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Wind and Seismic Analysis of RCC Building Using ETAB

M.Tech Scholar, Manoj Chopdey, Professor Dr. Rajeev Chandak
Department of Civil Engineering
JEC Jabalpur,MP, India

Abstract-The structural integrity and performance of Reinforced Concrete (RCC) buildings are paramount considerations in the face of natural disasters such as earthquakes and severe wind events. As the global population continues to concentrate in urban areas, the vulnerability of infrastructure to these dynamic forces becomes a pressing concern. Wind and seismic analyses are integral components of the design and evaluation process for structures, especially in regions prone to these hazards. This research is focused towards presenting the comparative analysis of a G+25 story structure to understand the effect of wind and seismic load on RCC structure. The modelling and analysis are performed using ETAB software. The G+25 RC multi storey framed building is considered for analysis to know the realistic behaviour during wind and seismic load with the general plan and elevation.

Index Terms-Wind analysis, seismic analysis, RCC building

I. INTRODUCTION

The structural integrity and performance of Reinforced Concrete (RCC) buildings are paramount considerations in the face of natural disasters such as earthquakes and severe wind events. As the global population continues to concentrate in urban areas, the vulnerability of infrastructure to these dynamic forces becomes a pressing concern. Wind and seismic analyses are integral components of the design and evaluation process for structures, especially in regions prone to these hazards. In the realm of civil engineering, the design and analysis of structures play a pivotal role in ensuring the safety and resilience of the built environment.

Reinforced Concrete (RCC) buildings, being fundamental components of our urban landscape, face constant exposure to dynamic forces, particularly those induced by wind and seismic activities. The natural environment is dynamic, subjecting structures to a myriad of forces that can challenge their stability and integrity. Wind, with its unpredictable nature, exerts lateral loads on structures, while seismic events introduce complex ground motions. The challenges lie in understanding and predicting how these forces interact with the unique properties of reinforced concrete, a material celebrated for its versatility and strength. As urbanization intensifies, the need for structures that can withstand these forces becomes increasingly urgent.

Over the years, the engineering community has responded to the challenges posed by wind and seismic forces by developing and refining design codes and standards. These guidelines serve as the foundation for structural engineers, providing a framework for the safe and efficient design of RCC buildings. The evolution of these codes reflects a deeper understanding of structural behavior under dynamic loads, emphasizing the importance of adaptability and resilience in the face of changing environmental conditions. The performance of RCC buildings under wind and seismic forces is intricately linked to the material properties of concrete and the detailing practices employed in construction. From the selection of appropriate reinforcement to the meticulous detailing of connections, each decision influences the overall structural response.

The wind and seismic analysis of Reinforced Concrete buildings stands at the forefront of contemporary structural engineering challenges. This study provides a comprehensive overview of the complexities involved, from the fundamental principles governing structural responses to the evolution of design standards, material properties, numerical modeling, and practical mitigation strategies. As we strive for resilient and sustainable urban infrastructure, understanding the dynamic interplay between RCC buildings and their environment becomes not only a scientific pursuit but a crucial endeavor for ensuring the safety and longevity of the structures that shape our communities.

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II.METHODOLOGY

2.1 General

This research is focused towards presenting the comparative analysis of a G+25 story structure to understand the effect of wind and seismic load on RCC structure. The modelling and analysis are performed using ETAB software.

2.2 Structure

The G+25 RC multi storey framed building is considered for analysis to know the realistic behaviour during an earthquake with the general plan and elevation is shown in figure 3.1. RCC multi-storey framed building is modeled in etab. Plan dimensions in X and Y direction are 11m and 8m respectively. The buildings are consisting of columns with dimension 500x300mm for all stories and beam with dimension 400x300mm. the floor slabs are taken as 150mm thick. The height of all floors is 3m. Modal damping 5% is assumed with SMRF and I=1. The columns are assumed to be fixed at the base. Material concrete grade is M30 and while steel Fe500 is used.

