Comparative Analysis of RCC Framed and Diagrid Structures for High-Rise Buildings for Varying Height From G+10 To G+50 Storeys

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Abstract
This research presents a comparative analysis of Reinforced Concrete (RCC) framed structures and RCC diagrid structures for high-rise buildings ranging from G+10 to G+50 storeys. Using ETABS software, the study evaluates structural performance under gravity, wind, and seismic loads in seismic zone V. Key parameters assessed include base reaction, storey displacement, storey drift, storey shear, stiffness, lateral loading, and overturning moment. Results indicate that diagrid structures exhibit superior lateral stiffness, reduced displacement (up to 45% lower), and better resistance to seismic forces compared to traditional framed structures. However, the efficiency of diagrids diminishes with increasing height, suggesting optimal use for mid-rise buildings. The findings highlight the potential of diagrid systems for enhanced structural efficiency and sustainability in high-rise construction.

Keywords
Diagrid structure, RCC framed structure, high-rise buildings, ETABS analysis, seismic performance, wind loads, storey displacement, storey drift, stiffness, overturning moment

1. Introduction

The evolution of high-rise buildings has driven the need for innovative structural systems that balance efficiency, aesthetics, and resilience against lateral loads such as wind and earthquakes. Traditional RCC framed structures rely on vertical columns and beams, while diagrid structures use a network of diagonal members to distribute loads more effectively, eliminating the need for perimeter columns.

This study compares RCC framed and diagrid structures for buildings from G+10 to G+50 storeys, focusing on seismic zone V with a zone factor of 0.36 and wind speed of 47 m/s. The objective is to assess performance parameters like displacement, drift, shear, stiffness, lateral loads, and overturning moments using ETABS simulations.

Diagrid structures, exemplified by buildings like the United India Insurance Ltd in Chennai, offer material optimization and enhanced lateral resistance. The need for this study arises from the growing demand for sustainable high-rise designs in seismic-prone regions like India.

2. Literature Review

Diagrid structures have evolved from traditional braced frames to efficient systems for tall buildings. Moon (2007) and Khan (1969) demonstrated that diagrids reduce material use by 20-30% through diagonal load paths. Ali and Moon (2008) established diagrids as viable for high-rises due to flexible interiors.

For RCC diagrids, Giri and Kumar (2018) found higher lateral stiffness and earthquake resistance. Gupta and Patel (2016) identified optimal diagrid angles of 60°-75° for lateral loads. Kalyani and Reddy (2020) noted improved load distribution in RCC diagrids.

Under seismic and wind loads, Prakash and Sangle (2019) reported reduced inter-storey drift. Kumar et al. (2020) confirmed better aerodynamic performance. Sharma and Bhattacharya (2017) highlighted energy dissipation benefits.

Material efficiency studies by Mendis et al. (2017) suggest 30% less concrete in diagrids. Sharma and Mehta (2021) emphasized lower carbon footprints. Case studies include Capital Gate Tower and Hearst Tower, showcasing RCC diagrid applications.
Challenges include complex joints and costs (Das and Pandey, 2022). Future scope involves AI optimization (Mishra and Sharma, 2023).

3. Methodology

A square plan of 30m x 30m was modeled in ETABS 2018 for G+10 to G+50 storeys. Both RCC framed and

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diagrid models were analyzed under dead, live, wind (IS 875 Part 3), and seismic loads (IS 1893:2016) in zone V.

