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Seismic and Wind Analysis of Different Lateral Load Resisting Systems

Madhav Jadiya[1], Vrunda Agarkar[2]
[1,2]Civil Engineering and applied mechanics department, MIT World Peace University Pune, India

Abstract:- The rapid increase in the population andscarcity of land has increased the demand of taller buildings. Expanding the building vertically seems to be anefficient option considering all the factors. The resistance of tall buildings to wind as well as to earthquakes is the main determinant in the formulation of new structuralsystems that evolve by the continuous efforts of structural engineers to increase building height while keeping the deflection within acceptable limits and minimizing the amount of materials. As the building height increases role of lateral load (Wind and Seismic) resisting systems becomes more prominent as compared to gravity load resisting system. Basically, there are three main types of buildings: steel buildings, reinforced concrete buildings, and composite buildings. The following research paper emphasizes on different types of lateral load resisting systems and how they react to different loads acting on them. The buildings modelled are done using Etabs software. The buildings are analyzed for both static as wellas dynamic analysis. Static analysis is carried out using ESM (Equivalent Static Method) and dynamic analysis is carried out using RSM (Response Spectra Method). The modeling is done to examine the effect of different cases onseismic and wind parameters like base shear, lateral displacements, lateral drifts and stiffness for zone-IV in medium soil as specified in IS: 1893-2016.

Keywords:- *Beam column system, Shear wall system, combined system, Linear static method, Response Spectrum method, Storey Displacement, Sotrey drift,Storey stiffness.*

I. INTRODUCTION

The rapid increase in the population and scarcity of land hasincreased the demand of taller buildings. Expanding the building vertically seems to be an efficient option considering all the factors. The resistance of tall buildings towind as well as to earthquakes is the main determinant in theformulation of new structural systems that evolve by the continuous efforts of structural engineers to increasebuilding height while keeping the deflection within acceptable limits and minimizing the amount of materials. As the building height increases role of lateral load (Wind and Seismic) resisting systems becomes more prominent as compared to gravity load resisting system. Basically, there are three main types of buildings: steel buildings, reinforced concrete buildings, and composite buildings.

A. Introduction to shear wall system:

In structural engineering, a shear wall is a vertical element of a system that is designed to resist in-plane lateralforces, typically wind and seismic loads. In many jurisdictions, the International Building Code and International Residential Code govern the design of shear walls. A shear wall resists loads parallel to the plane of the wall. Collectors, also known as drag members, transfer the diaphragm shear to shear walls and other vertical elementsof the seismic force resisting system. Shear walls are typically light-framed or braced wooden walls with shear panels, reinforced concrete walls, reinforced masonry walls,or steel plates.

B. Introduction to Bracing system:

For tall building, it has been found that Suitability and economic criteria of shear wall is limited up to some Heights Which leads to a requirement of the structural system which provides adequate stiffness And Strength Against the seismic loading and winds and satisfy economic criteria to a tall building. Bracing system provides better performance in term of the storey drift and storey displacement. With the same amount of material cost, which makes it economical compared to the other structural system, and it is the best option in economic criteria. With the addition of diagonals between floors, which act as truss members, better seismic performance can be achieved effectively. The primary purpose of diagonals is to transfer axial loads to columns and carry lateral loads, which behave as an effective natural structural system.

➢ *Diagonal bracing:*

It is obstructive because it blocks the opening, which affects the look of building elevation. Diagonal bracing can be placed as a single diagonal bracing or double diagonal bracing. If it's architectural limitation is removed, it can be considered as the most efficient to resist lateral forces by earthquake and wind forces because they behave as proper triangular trusses.

C. Introduction to Outrigger and belt truss system:

The lateral bracing system consisting of coupled shearwalls with outriggers is one of the most efficient systems used for high rise construction to resist lateral forces caused by windand earthquakes. Outrigger beams connected to the shear wall and external columns are relatively more complicated and it is understood that the performance of such coupled wall systems depends primarily on adequate stiffness and strength of the outrigger beams. Therefore overall rigidity is imperative in tall buildings in order to control lateral deflection and inter-storey drift.

