A Study on Tall RC Structure with Outrigger System Subjected to Seismic and Wind Loading

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Abstract **- Finite Element Analysis of the tall slender RC structure with and without outrigger system has been carried out to study the behaviour of tall RC structure in terms of time period, base shear, base moment, story displacement & story drift. Due to reduction of lateral stiffness with the increase in height of structures, outrigger system has been proposed in the present study to minimize the effect due to loss of stiffness. The three dimensional model has been considered and analyzed for the gravity loading, seismic and wind loading, for seismic loading both Equivalent Static Method (Static) and Response Spectrum Method (Dynamic) has been carried out, and in the same manner for wind loading both IS Code coefficient method (Static) and Gust Factor method (Dynamic) has been carried out, IS 875 part III has been used for wind loading calculation and analysis, and IS 1893:2002 has been used for seismic loading calculation and analysis.**

Keywords - Outrigger, Wind Load, Seismic Load, Gust Factor, Response Spectrum, Tall

I. INTRODUCTION

Now a day it is the most common trend in the world of structures to go for the tall buildings, this trend has raised many issues with it to be taken into consideration; the major issue that affects the design of tall structures is its sensitivity to the lateral load. One of the important criteria for the design of tall buildings is lateral sway (deflection) and storey drift together along with the strength criteria.

Now the question is how to ensure that the considered structure is safe and stable from the deflection and drift point of view, to ensure this IS code has laid some guidelines, according to the IS456:2000, Clause 20.5 "Under transient wind load the lateral sway at the top of should not exceed H/500, where H is the total height of the building" and according to IS1893:2002, Clause 7.11.1 "The storey drift in any storey due to the minimum design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height", and as per Clause 4.23, Storey drift may be defined as the displacement of one level relative to the other level above or below.

OUTRIGGER

outriggers are deep, stiff beam which connects the central core to the exterior columns which help in keeping the columns in their position in turn reducing the sway, Outriggers act as stiff arms engaging outer columns/shear walls, when the lateral wind or earthquake force attacks the central core, central core tries to tilt, its rotation at the outrigger level induces a tension-compression couple in the outer columns acting in opposition to that movement acting on the core at that level.

Outriggers have been used in tall buildings for nearly half a century, but the design principles has been used for millennia, the oldest "outriggers' were horizontal beams connecting the main canoe shaped hulls of Polynesian oceangoing boats to outer stabilizing floats or "amas", the outrigger concept is in widespread use today in the design of tall buildings. In this concept, "outrigger" trusses extend from a lateral load-resisting core to columns at the exterior of the building.

The key idea in conceptualizing the structural system for a narrow tall building is to think of it as a beam cantilevering from the earth, The laterally directed force generated, either due to wind blowing against the building or due to the inertia forces induced by ground shaking, tends both to snap it (shear), and push it over (bending), therefore, the building must have a system to resist shear as well as bending. In resisting shear forces, the building must not break by shearing off and must not strain beyond the limit of elastic recovery, when an outrigger-braced building deflects under wind or seismic load, the outrigger which connects to the core wall and the exterior columns/shear walls, makes the whole system to act as a unit in resisting the lateral force, the primary result of the outrigger trusses is the development of axial forces in the exterior columns due to lateral load action.

Outrigger serve to reduce the overturning moment in the core that would otherwise act as a pure cantilever, and to transfer the reduced moment to columns/shear walls, outside the core by the way of tension-compression coupled, which take advantage of the increase moment arm between these columns, in high-rise building this same benefit can be realized by a reduction of the base core over-turning moments and the associated reduction in the potential core uplift forces.