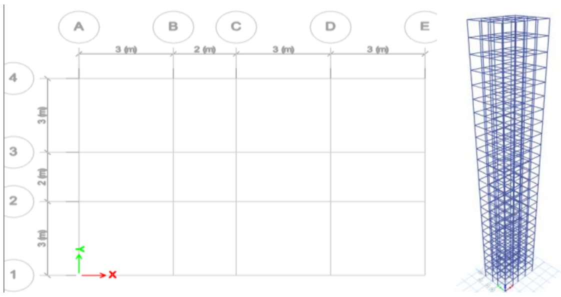

Fig. 1: Plan and elevation of building

2.3 Geometrical Specifications

Table 1: Geometrical Specifications of the Structure

Geometrical Specification	
Particulars of Item	Properties
Number of Storey	G+25
Total height of Structure	75m
Typical Storey height	3m
Bottom Storey Height	3m
Floor Diaphragm	Rigid
Number of Grid Lines in X-direction	4
Number of Grid Lines in Y-direction	3
Beam Size	400x300mm
Beam Shape	Rectangular
Column Size	500x300mm
Column Shape	Rectangular
Slab Depth	150mm
Slab Type	Thin Shell
Seismic zone	3

2.4 Properties of Material

Table 2: Properties of Concrete

Properties of Concrete	
Grade of Concrete	M30
Directional Symmetry Type	Isotropic
Weight per Unit Volume	24.9926 kN/m3
Mass per Unit Volume	2548.538 kg/m3
Modulus of Elasticity, E	27386.13 MPa
Poisson's Ratio, U	0.2
efficient of Thermal Expansion	0.000013 1/C
Shear Modulus, G	11410.89 MPa

Table 3 Properties of Rebar

Properties of Rebar	
Material Name	Fe500
Directional Symmetry Type	Unixial
Weight per Unit Volume	77 kN/m^3
Mass per Unit Volume	7851.81 kg/m^3
Modulus of Elasticity, E	25000 MPa
efficient of Thermal Expansion	0.0000117 1/C
ld strength of distribution bar (f	Fe500
ïeld strength of main bar (fy_{main}	Fe500

2.5 Types of Load

The present study is concerned with analyzing behaviour of building subjected to wind load. The main objectives of present study are stated in chapter 2 and relative literature has been covered in chapter 2. Knowledge and understanding of the different types of loads and their combinations to which the structure may be subjected is very essential for the safe design of the structure. Loads are simply the forces acting on the structure. Load types that occur in the structure are Dead Load, Live Load, Wind Load and Earthquake Load. Dead and live loads are applied in the direction of gravity, and wind and earthquake loads are applied in the lateral direction. Indian Standard Codes provide details on all types of loads for the design of structures and are discussed in the following section.

1. Dead Load

Dead loads refer to loads that are constant over time and are often referred to as permanent loads. Dead loads are the self-weight of the frame as well as the weight of the walls, floor slab, floor finish, etc. It is determined by finding the volume of each material and then multiplied by the unit weight of that particular material.IS 875 (PART-1) is used to calculate the unit weight of structural materials for dead load calculations.

2. Slab Weight Calculation

Thickness of slab=0.150m Density of concrete= 25kN/m3

Self-Weight of slab= Density of concrete x Thickness of slab

= 25x0.150

= 3.75kN/m2

Floor Finish at floor level = 1.5 kN/m2

Total Slab Weight at floor level= 5.25 kN/m2

3. Live Load

Live loads, also known as imposed loads, are typically temporary and changeable. Roof and floor live loads are created by intended use or occupancy of the structure, weight of movable partitions, furniture, etc. Live loads may be concentrated or distributed.IS 875 (PART-2) is used to calculate the value of floor live load and roof live load. Live Load Intensity specified (Public building) = 4 kN/m2 Live Load at roof level =1.5 kN/m2.

4. Seismic Load

Seismic loading takes place due to inertia created in the structure due to seismic excitation. Inertial force depends on the mass. This means that higher structural mass can contribute to higher earthquake loads. Vertical earthquake forces do not cause substantial damage to structures, whereas the impact of horizontal earthquake forces on structures is damaging if it is not designed for seismic loading. IS 1893 (Part 1) 2016 is used to calculate earthquake forces.

