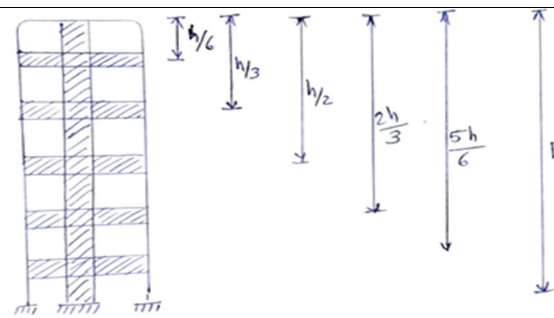
Table 3: List of models framed with assigned abbreviation for wind analysis

S. No.	Models framed for analysis for wind effects	Abbreviation
1.	G+79 storey Residential Apartment with no outrigger application and considering wind analysis	TS-WN
2.	G+79 storey Residential Apartment with single outrigger application and considering wind analysis.	TS-WA
3.	G+79 storey Residential Apartment with two outrigger application and considering wind analysis	TS-WB
4.	G+79 storey Residential Apartment with three outrigger application and considering wind analysis	TS-WC
5.	G+79 storey Residential Apartment with four outrigger application and considering wind analysis	TS-WD
6.	G+79 storey Residential Apartment with five outrigger application and considering wind analysis	TS-WE

A. Outrigger Calculation

Outrigger used single or multiple were selected and applied to the structure considering height from top of the tall structure as mentioned in the previous chapter as (1/n + 1), (2/n + 1), (3/n + 1),……(n/n + 1) respectively as per requirements. The table 4 shown below consist of outrigger case fixation and its story application calculation.

Table 4: Details of outrigger case fixation

Number of outriggers	Part divisions calculations	Outrigger diagram
Single Outrigger	$\frac{h}{2}$ & h	
Two Outriggers	$\frac{h}{3}, \frac{2h}{3}$ & h	
Three Outriggers	$\frac{h}{4}, \frac{h}{2}, \frac{3h}{4}$ & h	
Four Outriggers	$\frac{h}{5}, \frac{2h}{5}, \frac{3h}{5}, \frac{4h}{5}$ & h	
Five Outriggers	$\frac{h}{6}, \frac{h}{3}, \frac{h}{2}, \frac{2h}{3}, \frac{5h}{6}$ & h	