There are two types of outrigger system

1. Conventional outrigger system
2. Virtual outrigger system

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Conventional outrigger system
In the conventional outrigger system, the outrigger trusses or girders are connected directly to shear walls or braced frames at the core and to columns located outboard of the core. Typically (but not necessarily), the columns are at the outer edges of the building. Figure 1.9 is an idealized section through a tall building.
Virtual outrigger system

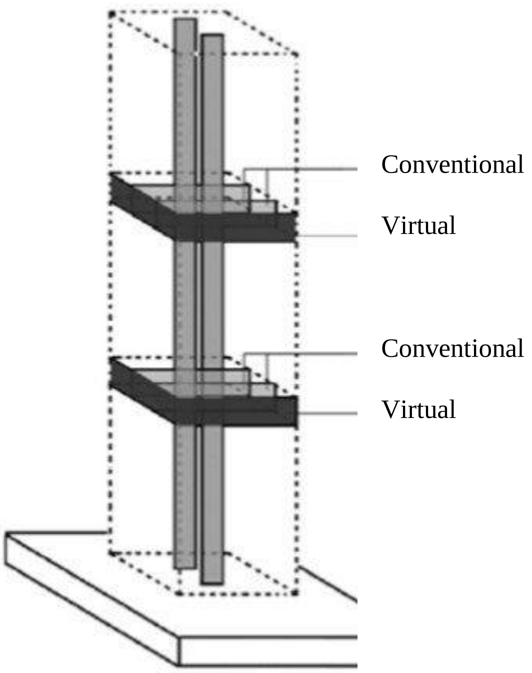

Fig. 1Types of Outrigger

Virtual outrigger system
In the conventional outrigger system, outrigger trusses connected directly to the core and to outboard columns convert the "virtual" outrigger concept, the same transfer of overturning moment from the core to elements outboard of the core is achieved, but without a direct connection between the outrigger trusses and the core. The elimination of a direct connection between the trusses and the core avoids many of the problems associated with the use of outriggers.

II. OBJECTIVES OF STUDY

1. To study various parameters such as Base shear, Base moment, Time period, Story displacement & Story drift.
2. To compare the behaviour of the structure with & without outrigger system.
3. To carryout static and dynamic analysis along with gust factor analysis.
4. To compare the effect of outriggers by both Equivalent static method and Dynamic Analysis method (Response spectrum method).
5. To insure that the deflection and displacement are within the permissible limits as specified by IS standards.
6. To prepare a three dimensional model in ETABS and to analyze the structure using Finite element analysis approach

III. METHODOLOGY

The said structure is modeled as three dimensional structure and all the loads are applied, gravity loading such as dead load and live load in the direction of gravity, lateral loads such as seismic and wind, and the behaviour of the structure has been studied and it has been insured the drift and displacements are within the limits specified by Indian standards.

Model Data

Material Properties

- Shear wall, core wall & column – M70
- Slab & beam – M35
- Reinforcement – FE415
- Fe490 for structural steel – FE490

Section Properties

- Beam - 300X450/700mmm modeled as line
- Shear wall - 750mm thk. modeled as shell
- Slab – 150 mm thk. Modeled as shell
- Outrigger – SHS 200X200X30mm

Gravity loading

- Floor Finish – 1.5 kN/m2
- Water proofing - 1.5 kN/m2
- Live Load – 2 kN/m2, 3 kN/m2
- Terrace Live load – 1.5 kN/m2
- Wall load 230 mm thk. – 9.16 kN/m,
- Wall load 150 mm thk. – 6.09 kN/m
- parapet wall load – 3.8 kN/m

Seismic loading
Zone factor – 0.36, for zone V, Table 2 of IS1893:2002
Building Frame Systems – Ductile shear walls
Response reduction factor – 4, Table 7 of IS1893:2002
Soil Type – I, Hard soil, Table 1 of IS1893:2002
Importance factor – 1, Table 6 of IS1893:2002
Time Period – 3.3Sec, user defined
No. of modes to be considered – 12
Modal Analysis – Ritz
Modal combination – CQC, cl 7.8.4.4 of IS1893:2002
Directional combination – SRSS
Initial scale factor – Ig/2R
Minimum eccentricity – 0.05
Damping – 5 percent, cl 7.8.2.1 of IS1893:2002
Mass source – 1DL + 0.25 LL
Diaphragm type – Semi rigid