II. METHODOLOGY

A. Details of the structural models:

For the present study three different models have been prepared with different lateral loads resisting systems i.e. beam column system, shear wall system and a models containing combination of different lateral loads resisting systems for the comparative study. Table 1 shows the geometric details of the structural models.

Table 1: Geometric detail of the structural models

Parameter	Beam Column	Shear wall	Combined
Bay	4m	4m	4m
No of bays	5	5	5
Plan dimensions	20m X 20m	20mX20m	20m X20m
Storey Height	3m	3m	3m
Height of Structure	124m	124m	124m

The maximum allowable slenderness ratio in seismic zone IV for structural walls + moment frame configuration as per IS 16700-2017 is 8.

A conventional model of 40 storey height has been modelled having frame elements i.e. beam and column, shear wall at the core of the structure and outrigger and belt truss system with bracing provided at all the four edges. The outrigger and belt truss are provided at the mid and top of the structure. The column beam and frame section for modelling are reinforced concrete sections and the outrigger, belt truss and braces that are modelled using structural steel.

Figure 1 shows a conventional frame system with beam and column elements with 40 storey height. Figure 2 shows a shear wall system at the core of the building. This shear wall acts as a vertical cantilever for theentire building and helps in resisting the lateral loads better. Figure 3 shows a combined lateral load resisting systems which includes a shear wall. In addition to that the structure also consists of a outrigger and belt truss system and bracing provided at the edge on all four sides.

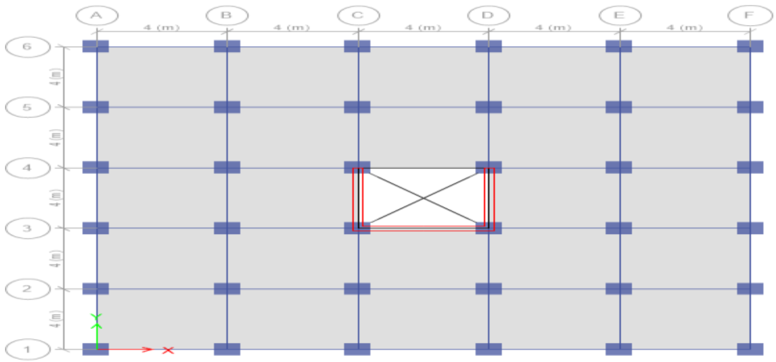

Fig. 1: Beam Column System

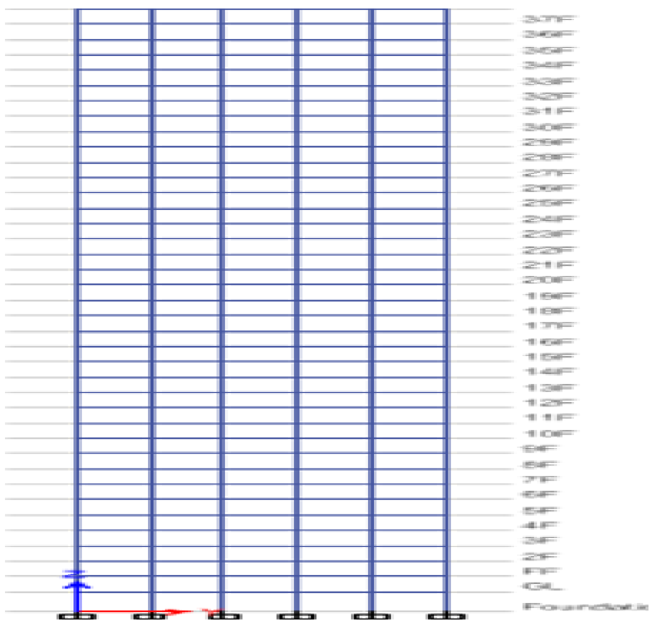
Fig. 2: Plan view of the model with shear wall at its core

