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ANALYSIS OF HIGH RAISED STRUCTURE IN TWO DIFFERENET SEISMIC ZONES WITH DIAGRID SYSTEM AND SHEAR WALL SYSTEM

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Abstract:

Urbanization has led to a surge in high-rise construction due to limited land availability and high costs in cities. As building heights increase, the significance of lateral load-resistant systems surpasses that of gravity load-resistant systems. Among these, diagrid and shear wall systems are prominent due to their cost-effectiveness, aesthetic appeal, and performance. Recently, diagrid systems have gained popularity because of their structural efficiency and distinctive geometric design.

This study presents a comparative analysis of high-rise buildings with different lateral load-resisting systems. Two 36-storey models were analyzed: one incorporating a diagrid system and the other utilizing a shear wall system. All other building parameters were kept constant. The models were evaluated for seismic performance in zones II and IV with medium soil conditions, following the guidelines of IS 1893 (Part 1): 2002, using ETABS software.

Key performance metrics such as maximum storey displacement, storey drift, and storey stiffness were examined and compared between the two systems. The analysis provides insights into the relative effectiveness of diagrid and shear wall systems in high-rise buildings.

Keywords:

High-rise buildings, Lateral load-resistant systems, Diagrid system, Shear wall system, Seismic analysis, Storey displacement, Storey drift, Storey stiffness, ETABS, IS 1893 (Part 1): 2002.

I. Introduction

The rapid urbanization and increasing demand for high-density development have led to the construction of tall buildings, where robust lateral load-resisting systems are essential for ensuring safety and structural integrity under seismic and wind loads[1,2]. Among the various strategies employed, the outrigger and belt truss system is recognized as particularly effective in enhancing the lateral stiffness and stability of tall buildings [3,4].The outrigger and belt truss system works by connecting external columns to a central core wall through stiffened outriggers and belt trusses at different levels of the building[5,6]. This system can be configured in various ways, with the core either centrally located and connected to outriggers on both sides, or positioned asymmetrically with outriggers extending to the building's columns on one side[7,8]. The core's connection to the external columns through outriggers and belt trusses effectively transforms the building into a unified structure that can resist lateral forces more efficiently[9,10].

The primary function of the outrigger beams and belt trusses is to tie the central core to the peripheral columns, significantly enhancing the building's resistance to lateral loads by reducing drift and minimizing the risk of both structural and non-structural damage [1,11]. The belt truss ties the exterior columns together, while the outriggers engage these columns with the central core, helping to resist overturning moments through the development of a tension-compression couple in the perimeter columns[13,14].In a conventional outrigger system, outrigger trusses are directly connected to shear walls or braced frames at the core, providing direct resistance to lateral forces[15]. This system functions similarly to virtual outrigger systems, where rigid floor diaphragms transfer moments from the core to the trusses and eventually to the exterior columns[16]. The diaphragms, being inherently stiff and strong within their plane, resist core rotation, converting part of the core's moment into a horizontal couple within the floors[17]. This horizontal couple is then transferred through the truss chords and converted into vertical forces at the exterior columns, further contributing to the building's lateral stability[18]. Additionally, basement walls and belt trusses can also act as effective virtual outriggers, providing similar benefits in terms of moment distribution and resistance to lateral forces[19, 20]

2. Objectives of the Work

- To investigate the behavior of a multi-storeyed building by comparing two different structural models: one featuring a diagrid system and the other incorporating shear walls.

- To determine the seismic response of the models using the response spectrum method.

- To analyze the building according to the seismic load requirements specified in IS 1893 (Part 1): 2002.

- To model the two structural systems of the building and perform analysis using ETABS software.

- To assess the seismic response of the building in terms of lateral displacement, storey drift, and storey stiffness.

- To compare the seismic performance of the two building models, one utilizing a diagrid system and the other featuring shear walls.

3. Scope of the Work

- The study is focused on comparing the seismic analysis of a symmetrical diagrid structure and a shear wall structure.