Wind loading

Wind speed – 44m/s
Terrain category – 2
Structure class – B
Risk coefficient, K1 – 1

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Topography factor – 1
Parapet height – 1.2m
Windward coefficient, Cp – 0.85
Leeward coefficient, Cp – 0.75

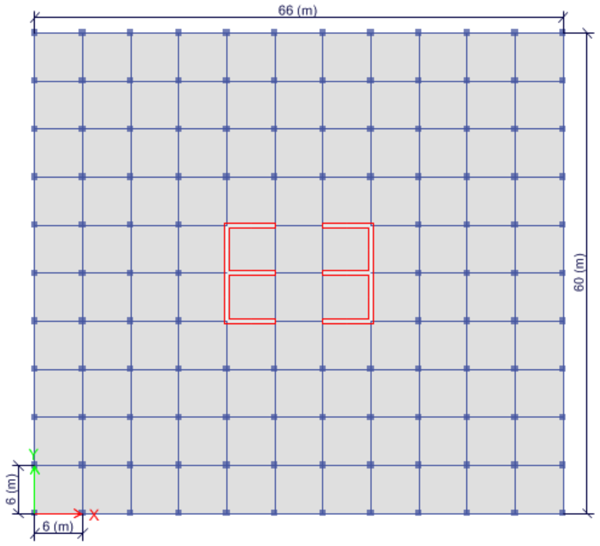

Fig. 2 Typical Plan View

Method of analysis

Following analysis has been carried in addition to analysis for gravity loading

Seismic analysis

Static method – Equivalent static method
Dynamic method – Response spectrum method

Wind analysis

Static method – IS 875 coefficient method
Dynamic method – Gust factor method

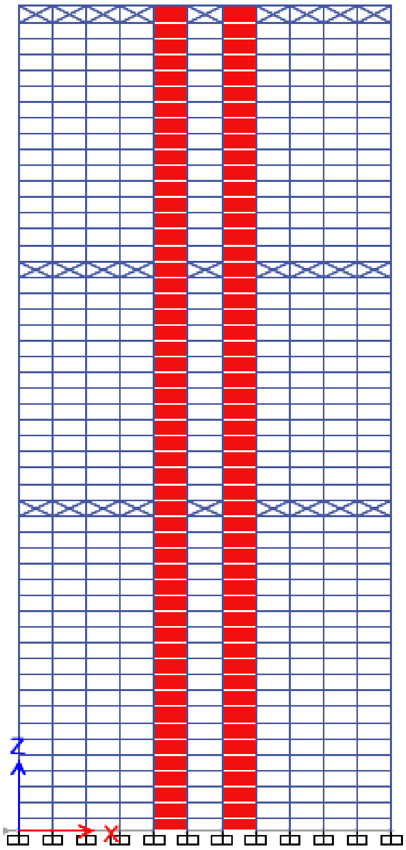

Fig. 3 Typical Elevation view

Load case

DL – Selfweight of structure
SDL – floor finish, waterproofing
LIVE – live load on floors
TERRACE LIVE – Live load on terrace
LLNR – Non reducible live load, MEP load
EQX, EQY – Seismic load
WX, WY – wind load
SPECX, SPECY – Response spectrum case
GUSTX, GUST Y – Gust factor load

Load Combinations

Limit state of strength

1. 1.5DL
2. 1.5DL+1.5LL
3. 1.5DL+1.5WL/EQ
4. 0.9DL+1.5WL/EQ
5. 1.2DL+1.2LL+1.2WL/EQ

Limit state of Serviceability

1. 1DL
2. 1DL+1LL
3. 1DL+1WL/EQ
4. 1DL+0.8LL+0.8WL/EQ

P-Delta load combination – 1.2DL+1.2LL

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IV. RESULTS AND DISCUSSION

Case 1 – Conventional, without outrigger, G+50-C
Case 2 – With outrigger system, G+50-OUT

3.1 Time Period

Fundamental Natural Time Period of Structure		
Type of	G+50-C	G+50-OUT
ESA	3.302	3.302
RSA	7.639	6.821
ESA-Equivalent Static Analysis, MA-Modal Analysis		

