Analysis and Design of High Rise Building Subjected to Combined Effect of Earthquake and Strong Wind using E-Tab Software

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Abstract - *The high rise building with a long lifetime may be exposed to one or more extreme peril .Traditionally; specifications individually treated the multiple extreme hazards according to controlling load case. Thus, the ability of high rise buildings designed by the current codes to face the combined threats of earthquake and wind is rather imprecise. This paper presents a multihazard-based framework to assess the damage risk of high rise buildings which can be broken into three parts: the modeling of hazards and the damage probability computation. Modern tall buildings have efficient structural systems, and utilize high-strength materials, resulting in reduced building height, and thus, become more slender and flexible with low damping. These flexible buildings are very sensitive to wind excitation and earthquake load causing discomfort to the building occupants. Therefore, in order to mitigate such an excitation and to improve the performance of tall buildings against wind loads and earthquake loads, many researches and studies have been performed. Numerical results indicates that story displacement, story drift, depth – capacity ratio and contributions of each hazard circumstances are sensitive to damage severity. The comprehensive application highlights the necessity of examining the responses of multistoried buildings subjected to multihazards.*

Key Words: **Seismic effect, wind effect, damage probabilities, story displacement, story drift.**

1. INTRODUCTION

The first high-rise buildings were constructed in the United States in the 1880s. They arose in urban areas where increased land prices and great population densities created a demand for buildings that rose vertically rather than spread horizontally, thus occupying less precious land area. High-rise buildings were made practicable by the use of steel structural frames and glass exterior sheathing. By the mid-20th century, such buildings had become a standard feature of the architectural landscape in most countries in the world. The foundations of high-rise buildings must sometimes support very heavy gravity loads, and they usually consist of concrete piers, piles, or caissons that are sunk into the ground. Beds of solid rock are the most desirable base, but ways have been found to distribute loads evenly even on relatively soft ground. The most important factor in the design of high-rise buildings, however, is the building's need to withstand the lateral forces imposed by winds and potential earthquake. Most high-rises have frames made of steel or steel and concrete. Their frames are constructed of columns (vertical-support members) and beams (horizontal-support members). Cross-bracing or shear walls may be used to provide a structural frame with greater lateral rigidity in order to withstand wind stresses. Even more stable frames use closely spaced columns at the building's perimeter, or they use the bundled-tube system, in which a number of framing tubes are bundled together to form exceptionally rigid columns.

1.1 Stages in Structural Design

Every structure follows a specific path from its initiation to ultimate design as follows:

1) Structural planning of the building.
2) Calculation of applied loads.
3) Structural analysis of the building
4) Design of the building as per analysis.
5) Drawing and detailing of the structural members.
6) Preparation of tables and graphs.
7) It is the responsibility of the structural engineer to construct the building structurally good, considering all the loads acting on the building. There are so many methods of conducting these design we use E-tab software.

1.2 Introduction to E-tab

For nearly 30 years, ETABS has been recognized as the industry standard for Building Analysis and Design Software. Today, continuing in the same tradition, ETABS has evolved into a completely Integrated Building Analysis and Design Environment. The System built around a physical object based graphical user interface, powered by targeted new special purpose algorithms for analysis and design, with interfaces for drafting and manufacturing, is redefining standards of integration, productivity and technical innovation. The integrated model can include Moment Resisting Frames, Braced Frames, Staggered Truss Systems, Frames with Reduced Beam Sections or

Side Plates, Rigid and Flexible Floors, Sloped Roofs, Ramps and Parking Structures, Mezzanine Floors, Multiple Tower Buildings and Stepped Diaphragm Systems with Complex Concrete, Composite or Steel Joist Floor Framing Systems. Solutions to complex problems such as Panel Zone Deformations, Diaphragm Shear Stresses, and Construction Sequence Loading are now at your fingertips. For Buildings, ETABS provides the automation and specialized options needed to make the process of model creation, analysis and design fast and convenient. Tools for laying out floor framing, columns, and frames and walls, in concrete or steel, as well as techniques for quickly generating gravity and lateral loads offer many advantages not available from most general purpose finite element programs. Seismic and wind loads are generated automatically according to the requirements of the selected building code. All of these modeling and analysis options are completely integrated with a wide range of steel and concrete design features. Full dynamic analysis, including nonlinear time-history capabilities for seismic base isolation and viscous dampers, along with static nonlinear pushover features offer state of the art technology to the engineer doing performance design. Powerful features for the selections and optimization of vertical framing members as well as the identification of key elements for lateral drift control provide significant time savings in the design cycle.