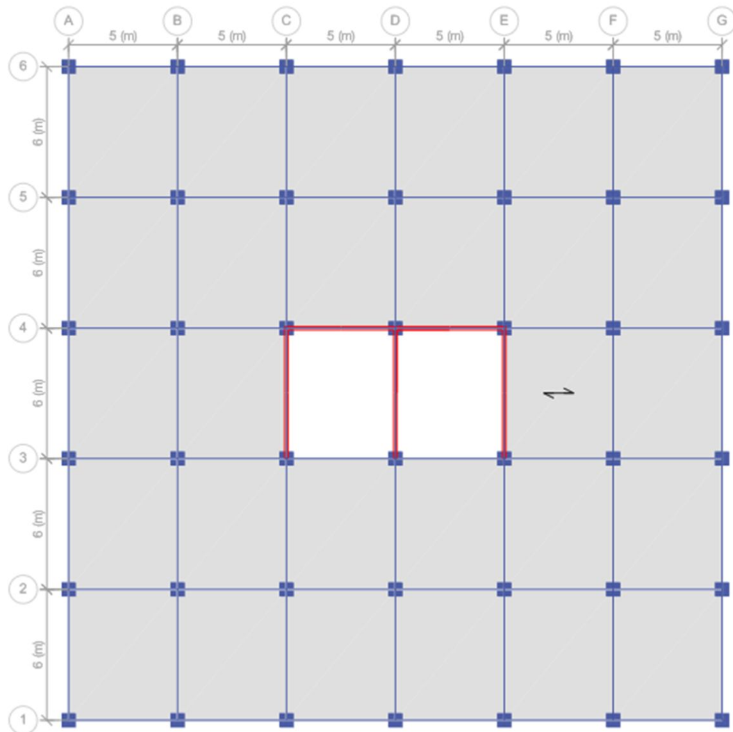


Fig. 1: Without wall outrigger – Plan of the tall structure

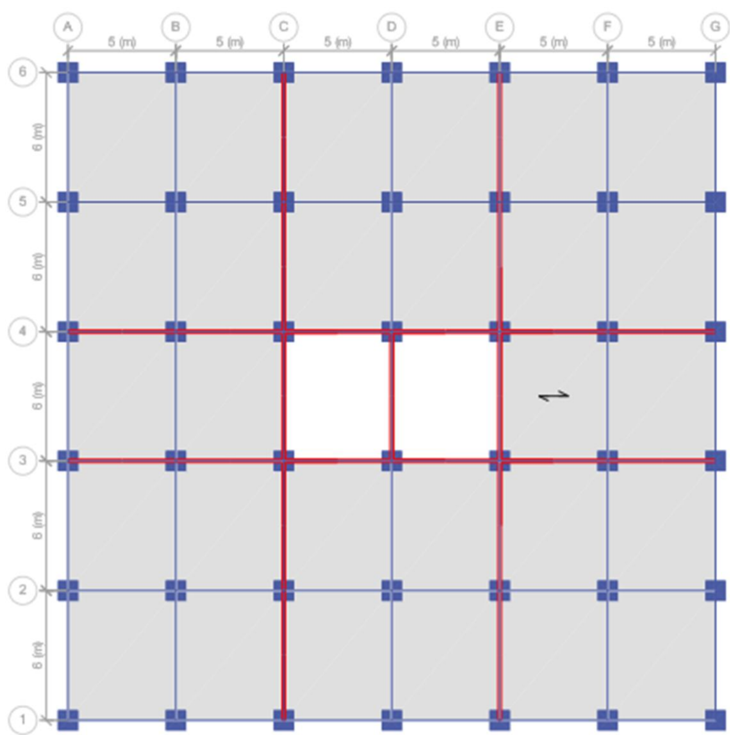


Fig. 2: With outrigger - Plan of the tall structure

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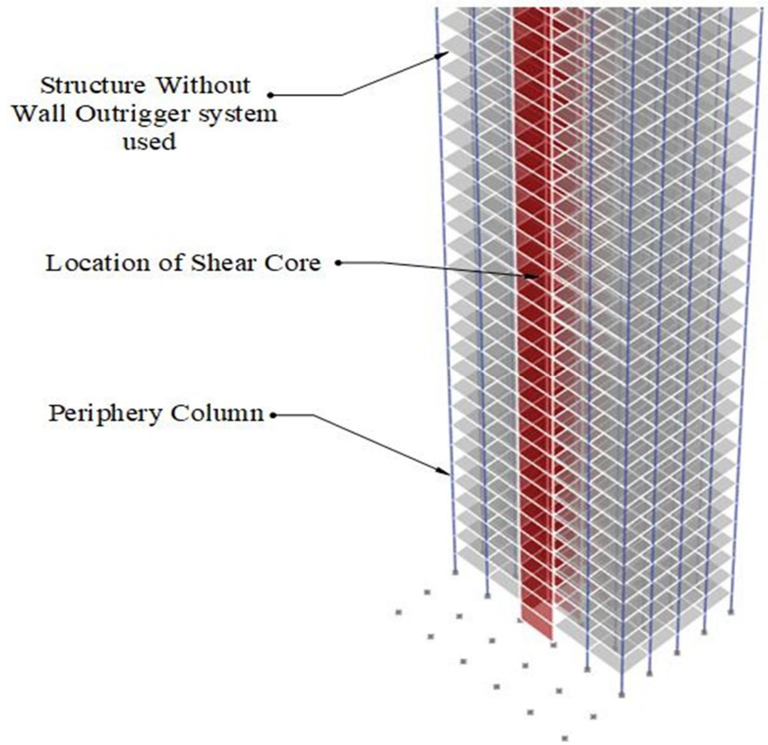