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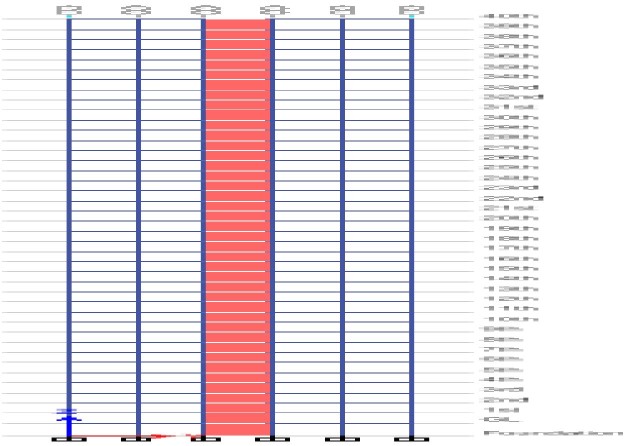

Fig. 3: Shear wall System

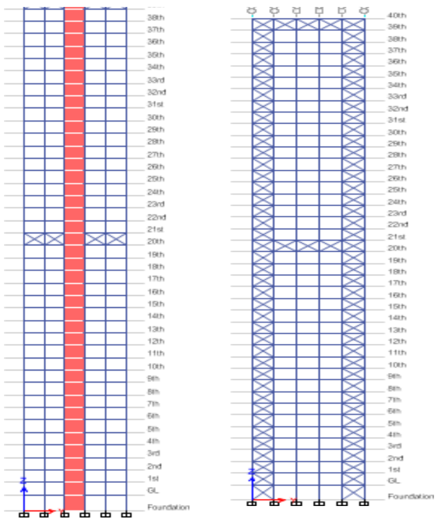

Fig. 3: Combined lateral load resisting system

III. USING THE TEMPLATE

A. Loading and Analysis

The various loads are applied as per the relevant IS codes. Live load is applied as per the IS 875 (Part 2) – 1987 considering the mercantile building, seismic load is applied as per the IS 1893 (Part 1) – 201 6and wind load is applied as per IS 875 (Part 3)– 1987. The loading details are mentioned below:

Table 2: Seismic loading details

Live Load	2kN/m^2 and 3kN/m^{2}on all the floors and1.5kN/m^2 on the roof
Dead Load	Self-weight of structural members isautomatically calculated by ETABS 2017 software according to the section dimensions
Floor Finish Load	1.5kN/m^2 on all the floors including roof
Wall Load	7.8kN/m
Seismic Zone	Zone IV
Seismic Zone Factor (Z)	0.24
Response Reduction Factor (R)	5 (SMRF)
Importance Factor (I)	1
Type of Soil	Type II – Medium soil

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Table 3: Wind loading Details

Live Load	$2kN/m^2$ and $3kN/m^2$on all the floors and$1.5kN/m^2$ on the roof
Dead Load	Self-weight of structural members is automatically calculated by ETABS 2017 software according to the section dimensions
Floor Finish Load	$1.5kN/m^2$ on all the floors including roof
Wind speed V_b(m/s)	44
Terrain category	2
Importance factor	1
Risk Coefficient	1
Topography	1

All the models are analyzed by the linear static method i.e. Equivalent Static Method (ESM) and the linear dynamic method i.e. Response Spectrum Method (RSM). The parameters considered for this comparative study are lateral displacement, storey drift and fundamental time period. The load combinations for ESM are considered as follows:

- *Seismic Loading combinations:1. 1.5 (D.L + L.L)*
- 1.2 (D.L + L.L + EQx)
- 1.2 (D.L + L.L – EQx)
- 1.2 (D.L + L.L + EQy)
- 1.2 (D.L + L.L – EQy)
- 1.5 (D.L + EQx)
- 1.5 (D.L – EQx)
- 1.5 (D.L + EQy)
- 1.5 (D.L – EQy)
- 0.9 D.L + 1.5 EQx
- 0.9 D.L – 1.5 EQx
- 0.9 D.L + 1.5 EQy
- 0.9 D.L – 1.5 EQy