5. Wind load

Wind loads can be applied by the movement of the air relative to the structure, and the analysis depends on the knowledge of meteorology, aerodynamics and structures. Wind loading may not be a major concern for small, large, low-level buildings, but it is important for high rise building. The use of lighter materials and the use of shapes that influence the flow of air, usually forming roofs are also crucial. Where the dead weight of the structure is inadequate to withstand wind loads, additional structures and fixings can be needed.

2.6 Indian Standard Code

I.S code 875(Part 3) provides the general formula for the determination of wind forces on a building. The wind calculation depends upon the different factors:

- Topography of surroundings
- Aspect ratio and shape of building
- The angle of wind direction
- Speed and density of air along the height

2.7 Computation of wind load

Design of wind speed(Vz):

Vz= Vb*k1*k2*k3*k4

Vb= basic wind speed in m/s;

where,

k1 is probability factor(risk coefficient)

k2 is terrain category

k3 is topography factor

k4 is the importance factor

The basic wind speed (Vb) for any site shall be obtained from the figure given in

IS code page No. 6 and shall be modified to include the following effects to get design

wind velocity at any height (Vz) for the chosen structure. a) Risk level

b) Terrain roughness height and size of the structure

c) Local topography; and

d) The Importance factor

1. Wind pressure and force on a building:

The wind pressure at any height above the mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

Pz= 0.6 (Vz)2

where,

Pz= wind pressure in N/m2 at height z, and

Vz= design wind velocity in m/s at height z

The design wind pressure,

Pd =Kd*Ka*Kc*Pz

where,

Kd= wind directionality factor

Ka = area averaging factor

Kc = combination factor

The calculation of wind load in individual structural elements such as roof and walls, and individual cladding units and their fittings, takes account of the pressure difference between opposite faces of such elements or units. For clad structures, it is necessary to know the internal pressure as well as external pressure. The wind load, F acting in a direction normal to the individual structural element of cladding unit is:

F = (Cpe-Cpi)*A*Pd

where,

Cpe = external pressure coefficient

Cpi = internal pressure coefficient

A = surface area of a structural element or cladding unit, and

Pd = design wind pressure

2.8 Load Combination

A load combination is given when more than one load type acts on the structure. Building codes usually proposed a set of load combinations along with load factors foreach load type in order to maintain the safety of the structure under various maximum load situations. For the study, a combination of different loads which produce an adverse effect on the structure may be used. In the present study following load combinations are being considered:

1. Loading Combination

Load Combination is define as a set of various loading condition that are acting together in structure which is used to ensure the required safety and economy in the design of a structure.

While, A load combination causing critical condition in structure such as maximum deformation and stress etc. known as a Critical Load Combination. It is a set of such load cases which is likely to act together on structure such as dead load, live load and wind load or dead load, live load and earthquake load etc. It is very high chance to not occurrence of earthquake and wind load on building simultaneously. That's why in load combination, wind load and earthquake loads are not in same sets.

Table 4: Loading combinations for seismic load

S.no	Load Combination
1	1.5(DL)
2	1.5(DL+LL)
3	1.2(DL + LL + EQ-X DIR.)
4	1.2(DL + LL – EQ-X DIR.)
5	1.2(DL + LL + EQ-Y DIR.)
6	1.2(DL + LL – EQ-Y DIR.)
7	1.5(DL + EQ-X DIR.)
8	1.5(DL – EQ-X DIR.)
9	1.5(DL + EQ-Y DIR.)
10	1.5(DL - EQ-Y DIR.)
11	0.9DL + 1.5EQ-X DIR.
12	0.9DL - 1.5EQ-X DIR.
13	0.9DL + 1.5EQ-Y DIR
14	0.9DL - 1.5EQ-Y DIR

Table 5: Loading combinations for wind load

S.no	Load Combination
1	1.5(DL)
2	1.5(DL+LL)
3	1.2(DL + LL + W-X DIR.)
4	1.2(DL + LL – W -X DIR.)
5	1.2(DL + LL + W-Y DIR.)
6	1.2(DL + LL – W-Y DIR.)
7	1.5(DL + W-X DIR.)
8	1.5(DL – W-X DIR.)
9	1.5(DL + W-Y DIR.)
10	1.5(DL - W-Y DIR.)
11	0.9DL + 1.5 W-X DIR.
12	0.9DL - 1.5 W -X DIR.
13	0.9DL + 1.5 W-Y DIR
14	0.9DL - 1.5 W-Y DIR