Fig. 3: Without wall outrigger - 3D cutout view of the tall structure

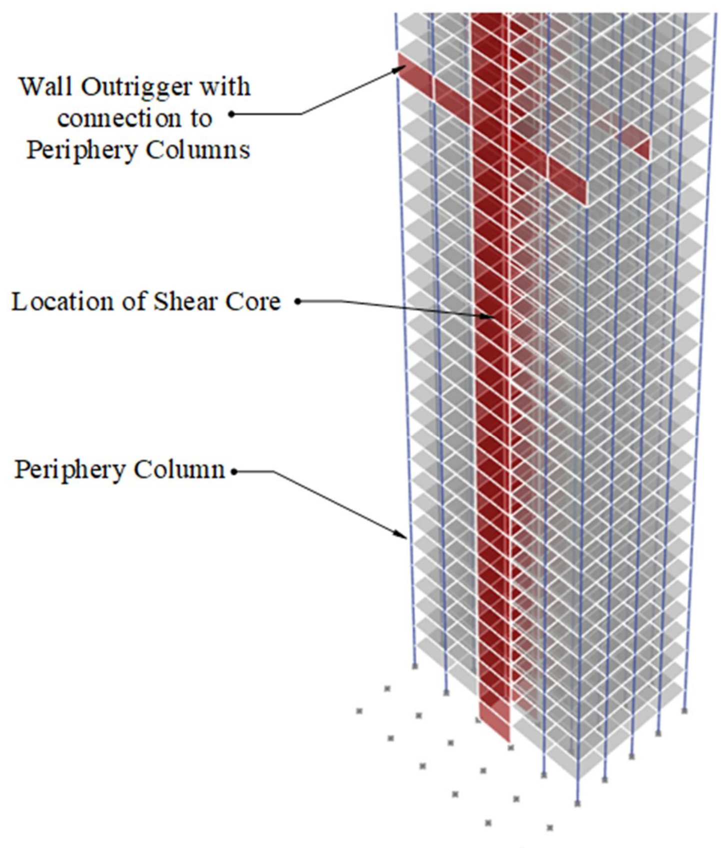

Fig. 4: With wall outrigger - 3D cutout view of the tall structure

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IV. RESULTS AND DISCUSSION

Results are shown in graphical form are as follows:

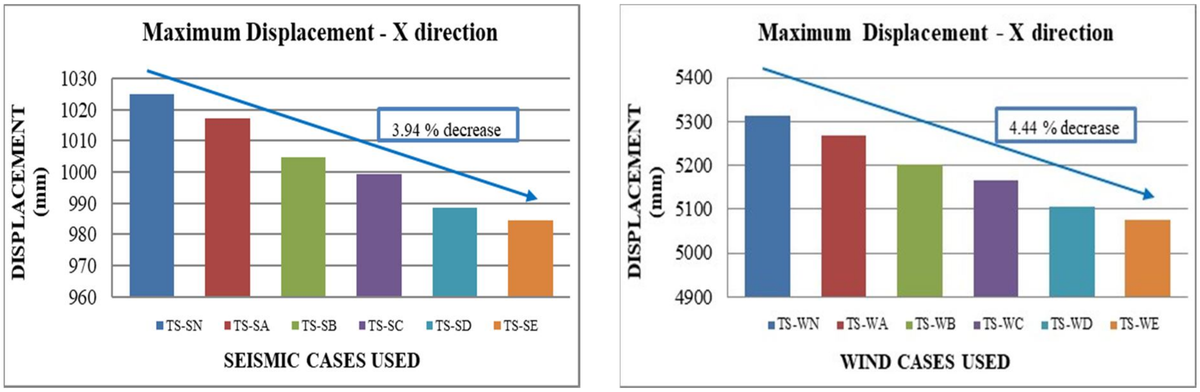

Fig. 5: Comparative analysis of effect of using outrigger system on Maximum Displacement in X direction for all cases

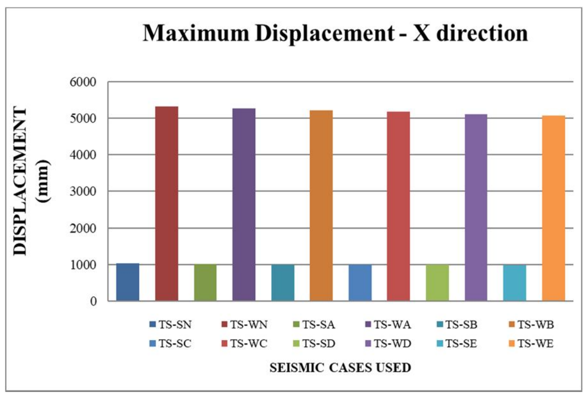

Fig. 6: Comparison on Maximum Displacement in X direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method