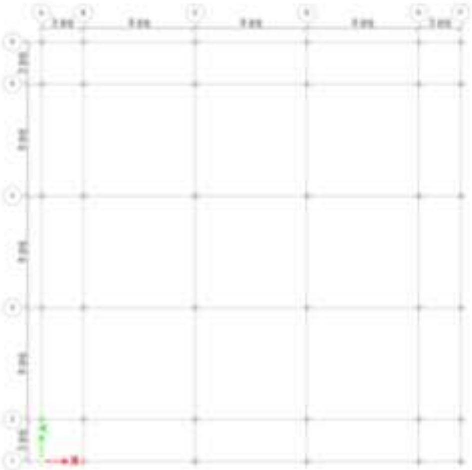

Fig. 1 Plan of Column locations

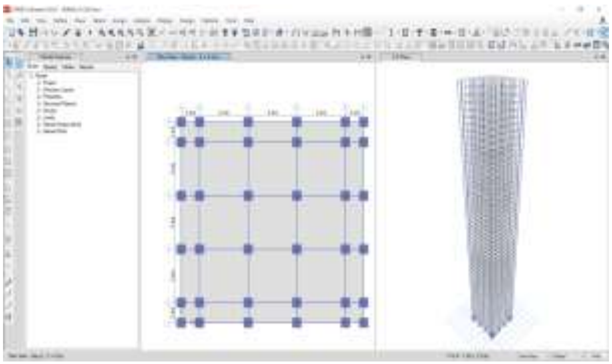

Fig. 2 Plan and elevation of Framed Structure building

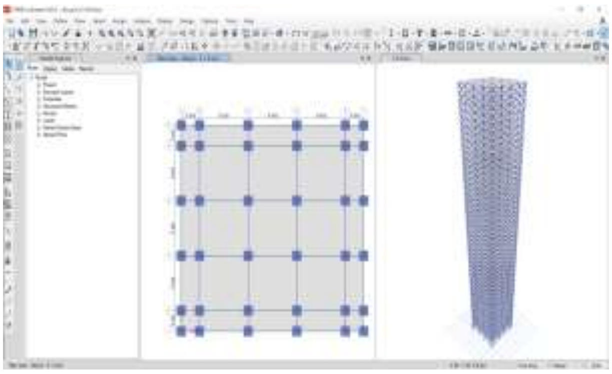

Fig. 3 Plan and elevation of Diagrid Structure building

Building specifications:

- Storey height: 4m
- Concrete grade: M40
- Density of RCC: 25 kN/m³
- Column size: 1500mm x 1500mm
- Beam size: 600mm x 750mm
- Slab thickness: 200mm
- Live load: 3 kN/m²
- Seismic zone factor: 0.36
- Importance factor: 1.5
- Response reduction factor: 5
- Models were fixed at the base

Basic Load Cases in ETABS:
Dead Load (DL) → Self-weight of structural elements
Live Load (LL) → As per IS 875 (Part 2)
Wind Load (WLx, WLy) → As per IS 875 (Part 3)
Seismic Load (EQx, EQy) → As per IS 1893

Load combinations followed IS 456:2000, including:

1.5 (DL + LL)	0.9 (DL)- 1.5(WLy)
1.2 (DL + LL + WLx)	1.2 (DL + LL + EQx)
1.2 (DL + LL - WLx)	1.2 (DL + LL - EQx)
1.2 (DL + LL + WLy)	1.2 (DL + LL + EQy)
1.2 (DL + LL - WLy)	1.2 (DL + LL - EQy)
1.5 (DL + WLx)	1.5 (DL + EQx)
1.5 (DL - WLx)	1.5 (DL - EQx)
1.5 (DL + WLy)	1.5 (DL + EQy)
1.5 (DL - WLy)	1.5 (DL - EQy)
0.9 (DL) + 1.5(WLx)	0.9 (DL) +1.5(EQx)
0.9 (DL) – 1.5(WLx)	0.9 (DL) – 1.5(EQx)
0.9 (DL) + 1.5(WLy)	0.9 (DL) + 1.5(EQy)
	0.9 (DL) – 1.5(EQy)

4. Results and Discussion

4.1 Base Reaction

Diagrid structures show lower base reactions due to efficient load transfer.