- The model considered is a reinforced concrete (RC) building with G+36 storeys, covering a plan area of 36m x 36m. The building's performance is analyzed in seismic Zone II and Zone IV using the response spectrum method.

- The modeling and analysis of the structure are carried out using ETABS software.

- Storey displacements (SD), storey drifts (SDR), and storey stiffness (SS) are evaluated and compared between the two models.

4.Theory and Methodology

4.1.1 Seismic Analysis

Seismic analysis involves calculating the seismic design forces and ensuring structural ductility. Unlike dead, live, and wind loads, seismic forces are unpredictable and vary in direction, magnitude, and duration. These forces result from the ground motion and are influenced by the building's mass, stiffness, and energy-absorbing characteristics. Analysis methods include:

-Linear Static Analysis: Uses a pseudo-lateral static load pattern to estimate forces and displacements due to strong ground motion. This method is unsuitable for structures with irregularities or high ductility demands[21]Linear Dynamic Analysis: Employs modal analysis, response spectrum, or time-history analysis to compute forces and displacements. Response spectrum analysis is preferred for its efficiency in handling multiple modes of vibration[22]. Non-Linear Static Analysis: Known as Pushover Analysis, this method applies increasing lateral loads to simulate inelastic behavior and failure points of structural component[23].Non-Linear Dynamic Analysis**: Also called Inelastic Time-History Analysis, this approach captures actual structural behavior during an earthquake by numerically integrating the equations of motion, considering elasto-plastic deformation[24].

4.1.2 Response Spectrum Analysis

This method, also known as the modal method, is used to analyze structures subjected to medium-intensity ground shaking. It evaluates the response in different vibration modes, combining modal responses to estimate total structural response[25] The primary limitation is that it assumes linear behavior and may not capture non-linear effects accurately[26].

4.1.3 Earthquake Design Philosophy

Seismic design aims to create earthquake-resistant buildings that, while not impervious to damage, will avoid collapse and ensure safety during strong earthquakes. The philosophy includes:

- Minor shaking: Non-load-carrying parts may sustain repairable damage.

- Moderate shaking: Main structural elements may be damaged but are repairable.

- Strong shaking: Main elements may suffer severe damage, but collapse should be avoide[27]

5. Modelling and Analysis

This chapter outlines the modelling and analysis of two G+36 storey building structures using ETABS V16.2.1. The first model features a diagrid system along the building's periphery, while the second model includes shear walls at the exterior frame corners extending 6m in both X and Y directions. The structures are analyzed in seismic zones II and IV of India with medium-stiffness soil conditions. ETABS provides comprehensive tools for 3D modelling, linear and non-linear analysis, and design optimization, offering detailed results and customizable reports for both structural models. Fig.1Plan&3D view of model with diagrids and Table.1Description of the Building Data as shown in table.

StoreyDisplacement-Zone II

It is the total displacement of ith storey with respect to the ground. The storey displacements of the modelled structures located in zone II by response spectrum method are shown in Table.3

1	**Details of the building**		
	Plan area		36mx36m
	Number of storeys		G+36
	Type of building		Regular and Symmetrical in plan
	Structure		SMRF
	Height of the building		115.4m
	Storey height–Bottom storey Typical storey		3.4m 3.2m
	Support		Fixed
	Seismic zones		II,IV
2	**Material properties**		
	Grade of concrete		M50,M45,M40
	Grade of steel		Fe415,Fe500
	Density of reinforced concrete		$25kN/m^3$
	Young'smodulus of concrete, E_C		$5000\sqrt{fck}x10^3kN/m^2$
	Young's modulus of steel,E_S		$2x10^8kN/m^2$
3	**Type of loads &the irintensities**		
	Floor finish		$1.5kN/m^2$
	Live load on floors		$3kN/m^2$
	Wall load on beams		$3.9kN/m^2$
	Parapet wall load		$1kN/m^2$
	Glass load		$3.5kN/m^2$
4	**Seismicproperties**		
	Zones	II	0.10
		IV	0.24
	Importance factor(I)		1