Table 1- Fundamental Natural Time Period

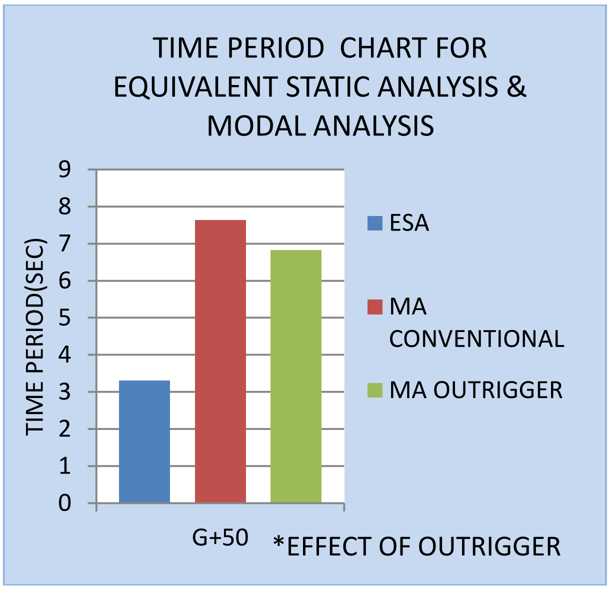

Fig. 4 Time Period Comparison

Modal Time Period, Modal Analysis		
Mode No.	G+50-C	G+50-OUT
1	7.639	6.821
2	7.256	5.652
3	5.867	4.483
4	2.049	1.662
5	1.465	1.239
6	0.981	0.98
7	0.644	0.784
8	0.593	0.576
9	0.377	0.414
10	0.375	0.355
11	0.196	0.229
12	0.188	0.124

Table 2 Time Period from Modal analysis

3.2 Base Shear

TABLE: Base Reactions				
	G+50-C-1		G+50-OUT-1	
Load Case	Shear	Moment	Shear	Moment
	kN	kN-m	kN	kN-m
SPECX Max	30361.17	2581028	43840.13	2558829
GX	31153.56	3077529	31153.56	2917261
EQXD 1	34203.53	4684011	34512.26	4477789
SPECY Max	30906.61	2393452	33229.19	2382900
GY	34268.92	3198649	34268.92	3081384
EQYD 1	34203.53	4447141	34512.27	4321560