1.3 Getting Started

This paper includes detailed information on the methodology to analyze and design a high rise structure on E-tab software. Model generation, fixation of supports, load analysis and finally building design. Step by step procedure has been explained with the help of diagrams. Next to that, load calculations have been explained in depth and effect of seismic and wind calculations have been undertaken.

2. LITERATURE REVIEW

Xiao –Wei zheng, Hong-Nan Li,Yeong –Bin Yang, Gang Li,(2019)(1)In this paper they studied about multihazard based framework to access the damage risk of high rise building subjected to earthquake and wind hazard separately and simultaneously .Numerical values indicate that the damage probability and contribution of each hazard conditions are sensitive to damage severity .the extensive application highlight the necessity of examining the responses of high rise buildings subjected to multihazard.

Ferrareto A.Johann (2018)(2) In this paper they studied about accessing tall building oscillations due to wind –induced motion is a multidisciplinary task that involve knowledge from several fields of study ,including structural engineering ,wind engineering ,reliability ,and even human physiology .

Alfonso Vulcano ,(1998)(3)this paper presented a study about based isolation is a very effective technic for reducing the seismic forces trough a de coupling of the structure option from that of the soil. With regard to the earthquake, the insertion of very flexible based isolation system is generally favorable, particularly for reducing the ductility demand .main purpose of this paper is to conclude the dynamic response of base isolated structures subjected to strong earthquakes and wind loads in order to achieve an optimal design of the base isolation system.

Siu-Kui Au, Feng-Liang zhang ,ping To ,(2011)(4)This paper describes observation on the identified model properties of two tall buildings using ambient vibration data collected during strong wind moments. The approach views model identification as an inference problem where probability is used as a measure for the relative possibility of outcome given in a model of the structure and measured data .identification of the identified natural frequencies and damping ratios verses the model root –mean-square value indicate a significant trend that is statistically repeatable across events .

Dat Duthinh1 and Emil Simiu2,(2010)(5)In accordance with the ASCE Standard 7-05, in regions subjected to wind and earthquakes, structures are designed for loads induced by wind and, separately, by earthquakes, and the final design is based on the more demanding of these two loading conditions. Implicit in this approach is the belief that the standard assures risks of exceedance of the specified limit states that are essentially identical to the risks inherent in the provisions for regions where only wind or earthquakes occur. We draw the attention of designers, code writers, and insurers to the fact that this belief is, in general, unwarranted, and that ASCE 7 provisions are not risk consistent, i.e., in regions with significant wind and seismic hazards, risks of exceedance of limit states can be up to twice as high as those for regions where one hazard dominates.

Azlan Adnan, Suhana Suradi,(2008)(6) This study addresses the performance of reinforced concrete buildings with the comparison on the effect of earthquake and wind loads for existing buildings in Malaysia, so that the adequacy of the design capacity can be checked. This study investigated seven existing buildings from West and East Malaysia. The buildings were categorized as medium and high-rise reinforced concrete moment resisting frames.

Sanchita hirde (et.al) (7) The paper presented a study on the severity of earthquake verses against wind forces or multy story RCC building the main aim is to analyze the multistoried structure situated in wind zone vi and compare its performance to the buildings situated in zone v the analysis is carried out using the software ETABS .he observed that the effect of both earthquake forces and wind forces on multistory building increases with increase in height of a building.

3. OBJECTIVES

The main objective of this paper is to undergo lateral load analysis and design of high rise building subjected strong wind and earthquake on E-Tab. The objectives have been specified as follows:

1. Generation of building model on E-Tab.
2. To study various design and drawings of RC building.
3. Comparison of severity of forces acting on the structure.
4. Finding out effects on various parameters of RC building under seismic events and strong wind
5. The focus of this study, in the field of wind and earthquake engineering is on the comparison of the dynamic behavior of a multi-story reinforced concrete building and how they respond to wind and earthquake induced excitation.
6. To find story drift, story displacement ratio, story stiffness, story shear of G+15 high rise building.
7. Analysis and design of the high rise structure on E-Tab.
8. Study of the reaction forces, shear force, bending moment and node displacement, story displacement.

4. METHODOLOGY TO UNDERTAKE ANALYSIS AND DESIGN OF G+15 BUILDING ON E-Tab.

Step by step procedure to learn ETABS

1. Modeling using ETABS.
2. Comparison of total DL, LL, WL, EL.
3. Time period and Mode participation factor of building in X and Y direction.
4. Seismic force calculation as per IS: 1893(Part 1) – 2002.
   a. Static method
   b. Dynamic method
5. Site specific response spectra
6. Site specific time history
7. Design under gravity and seismic load

The analysis and design is undertaken as per IS 456:2000. M25 concrete and FE500 is used as design parameters. Percentage steel of 4% has been specified as per IS Code standards and the design parameters have been assigned to respective beam and column. After the final design of the structure, the output file is generated containing the structural design of every individual beam and column member.