- DL= Dead load
- LL= Live load
- WL = Wind load
- EQ-X DIR = Earthquake load in X- Direction
- EQ-Z DIR = Earthquake load in Z- Direction

III. RESULTS AND DISCUSSION

3.1 Results of Seismic Analysis

Storey displacement is a critical parameter in earthquake engineering as it affects the structural integrity and safety of a building during seismic events. Storey displacement refers to the lateral movement experienced by different levels or floors of a building during an earthquake. When seismic waves pass through the ground, they exert horizontal forces on a structure. This results in a relative shift between storeys, causing them to move independently of each other. The magnitude of storey displacement depends on various factors, including the building's height, mass distribution, structural system, and the intensity of the seismic event. Taller buildings tend to experience more significant storey displacements compared to shorter structures. There these displacements should be carefully consider in the design process to ensure that the building can withstand the forces generated by the earthquake without sustaining damage or compromising the safety of its occupants.

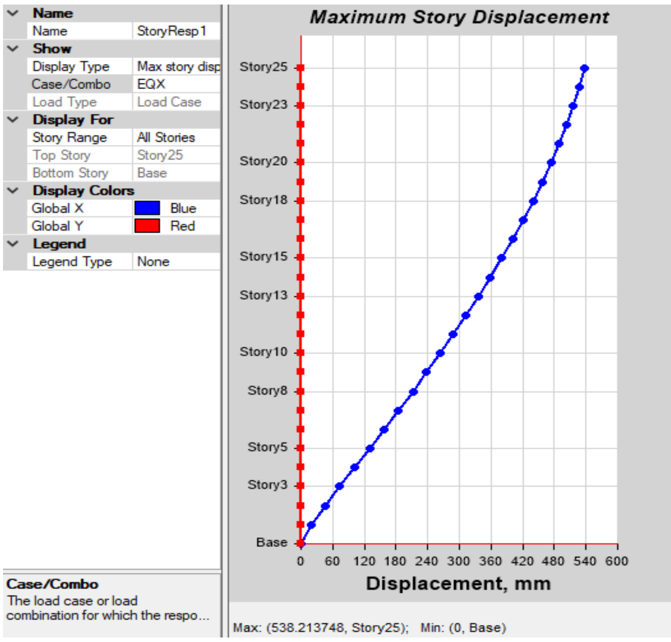

Fig. 2 Storey displacement in structure due to seismic load

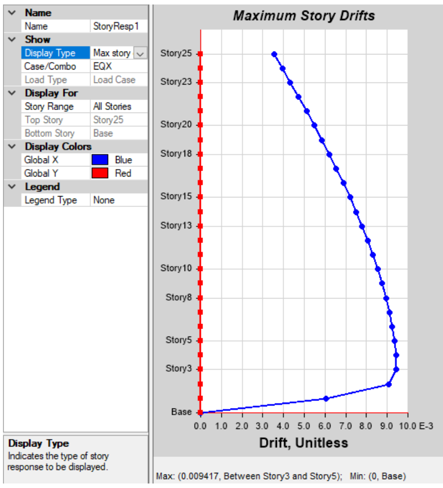

Fig. 3 Storey drift in structure due to seismic load

Storey drift, a critical parameter in earthquake engineering, describes the relative horizontal displacement between adjacent floors or storeys within a building when subjected to seismic forces. It is a direct consequence of the lateral movement induced by ground motion during an earthquake. The magnitude of storey drift depends on various factors including the building's height, stiffness, and the intensity of the seismic event. Tall and flexible structures tend to experience more significant drift compared to shorter, stiffer ones. Engineers carefully consider storey drift in the design process to ensure that it remains within acceptable limits prescribed by building codes. Excessive storey drift can lead to structural damage, impaired functionality, and safety risks for occupants. Thus, accurate assessment and mitigation of storey drift are essential to guarantee the structural integrity and seismic resilience of a building.