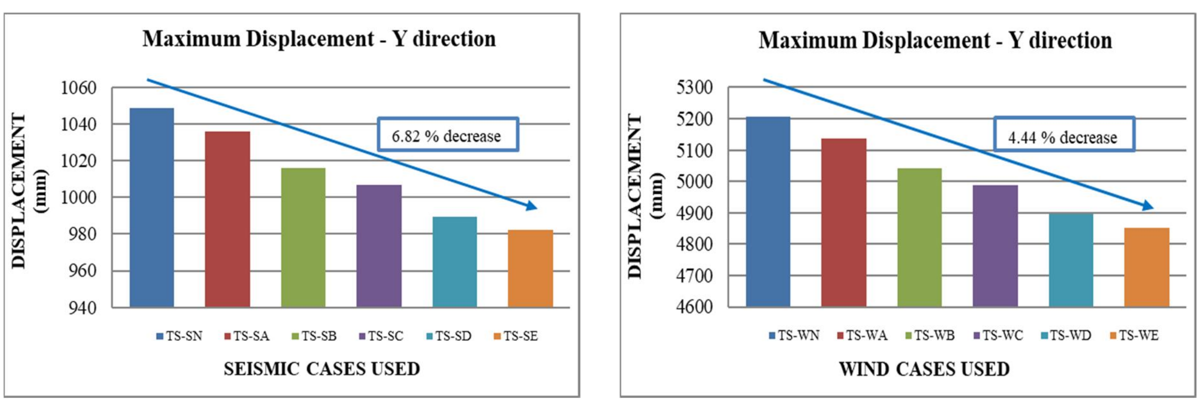

Fig. 7: Comparative analysis of effect of using outrigger system on Maximum Displacement in Y direction for all cases

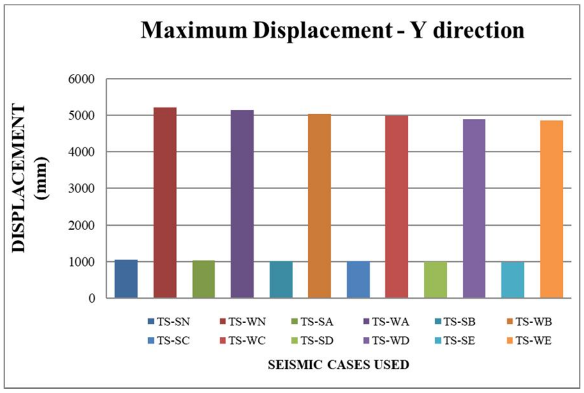

Fig. 8: Comparison on Maximum Displacement in Y direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method

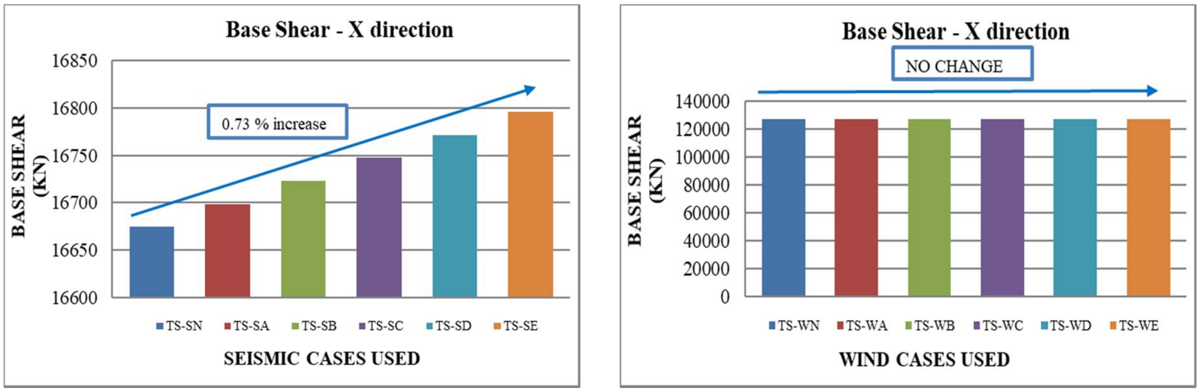

Fig. 9: Comparative analysis of effect of using outrigger system on Base Shear in X direction for all cases