5. ANALYSIS OF G+15 BUILDING

Linear static method of analysis is selected for the given structure. This approach defines a series of forces acting on the building to represent the effect of earthquake ground motion and strong lateral forces such as wind, typically defined by a seismic design response spectrum. It considers that the building vibrates in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the ground moves and in case of strong wind. The seismic zoning map of India is given below categorizing every zone as zone II, III and IV, V

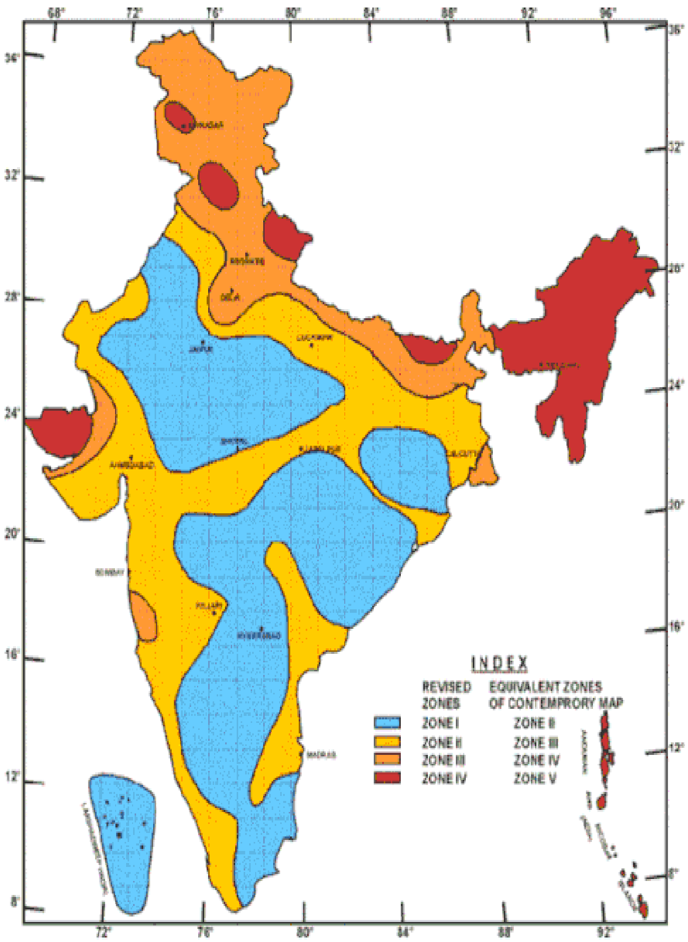


Fig.no. 1: Seismic Zoning Map of India

5.1 Response Spectrum

The response spectrum coefficient considered as per Indian Standards for the purpose of design, which is shown in the figure shown below for different soil type based on suitable natural periods and damping ratio of the structure. The spectral acceleration coefficient (Sa/g) considered as per IS 1893 (Part 1): 2002 is given below

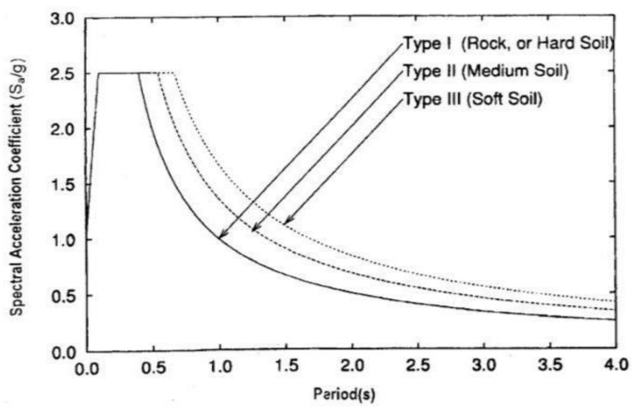


Fig .no. 2: Response spectra for 5% damping

5.2 Project Statement

A structure considered here is a residential building with plan dimension. For wind load IS 875(1987) part-3 is used and IS:1893 (part -1) 2002 is used for seismic loading.