Table 3 Base Shear of conventional & outrigger system

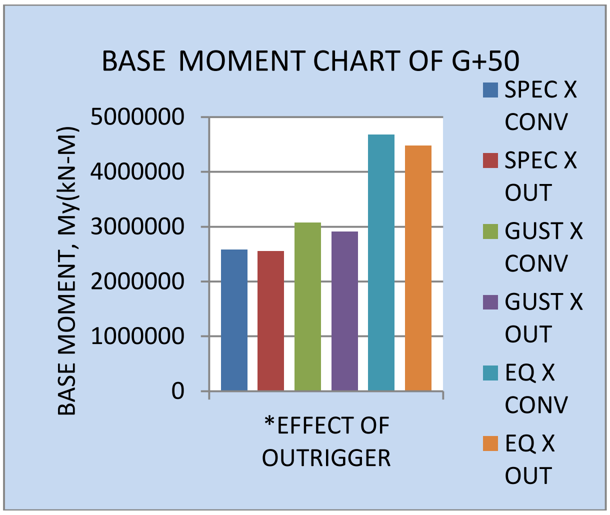

Fig. 5 Base Moment Comparison, My

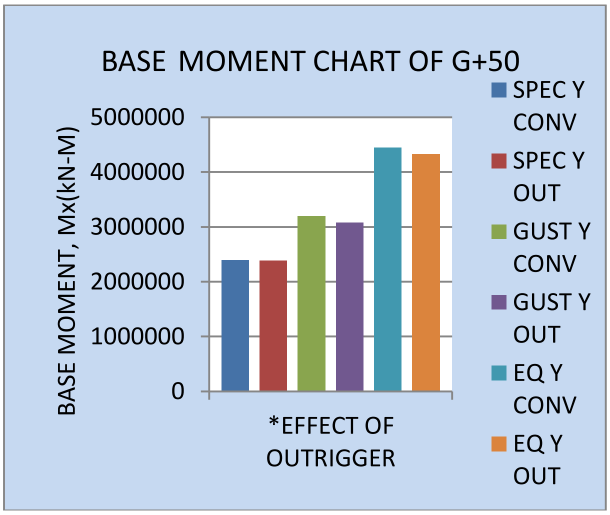

Fig. 6 Base Moment Comparison, Mx

3.3 Story Displacement.

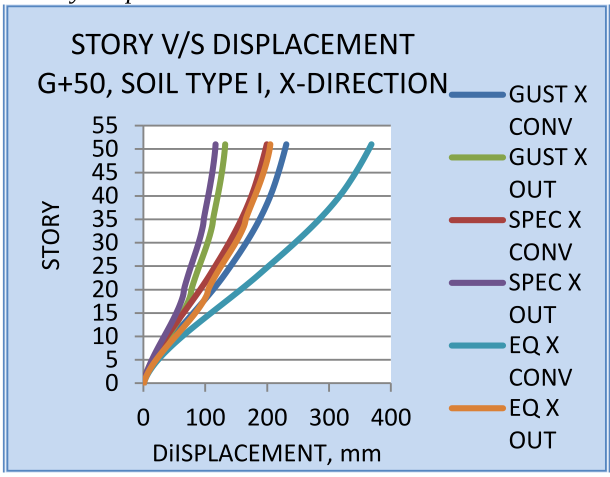

Fig. 7 Story Displacement Comparison

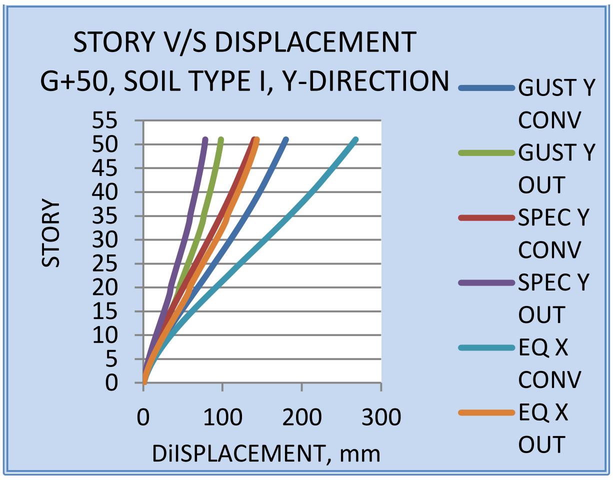

Fig. 8 Story Displacement Comparison

3.4 Top Story Displacement

Top Story Displacement			
		G+50-C	G+50-OUT
Load Case	Direction	Maximum	Maximum
		mm	mm
SPECX	X	199.3	116.7
GX	X	230.9	132.437
EQX	X	368.6	205.264
SPECY	Y	140.1	78.3
GY	Y	179.8	98.0
EQY	Y	267.9	143.3