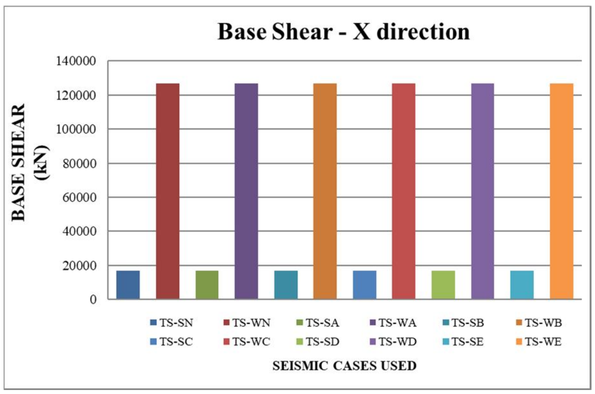

Fig. 10: Comparison on Base Shear in X direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method

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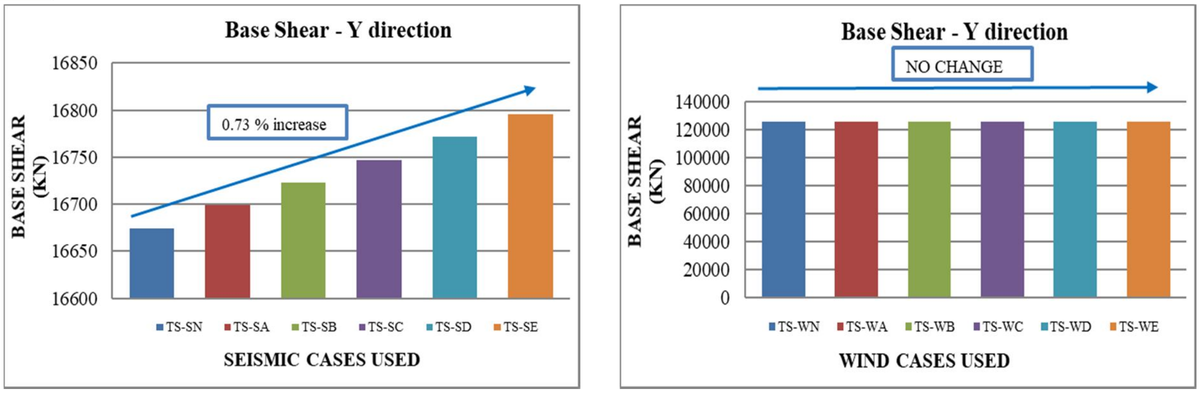

Fig. 11: Comparative analysis of effect of using outrigger system on Base Shear in Y direction for all cases

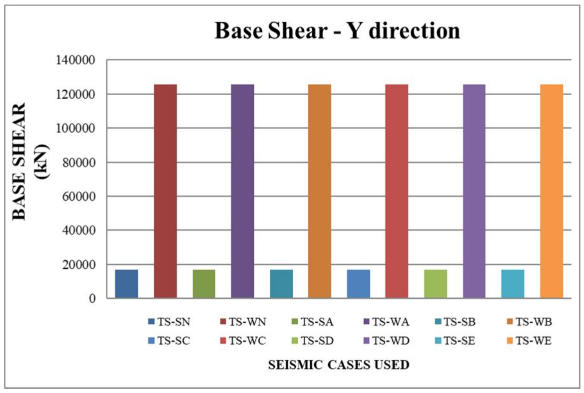

Fig. 12: Comparison on Base Shear in Y direction for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method