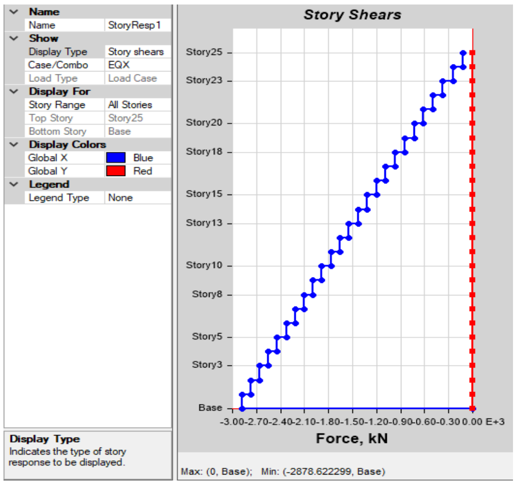

Fig. 4 Storey shears in structure due to seismic load

Storey shears represent the internal forces that act horizontally at each floor level within a building when it is subjected to seismic loads. These forces arise from the lateral movement induced by ground motion during an earthquake. Essentially, storey shears are the result of the structure's efforts to resist and redistribute the seismic forces to maintain stability. They are a crucial consideration in the design and analysis of seismic-resistant buildings. The magnitude of storey shears varies depending on factors such as the building's height, stiffness, and the intensity of the seismic event.

3.2 Results of Wind Analysis

Storey displacement in a structure due to wind load refers to the lateral movement experienced by different levels or floors of a building as a result of the forces exerted by wind. When strong winds blow against a building, they apply horizontal pressure, causing the structure to sway.

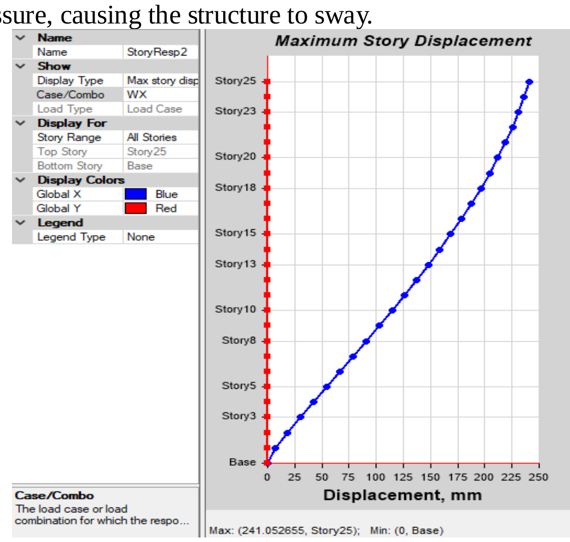

Fig. 5 Storey displacement in structure due to wind load

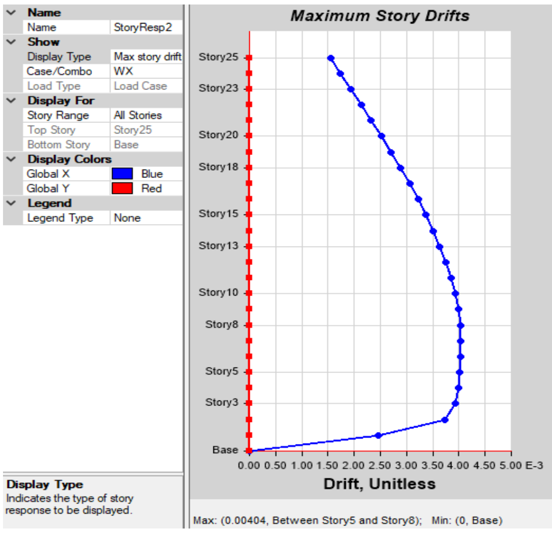

Fig. 6 Storey drift in structure due to wind load

This results in a relative shift between storeys, with higher levels experiencing more displacement compared to lower ones. The extent of storey displacement depends on various factors, including the building's height, shape, and the intensity of the wind. Tall and slender buildings are more susceptible to significant displacements due to their increased susceptibility to wind forces. Storey drift, a critical parameter in structural engineering, describes the relative horizontal displacement between adjacent floors or storeys within a building in response to wind loads. It is a consequence of the lateral forces generated by wind pressure acting on the building's surfaces.