Table 4 Top Story Displacement Comparison

3.5 Story Drift.

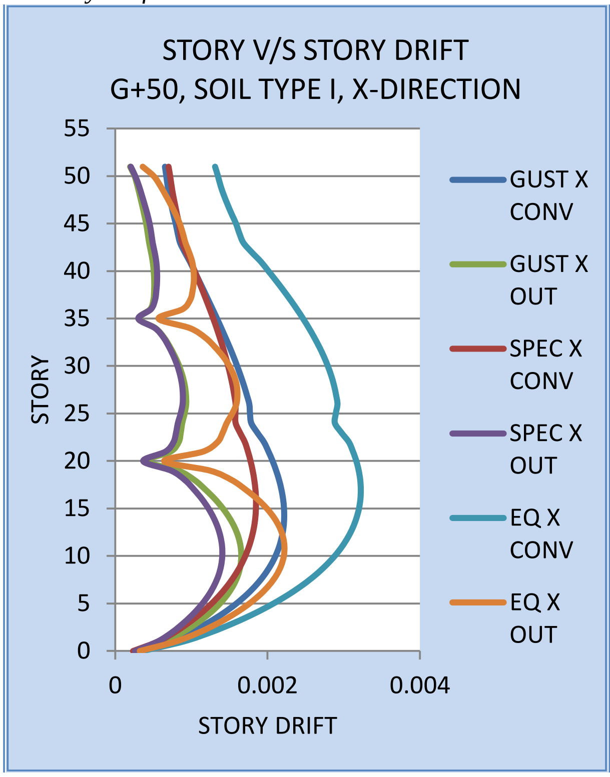

Fig. 9 Story Drift Comparison, X-Direction

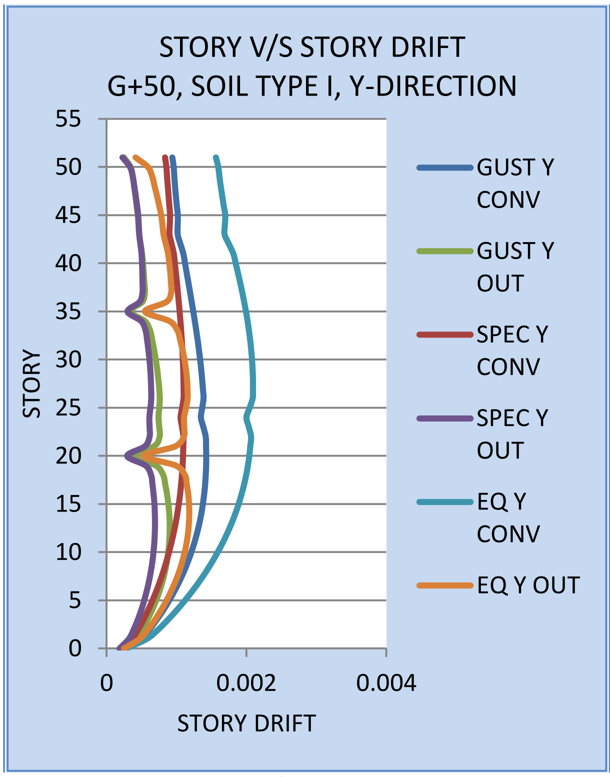

Fig. 10 Story Drift Comparison, Y-Direction

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V. CONCLUSION & FUTURE COPE OF STUDY

The most effective and deciding basic parameter studied during this whole analysis was drift and deflection of the structure. Fig 7 to fig. 10 shows the variation of drift and deflection of the structure with & without outrigger system. It is observed that the deflection is reduced by 40% after adding outriggers to the conventional structure. Base moment is also reduced by adding outriggers to the conventional structure is controlled by providing the outrigger at 0.3H, 0.7H & 1H, where H is the height of structure.

The following conclusions are made from the present study.

1. The use of outrigger system in high rise structure increases the stiffness and makes the structure more efficient under seismic and wind loading.
2. The maximum displacement at the top of structure Without outrigger system was 368.6 mm, which was reduced to 202.5 mm after providing outrigger at 0.4H 0.7H & 1H.
3. The reduction in drift is more than 50 % at the story where outrigger is provided.
4. It can be concluded from this study that the outrigger system provides reduction in displacement, drift and base moment, which will further the size and depth of foundation.
5. It can be concluded after reviewing the values in table no.03 that Equivalent static analysis load case governs the analysis as well as design, as the base shear generated by the Gust Factor load case among all load case.

Scope of future study

1. More detailed analysis such as Pushover analysis and time history analysis will carried out of the said structure and their results will be compared
2. Structural design of the members namely beam, column slab, shear wall will be done
3. Ductile detailing of the structure will be done
4. Further optimization of the sizes of the members will be done
5. Analysis will be done on one unsymmetrical plan and the results will be compared with the symmetrical layout plan.

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