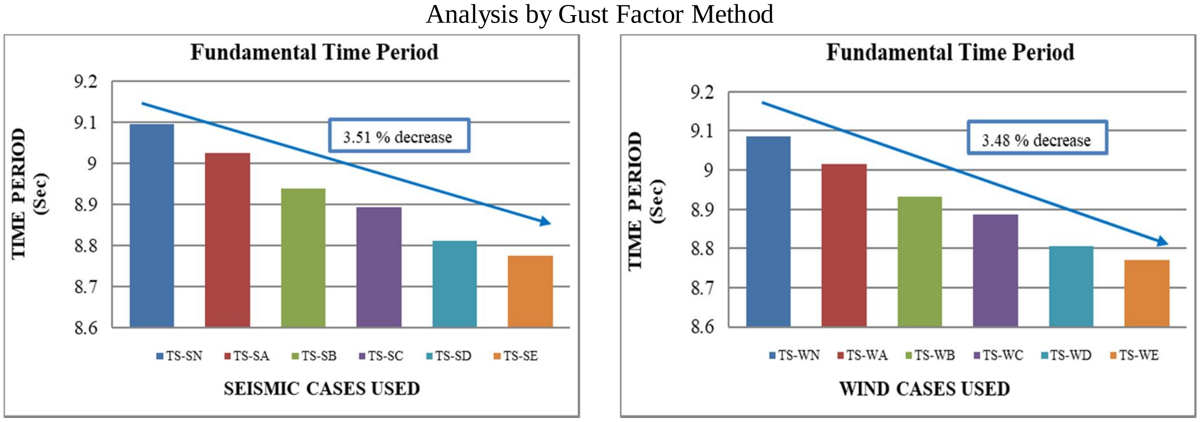

Fig. 13: Comparative analysis of effect of using outrigger system on Fundamental Time Period for all cases

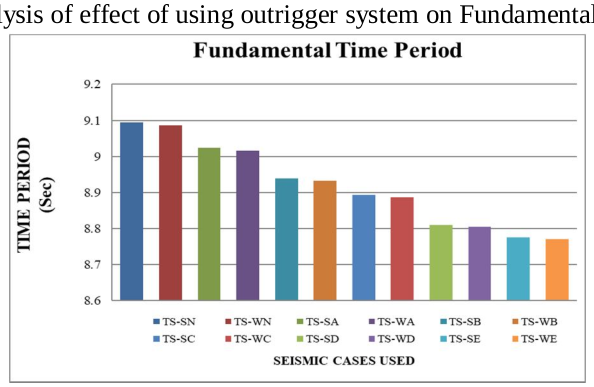

Fig. 14: Comparison on Fundamental Time Period for all cases of Response Spectrum Analysis and Wind Analysis by Gust Factor Method

V. CONCLUSION

The conclusion can be pointed out are as follows:-

1) Maximum Displacement in X direction
   a. In case of Maximum displacement in X direction, there has a cumulative percentage decrease obtained with a value of 3.94% when using multiple outriggers under seismic effects and 4.44% cumulative percentage decrease under wind effects.
   b. There has a percentage rise in maximum displacement in X direction observed from seismic to wind forces.

2) Maximum Displacement in Y direction
   a. In case of Maximum displacement in Y direction, there has a cumulative percentage decrease obtained with a value of 6.35% when using multiple outriggers under seismic effects and 6.82% cumulative percentage decrease under wind effects.
   b. There has a percentage rise in maximum displacement in Y direction observed from seismic to wind forces.

3) Base Shear in X direction
   a. In case of Base Shear in X direction, there has a cumulative percentage increase obtained with a value of 0.73% when using multiple outriggers under seismic effects and no change in cumulative percentage under wind effects with same values.
   b. There has a percentage rise in Base Shear in X direction observed from seismic to wind forces.

4) Base Shear in Y direction
   a. In case of Base Shear in Y direction, there has a cumulative percentage increase obtained with a value of 0.73% when using multiple outriggers under seismic effects and no change in cumulative percentage under wind effects with same values.
   b. There has a percentage rise in Base Shear in Y direction observed from seismic to wind forces.

5) Fundamental Time Period
   a. In case of Fundamental Time Period for entire structures, there has a cumulative percentage decrease obtained with a value of 3.51% when using multiple outriggers under seismic effects and 3.48% decrease in cumulative percentage under wind effects.
   b. There has a percentage fall in Fundamental Time Period for entire structures observed from seismic to wind forces.