TOTAL BASE REACTION (KN)		
	DAIGRID STRUCTURE	RCC FRAMED STRUCTURE
G+10 FLOOR	361877	441146
G+20 FLOOR	786105	821627
G+30 FLOOR	1147931	1201475
G+40 FLOOR	1509859	1581323
G+50 FLOOR	1872069	1961657

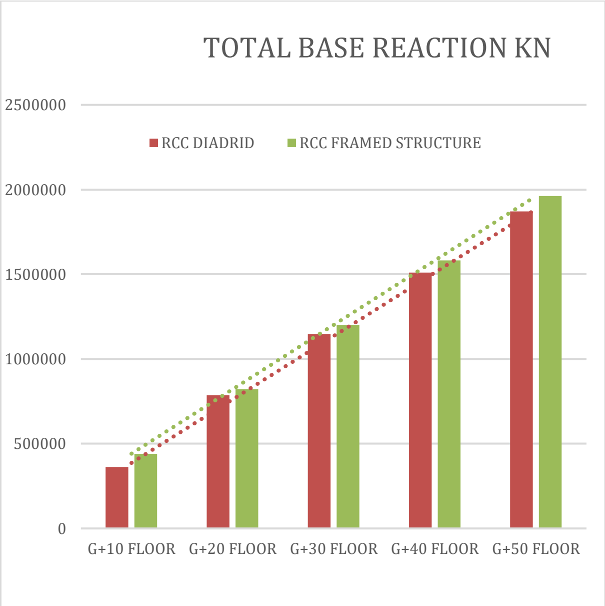

Fig. 4 Graph of Base Reaction

Diagrid reactions are 10-20% lower, improving foundation efficiency.

4.2 Storey Displacement
Diagrid systems reduce displacement by 30-45%.

MAXIMUM STOREY DISPLACEMENT (MM)		
	DAIGRID STRUCTURE	**RCC FRAMED STRUCTURE**
G+10 FLOOR	**24.16**	**41.7**
G+20 FLOOR	**53.53**	**86.62**
G+30 FLOOR	**102.89**	**166.38**
G+40 FLOOR	**171.47**	**264.12**
G+50 FLOOR	**302.24**	**432.78**

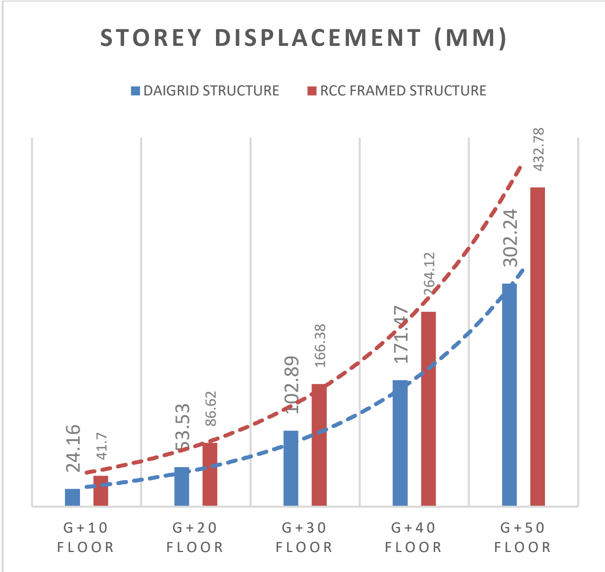

Fig. 5 Graph of Storey Displacement

4.3 Storey Drift
Drift is lower in diagrids, ensuring better seismic performance.

MAXIMUM STOREY DRIFT (MM)		
	DAIGRID STRUCTURE	**RCC FRAMED STRUCTURE**
G+10 FLOOR	**0.000597**	**0.001106**
G+20 FLOOR	**0.00073**	**0.00124**
G+30 FLOOR	**0.000984**	**0.001748**
G+40 FLOOR	**0.00127**	**0.002485**
G+50 FLOOR	**0.00183**	**0.00323**