- *Wind loading combinations:1. 1.5 (D.L + L.L)*
- 1.2 (D.L + L.L + Wx)
- 1.2 (D.L + L.L – Wx)
- 1.2 (D.L + L.L + Wy)
- 1.2 (D.L + L.L – Wy)
- 1.5 (D.L + Wx)
- 1.5 (D.L – Wx)
- 1.5 (D.L + Wy)
- 1.5 (D.L – Wy)
- 0.9 D.L + 1.5 Wx
- 0.9 D.L – 1.5 Wx
- 0.9 D.L + 1.5 Wy
- 0.9 D.L – 1.5 Wy

The response spectrum function is defined in ETABS 2017as per IS 1893 (Part 1) – 2016. The response spectrum curve isselected for Zone IV and Type II Medium Soil for the dampingof 5%. An eccentricity of 0.05 is taken for all the diaphragms to account for any accidental eccentricity arising in the structure. CQC method is implemented for combining the responses of various modes. The following load combinations are considered for response spectrum analysis:

- 1.2 (D.L + L.L + RSx)
- 1.2 (D.L + L.L + RSy)
- 1.5 (D.L + RSx)
- 1.5 (D.L + RSy)
- 0.9 D.L + 1.5 RSx
- 0.9 D.L + 1.5 RSy

B. Section details:

The details of the reinforced concrete and steel sections provided for various structural members in the structural models of beam column, under consideration are shown in Table 6. The sections are designed and checked as per the relevant IS codes using the ETABS 2017 software package.

Table 4: Section properties of the structural members

Beam Column System	Shear wall System	Combined resisting system
Beams – 230mm x 600mm (M30)	Beams – 230mm x 600mm (M30)	Beams – 230mm x 600mm (M30)
Columns – 900mm x 900mm (M30) Columns – 850mm x 850mm (M30) Columns – 800mm x 800mm (M30) Columns – 750mm x 750mm (M30)	Columns – 900mm x 900mm (M30) Columns – 850mm x 850mm (M30) Columns – 800mm x 800mm (M30) Columns – 750mm x 750mm (M30)	Columns – 800mm x 800mm (M30)
Slabs – 130mm thick (M30)	Slabs – 130mm thick (M30)	Slabs – 130mm thick (M30)
Shear walls – NA	Shear walls – 300mm thickness (M30)	Shear walls - 300mm thickness (M30)
Outrigger Beams – NA	Outrigger Beams – NA	Outrigger Beams – ISHB350 (Fe250)
Outrigger Bracings – NA	Outrigger Bracings – NA	Outrigger Bracings – ISHB350 (Fe250)with300mm x 40mm cover plates
Diagonal Bracing –	Diagonal Bracing –	Diagonal Bracing – ISHB450 (Fe250)

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IV. RESULTS AND DISCUSSIONS

A. Lateral Displacement:

The results of conventional beam column, shear wall and combined load resisting system of maximum roof displacement by ESM and RSM are shown in table 7. The introduction of shear wall at the core of the building reduces the storey displacement by 17 percent. While introducing a combined system of outrigger and bracingto the structure the displacement reduces by 14.8 percent when compared to the shear wall system. Therefore a

Table 5: Maximum Storey Displacement at the top of the models

Type of model	Equivalent Static Method			Response Spectrum Method		
	Displacement (mm)	Change in Displacement (mm)	% Change in Displacement	Displacement(mm)	Change in Displacement (mm)	% Change in Displacement
Conventional	227.896	-	-	63.776	-	-
Shear wall	189.092	38.804	17%	57.417	6.36	10%
Combined	161.081	28.011	14.8%	45.511	11.906	20.74%

B. Storey Drift:

The subsequent storey drift ratios and increasing the lateral load resisting structures like shear wall and a combination of various load resisting structures isshown in table 6.