Observing all the parameters, after the application of outrigger wall provided at different stories in tall structures, it has proved that the lateral forces resistance is more and depends on the usage. It has also observed that the wind forces and its effect is very high as compared to seismic forces. The use of multiple outriggers has observed to be a best approach as efficiency and stability of the structure increases accordingly and should be recommended when this type of stability enhancing system in tall structure will be provided.

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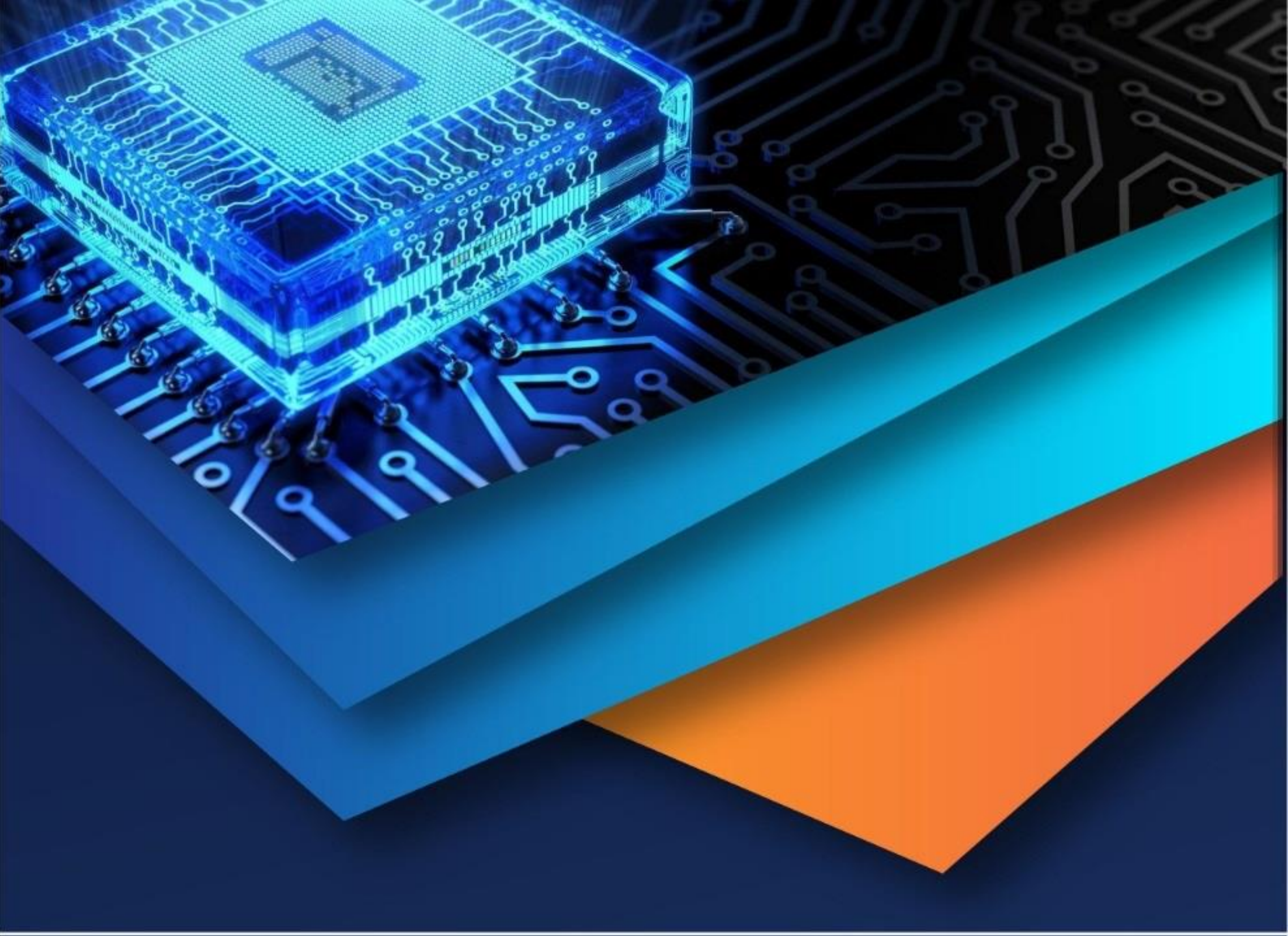

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