Table no 1: Specification of building model

Location of building	Arunachal Pradesh
Dimension of building	11mx15m
Number of stories	G+15
Height of ground floor	4.155m
Size of beam	200mmx600mm
Size of column	200mmx1200mm
Thickness of slab	140mm
Thickness of exterior wall	230mm
Thickness of interior wall	100mm
Seismic zone	V
Zone factor	0.36
Importance factor	1.15
Response reduction factor	5
Live load	2kN/m
Floor finish	1kN/m
Live load on roof	2Kn/m
Density of masonry wall	20kN/m^3
Thickness of shear wall	200mm
Type of soil	Hard strata
Wind speed	59 m/sec
Windward coefficient	0.8
Leeward coefficient	0.5
Risk coefficient	1
Topography coefficient	1
Grade of steel	Fe500
Grade of concrete	M25

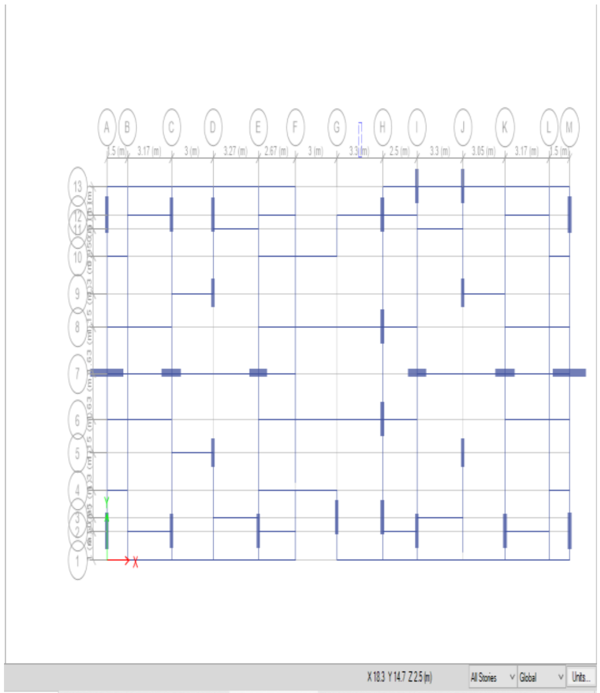


Fig.no.3: Plan view of G+15 RC building.

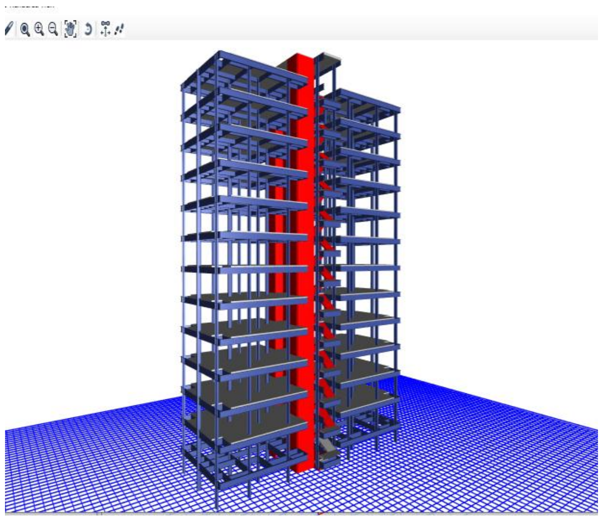


Fig.no.4: Extruded 3D view of G+ 15 storied building models with properties.

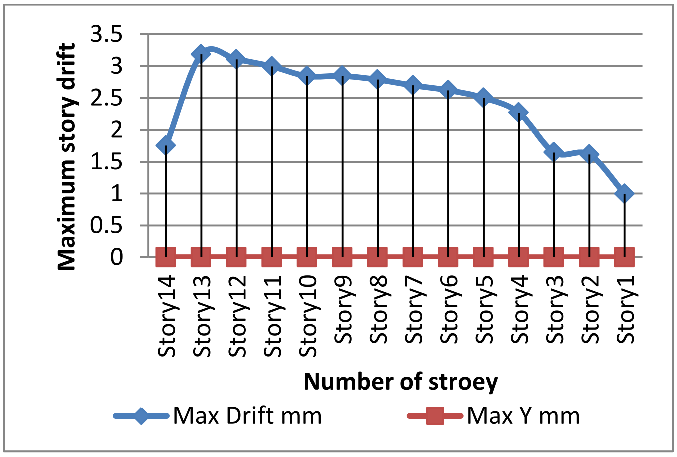
6. RESULTS AND DISCUSSION

6.1 STORY DRIFT: Story Drift is the lateral displacement of one level relative to the level above or below. Story Drift Ratio is the story drift divided by the story height.

Values of drift at different story is given in following table and shown by graph.