Similarly to the lateral displacement parameter, storey drift also reduces by about a considerable magnitude by employing shear wall at the core of the subsequent change in the roof displacement is seen on introducing various load resisting systems to the structure. The results also show a confident result when the models are analyzed using the Response Spectra Method (RSM). This means that adding lateral loadresisting system to the structure helps reduce the displacement at the top. building. On adding bracing and outrigger the structure the model shows strong proof to both the conventional model as well as the one with shear wall. There is a decrease of around 15 percent when a combination of different lateral load resisting system is analyzed.

Table 6: Maximum Storey Drift of Models

Type of model	Equivalent Static Method			Response Spectrum Method		
	Drift (mm)	Change in Drift (mm)	% Change in Drift	Drift (mm)	Change in Drift (mm)	% Change in Drift
Conventional	0.002497	-	-	0.000669	-	-
Shear wall	0.001951	0.000546	21.87%	0.000596	0.000073	10.92%
Combined	0.001669	0.000282	14.45%	0.000468	0.000128	21.48%

C. Storey Stiffness

Table 7 shows the storey stiffness of different modelsthat are discussed in this research paper. the results are same as that of the lateral displacement and storeydrift. The introduction to shear wall at the core of the building increases the overall stiffness therby leading to a stiffer strcutural configuration. In addition to thatintroducing outrigger at the mid height and top of the

Table 7: Maximum storey stiffness of models structure in addition to bracing at edges gives a boostto the stiffness that is then contained by the structure.

Type of model	Equivalent Static Method			Response Spectrum Method		
	Stiffness (mm)	Change in Stiffness (mm)	% Change in Stiffness	Stiffness (mm)	Change in Stiffness (mm)	% Change in Stiffness
Conventional	1848917.63	-	-	1889347.805	-	-
Shear wall	4012777.926	2,163,860.296	102.17%	4336296.358	2,446,948.553	102.3%
Combined	4851048.958	838,271.032	101.21%	5365707.138	1,029,410.78	101.24%

V. CONCLUSION

The following conclusions can be drawn on the basis of the results obtained from this comparative study bylinear static and linear dynamic methods of analysis:

- A conventional beam column system proves to be the most vulnerable to resist any kind of lateral loads. Introduction to lateral load resisting systems helps improve the overall stability and structural integrity of the structure.
- Introduction of just a shear wall at the core of the building provides good resistance to the coming lateral loads while introduction to outrigger and bracing provides better resistance.
- A combined lateral load resisting systems for high rise buildings proves to be efficient in every way possible but adding such elements to the structure makes it uneconomical. Hence some other structural elements must be incorporated in order to achieve further reduction in storey drift and displacement considerably

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REFERENCES

[1.] Kiran Kamath, A Study on Static and Dynamic Behavior of Outrigger Structural System for Tall Buildings.

[2.] Khushbu Jani, Analysis and Design of Diagrid Structural System for High Rise Steel Buildings

[3.] N. Herath, N. Haritos, T. Ngo & P. Mendis, Behaviour of Outrigger Beams in High rise Buildings under Earthquake Loads

[4.] Yogesh Dudhe and Dr. Swati Ambadkar, Comparative Analysis of Different Lateral Load Resisting System for High Rise Building

[5.] Saif Azhar and Amit Pratap Singh, Comparative Study by Varying the Number of Outriggers for High Rise Building

[6.] Neeraj Kushwaha, N. Binnani, V. R. Rode and Saif Azhar, Comparative Study of Different Bracing System in Seismic Zone 3 and 4

[7.] IS 1893(Part I):2016, Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standard, New Delhi.

[8.] IS 16700:2017, Criteria for Structural Safety of Tall Concrete Buildings, Bureau of Indian Standard, New Delhi.