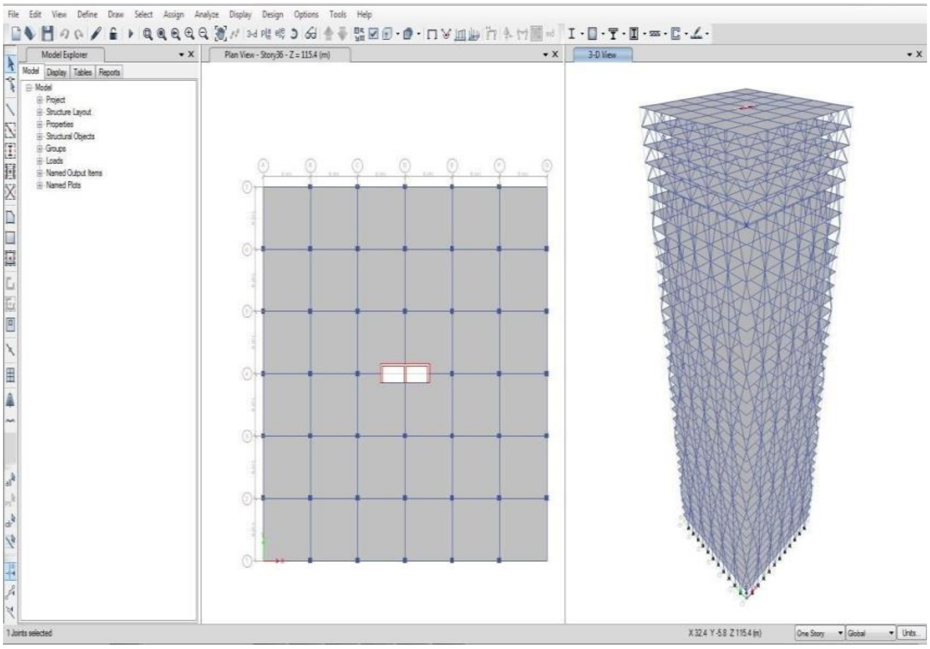
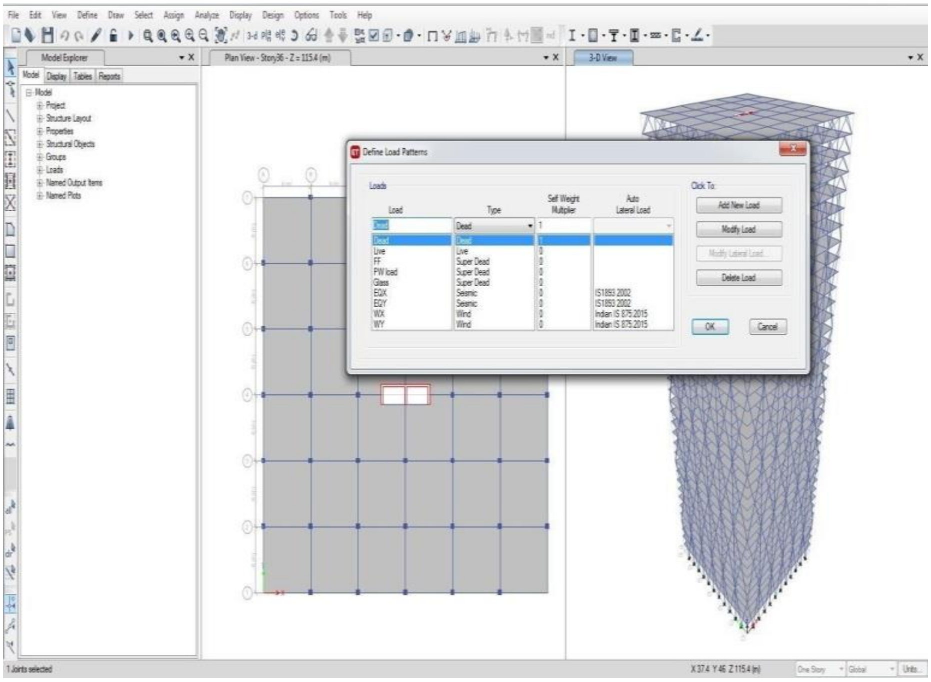