Table no. 2:Story drift of G+15 RC Building

Story	Max Drift	Max Y
	mm	Mm
Story14	1.753324	0.000584
Story13	3.183596	0.001061
Story12	3.105447	0.001035
Story11	2.994398	0.000998
Story10	2.842675	0.000948
Story9	2.845554	0.000949
Story8	2.787239	0.000929
Story7	2.696967	0.000899
Story6	2.620251	0.000873
Story5	2.501055	0.000834
Story4	2.268071	0.000756
Story3	1.64621	0.000549
Story2	1.611888	0.000537
Story1	0.996029	0.000398



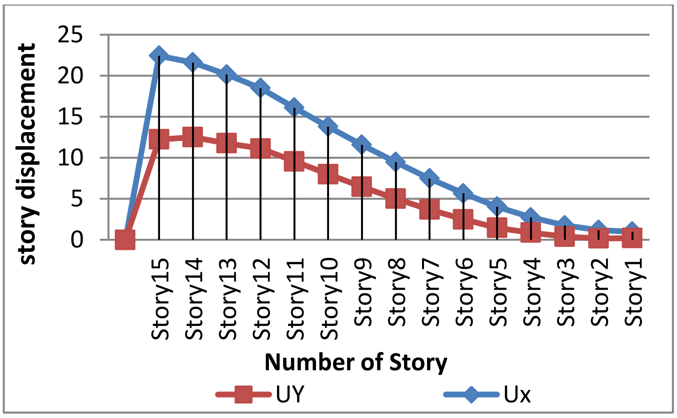
Graph no.1-Max.Story drift of G-15 Building

6.2 Story Displacement:

It is defined as the displacement of a story with respect to the base of a structure. Values of displacement of different story is given by following tables and graphs:

Table no.3: Story displacement of G+15 RC Building

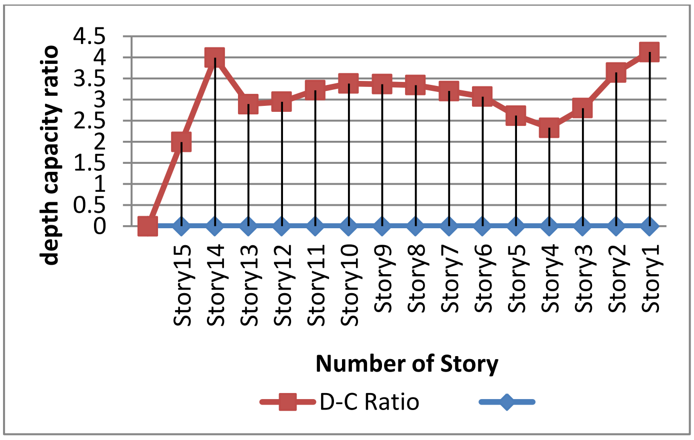
Story	Step Type	Ux	UY
Story15	Max	22.43	-10.198
Story14	Max	21.60413	-9.098
Story13	Max	20.1546	-8.378
Story12	Max	18.48874	-7.358
Story11	Max	16.09398	-6.523
Story10	Max	13.79305	-5.797
Story9	Max	11.57293	-5.114
Story8	Max	9.465401	-4.449
Story7	Max	7.47832	-3.801
Story6	Max	5.662429	-3.174
Story5	Max	4.037101	-2.572
Story4	Max	2.733937	-1.861
Story3	Max	1.745233	-1.367
Story2	Max	1.182227	-1.01
Story 1	Max	0.997438	-0.781



Graph no 2: story displacement at different floors

Table no .4: 3Depth capacity ratio of G+ 15 RC building

Story	D-C Ratio
Story15	1.994569611
Story14	3.994569611
Story13	2.89321599
Story12	2.951896904
Story11	3.221132515
Story10	3.38230779
Story9	3.368322467
Story8	3.34481401
Story7	3.202764257
Story6	3.070789297
Story5	2.620304297
Story4	2.331528576
Story3	2.799107778
Story2	3.642826877
Story1	4.126733727



Graph no 3. Depth –Capacity ratio at different floors

7. CONCLUSIONS

1. While multistoried RC building is subjected to multihazard of wind and earthquake then variations in storey displacement at each floor i.e. storey displacement doesn't increase with height of building as compare to normal earthquake excitation.
2. Storey drift values of building with wind & earthquake excitation increase with building height but it suddenly fall at at 14 storey.
3. A design model is generated on E-Tab to counteract effects of story drift and story displacement due to multihazard of wind and earthquake on a building by selecting proper size of structural members and reinforcement in different components of a building.

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