The magnitude of storey drift depends on various factors, including the building's height, stiffness, and the intensity of the wind. Taller and more flexible structures typically experience greater drift compared to shorter and stiffer ones. Engineers meticulously analyze and design structures to ensure that the anticipated storey drift remains within acceptable limits defined by building codes. Excessive storey drift can lead to structural damage, discomfort for occupants, and potential impairments to building functionality. Therefore, precise assessment and control of storey drift are crucial in guaranteeing the structural integrity and safety of a building under wind loads. Storey shear in a structure resulting from wind load refers to the internal horizontal forces that act at each floor level due to the pressure exerted by wind on the building's surfaces. When strong winds impinge upon a building, they create lateral forces that can induce a shearing effect.

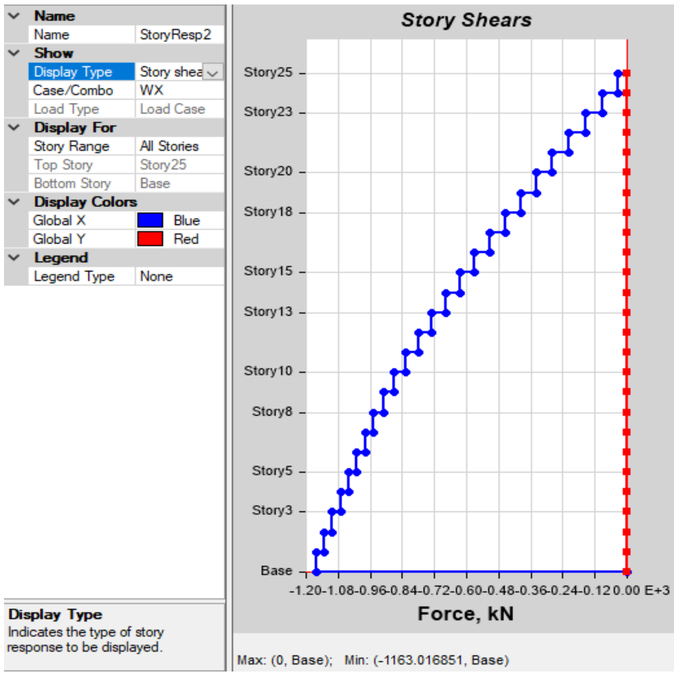

Fig. 7 Storey shear in structure due to wind load

This means that different levels or storeys of the building experience varying degrees of horizontal force. The magnitude of storey shear is influenced by factors such as the building's height, shape, and the intensity of the wind. Tall and slender structures are more susceptible to significant shear forces due to their increased exposure to wind pressure.

IV.CONCLUSION

1. Under the effect of seismic load, the max. storey displacement is obtained as 538.21 mm. Based on the results, it is verified that as number of storey increases, storey displacement was also increases.
2. The max. storey displacement for critical load combination is observed for 1.5(DL + EQ-Y DIR.) which is 1182.36 mm under seismic loading condition. Hence, the load combination “1.5(DL + EQ-Y DIR.)” is critical.
3. Under the effect of seismic load, the max. storey drift is obtained as 0.009417.
4. Under the effect of seismic load, the max. storey shear is obtained as 0 and min. storey shear obtained as -2878.62 kN.
5. Under the effect of wind load, the max. storey displacement is obtained as 241.05 mm. Based on the results, it is verified that as number of storey increases, storey displacement was also increases.
6. Under the effect of wind load, the max. storey drift is obtained as 0.00404.
7. Under the effect of wind load, the max. storey shear is obtained as 0 and min. storey shear is obtained as -1163.01 kN.

8. The max. storey displacement for critical load combination is observed for 1.5(DL + W-Y DIR.) which is 804.62 mm under wind loading condition. Hence, the load combination "1.5(DL + W-Y DIR.)" is critical. From analysis it is observe that wind on Y direction produce more diaphragm displacement than wind in X direction.

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