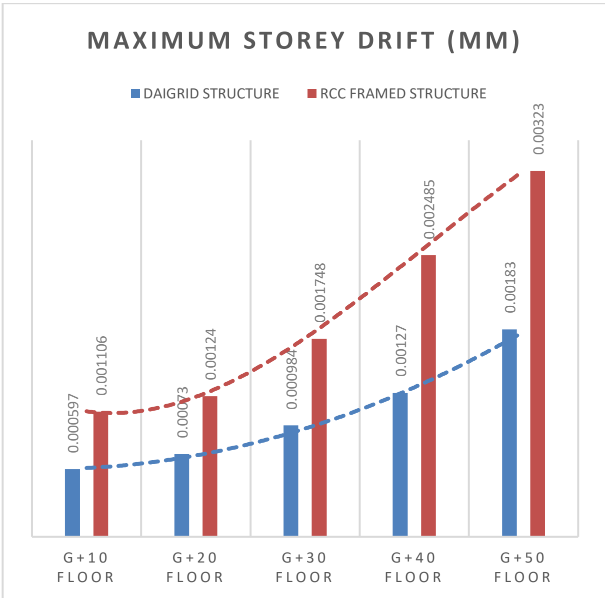

Fig. 6 Graph of Storey Drift

4.4 Storey Shear
Diagrids distribute shear more evenly.

MAXIMUM SHEAR FORCE (KN) AT BASE				
	DAIGRID STRUCTURE	**RCC FRAMED STRUCTURE**	**DAIGRID STRUCTURE**	**RCC FRAMED STRUCTURE**
	MAXIMUM		**MINIMUM**	
G+10 FLOOR	**17325**	**11677**	**-388**	**-398**
G+20 FLOOR	**17485**	**8267**	**-1004**	**-1671**
G+30 FLOOR	**14123**	**7932**	**-1328**	**-2213**
G+40 FLOOR	**11513**	**10275**	**-1591**	**-2548**
G+50 FLOOR	**12035**	**13123**	**-1998**	**-2850**

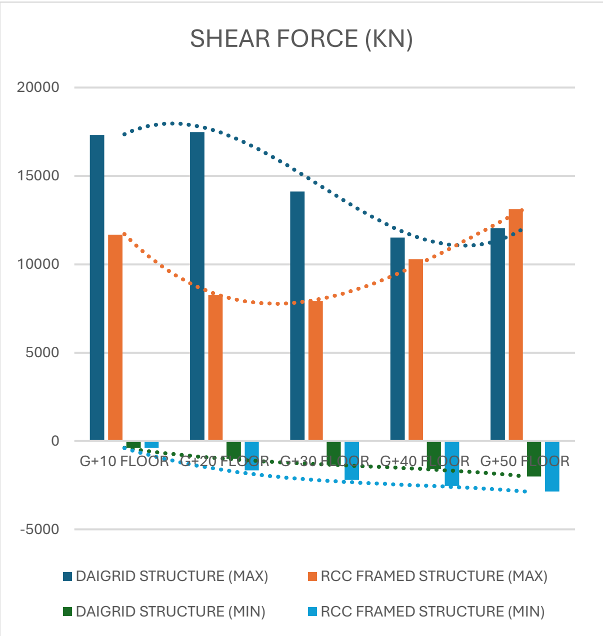

Fig. 7 Graph of Shear Force

4.5 Stiffness
Diagrids are stiffer, with higher values.

MAXIMUM STIFFNESS (KN/M)		
	DAIGRID STRUCTURE	**RCC FRAMED STRUCTURE**
G+10 FLOOR	**15.16**	**11.39**
G+20 FLOOR	**16.04**	**8.72**
G+30 FLOOR	**16.14**	**8.54**
G+40 FLOOR	**16.26**	**8.43**
G+50 FLOOR	**16.39**	**8.35**

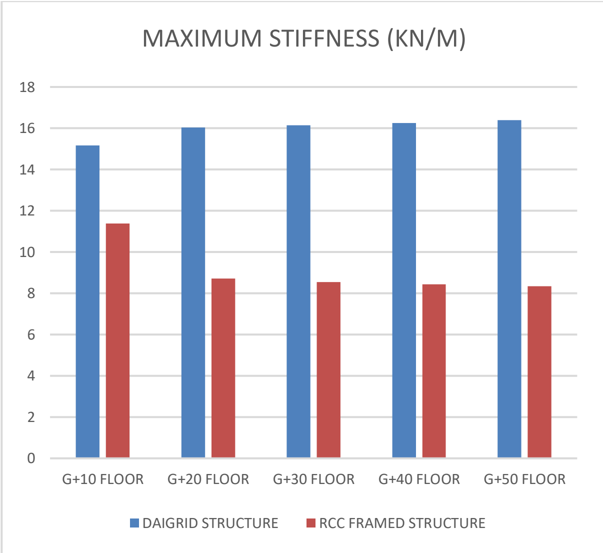

Fig. 8 Graph of Stiffness

4.6 Lateral Loading
Lower in diagrids for lower heights.

Auto Lateral Load (KN)		
	DAIGRID STRUCTURE	RCC FRAMED STRUCTURE
G+10 FLOOR	2300	1550
G+20 FLOOR	1450	770
G+30 FLOOR	870	510
G+40 FLOOR	575	520
G+50 FLOOR	490	530

4.7 Overturning Moment

Diagrids show lower moments.