Fig.5.1Plan&3D view of model with diagrids



Load	Type	Self Weight Multiplier	Auto Lateral Load
Dead	Dead	1	
Dead	Dead	1	
Live	Live	0	
FF	Super Dead	0	
PW load	Super Dead	0	
Glass	Super Dead	0	
EQX	Seismic	0	IS1893 2002
EQY	Seismic	0	IS1893 2002
WX	Wind	0	Indian IS 875:2015
WY	Wind	0	Indian IS 875:2015

Fig.2.Loading patterns in diagrid structure

Table.1Description of the Building Data

Storey20	64.2	24.025	0.637	0.682	24.870
Storey19	61.0	22.855	0.615	0.665	23.772
Storey18	57.8	21.707	0.592	0.645	22.680
Storey17	54.6	20.485	0.565	0.612	21.452
Storey16	51.4	19.250	0.537	0.582	20.210
Storey15	48.2	18.080	0.512	0.560	19.072
Storey14	45.0	16.905	0.485	0.537	17.955
Storey13	41.8	15.762	0.460	0.515	16.872
Storey12	38.6	14.625	0.432	0.490	15.777
Storey11	35.4	13.417	0.402	0.457	14.577

Storey	**Storey Level (m)**	**For EQX**		**For EQY**	
		X-Dir (mm)	**Y-Dir (mm)**	**X-Dir (mm)**	**Y-Dir (mm)**
Storey36	115.4	39.797	0.955	0.982	40.390
Storey35	112.2	39.287	0.920	0.955	39.907
Storey34	109.0	38.755	0.902	0.942	39.405
Storey33	105.8	38.195	0.887	0.930	38.877
Storey32	102.6	37.610	0.840	0.898	38.325
Storey31	99.4	36.857	0.837	0.897	37.660
Storey30	96.2	35.957	0.835	0.892	36.757
Storey29	93.0	34.897	0.820	0.867	35.632
Storey28	89.8	33.865	0.815	0.857	34.577
Storey27	86.6	32.792	0.800	0.847	33.532
Storey26	83.4	31.617	0.777	0.825	32.405
Storey25	80.2	30.465	0.762	0.815	31.327
Storey24	77.0	29.252	0.742	0.797	30.145
Storey23	73.8	27.932	0.715	0.762	28.767
Storey22	70.6	26.602	0.690	0.730	27.387
Storey21	67.4	25.315	0.665	0.707	26.107

CONCLUSIONS

The seismic performance of the building was evaluated through response spectrum analysis. Two building models—one with a diagrid system and the other with a shear wall system—were analyzed in seismic zones II and IV using ETABS software. The following conclusions are drawn from the results:

- In seismic zone II, the maximum story displacement of the diagrid structure is reduced by 35.45% compared to the shear wall structure in both X and Y directions.

- In seismic zone IV, the maximum story displacement of the diagrid structure is reduced by 43.14% compared to the shear wall structure in both X and Y directions.

- The maximum story drift of the diagrid structure is reduced by 23.97% compared to the shear wall structure in seismic zone II.

- In seismic zone IV, the maximum story drift of the diagrid structure is reduced by 29.81% compared to the shear wall structure.

- The maximum story stiffness of the diagrid structure is increased by 29.096% compared to the shear wall structure in seismic zone II.

- In seismic zone IV, the maximum story stiffness of the diagrid structure is increased by 30% compared to the shear wall structure.

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