MAXIMUM OVERTURNING (KN-M)				
	DAIGRID STRUCTURE	RCC FRAMED STRUCTURE	DAIGRID STRUCTURE	RCC FRAMED STRUCTURE
	MAXIMUM		MINIMUM	
G+10 FLOOR	5459000	5960000	-6114000	-6410000
G+20 FLOOR	10610000	10460000	-11840000	-9930000
G+30 FLOOR	15500000	17190000	-17000000	-16310000
G+40 FLOOR	20000000	22890000	-22000000	-21500000
G+50 FLOOR	25000000	28910000	-27000000	-26620000

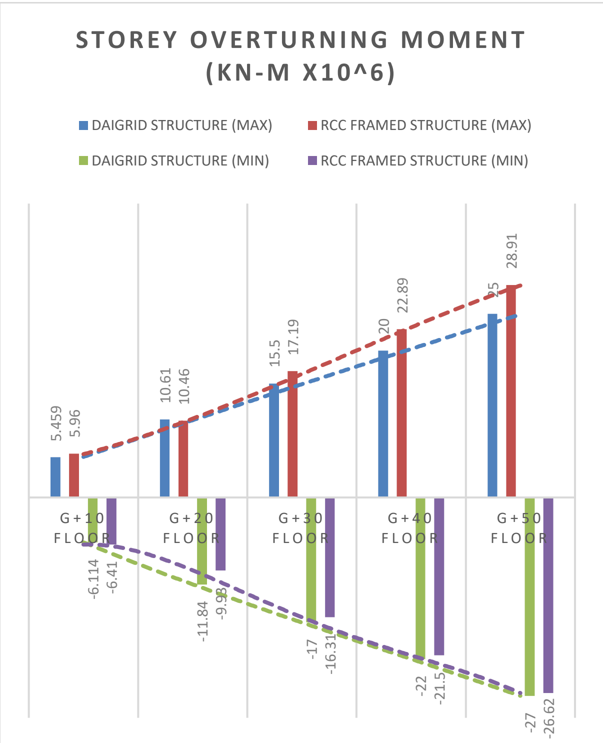

Fig. 9 Graph of Overturning Moment

5. Conclusion

The comparative study between RCC diagrid structures and RCC framed structures shows that diagrid systems generally perform better in terms of structural stability and displacement control. Storey displacement in diagrid structures is significantly lower than in RCC framed structures. At a building height of G+10, the storey displacement in a diagrid structure is about 42% less than that of a framed structure. However, as the building height increases, the effectiveness of the diagrid system decreases, and this reduction drops to about 30% at G+50. Similarly, storey drift is also lower in diagrid structures. The reduction in storey drift is approximately 46% at G+10 and slightly decreases to about 43% at G+50. Base reactions are also comparatively lower in diagrid structures because the diagrid system efficiently carries both vertical and lateral loads. This reduces the need for outer edge columns, making the structure more aesthetically appealing. However, the effectiveness of base reaction reduction decreases from around 17% at G+10 to nearly 4% at G+50.

Overturning moment at the base is also lower in diagrid structures compared to RCC framed structures. The reduction is about 9% at G+10 and improves to nearly 13.5% at G+50. Additionally, diagrid structures are stiffer and help reduce joint reactions, which contributes to improved structural performance and better comfort for occupants.

Analysis of result graphs shows a noticeable change in the trend around G+30 height, indicating that the diagrid system performs efficiently up to approximately 30 storeys. Beyond this height, the system becomes less economical. Therefore, for taller buildings, additional structural techniques such as outriggers, dampers, or alternative materials may be required to maintain efficiency and stability.

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