

# Behavioral Analysis of Eccentric Diagrid Structural Systems for Tall Buildings

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**Abstract**—The development of tall buildings has been rapidly increasing in number worldwide. The trends in tall building design are now towards integrating optimal building form with the Structure to produce an efficient design. Following the recent trends in tall buildings design practice, the first analyzed structural scheme is the Diagrid system, a perimeter structural configuration characterized by a narrow grid of diagonal members involved in gravity and lateral load resistance. The present work demonstrates the linear dynamic analysis of tall buildings considering Diagrid and frame tube structure. The building studied in this work is a G+30, G+40 reinforced concrete moment resisting frame designed for gravity, and seismic using 1893:2016. And is studied using the response spectrum Analysis. It was observed by the dynamic analysis method i.e. response spectrum Analysis, the parameters which were compared between three structural system observed that building with eccentric diagrid system (EDS). system performs better than framed tube and concentric diagrid system (CDS) system. Eccentric diagrid system (EDS). have more lateral displacement resisting stability for about 43% and 12 % lesser displacement compared to framed tube and concentric diagrid system (CDS).

**Index Terms**—Tall buildings, diagrid system, framed tube system, concentric diagrid system (CDS), and eccentric diagrid system (EDS).

## I. INTRODUCTION

An eccentric diagrid structural system is a variation of the traditional diagrid system where the diagonal members are intentionally offset from the center of node and link is introduced, which behaves as a shear link. The eccentric diagrid structural (EDS) system is an innovative and efficient load-bearing framework that enhances both aesthetic and structural performance. Unlike conventional diagrid systems, the

EDS is specifically designed to address and improve post-yield behavior, which is a critical aspect of seismic performance. Comparative studies utilizing numerical models have demonstrated that eccentric diagrid structures exhibit superior post-structural behavior, including an increased collapse point and improved ratios of ultimate resistance to design base shear, reflecting enhanced ductility and over strength. Conventional diagrid structures rely heavily on the aspect ratio and diagonal angle for stiffness, with nonlinearity predominantly arising from diagonal members. However, in EDS, the presence of link beams, which generally increase structural softness, significantly influences the system's elastic stiffness. Nonlinear static analyses have shown that in EDS, the shear links yield first, with diagonal members remaining elastic at this stage. This behavior contrasts with conventional diagrids, where failure typically results from yielding of peripheral diagonals. To study different types irregularities as mass, geometric and stiffness and their effect with outrigger.

- Investigate the behavior of composite buildings, under the seismic zone III Using the response spectrum analysis.
- To check the reliability of Structure with concentric diagrid system (CDS), and eccentric diagrid system (EDS) and frame tube system for 30 and 40 story building.
- To study various responses such as story displacement, bending moment, axial force, inter-story drift, story shear, story stiffness and time period

## II. LITERATURE REVIEW

Fang and Liu (2021): Derived vertical and lateral stiffness of diagrid structure with arbitrary polygon plane under vertical load and horizontal load. Equations of vertical stiffness, lateral shear stiffness, lateral bending stiffness and displacement were proposed by them which can be used for low to high rise diagrid structures. They carried out laboratory experiments and also numerical analysis of reduced scale steel diagrid structure models with octagonal planes. Their results showed that the experimental results and numerical results are in good agreement with each other.

Mohsenian. Et al. (2020): Assessed the seismic reliability of diagrid structural systems. They calculated demand and supply response modification factors for 16, 24 and 32-storey buildings with diagrid structural systems using 65 degree angle and designed in compliance with current standards under a set of 12 spectrum compatible earthquakes. They also performed seismic reliability analysis to assess the seismic performance of structures under earthquake intensity of Design Basis Earthquake (DBE) and Maximum Considered Earthquake (MCE). Their results showed that due to higher mode contributions in tall diagrid systems, the analysis methods based on triangular or first mode lateral load distributions are not suitable for the preliminary design. Under DBE and MCE, higher drift ratio was observed in the top diagrid module

Song and Zhang (2020) : Investigated the influence of diagonal angle, twist rate, aspect ratio, and plan form on the lateral stiffness of twisted diagrid tube structures. They considered 60, 42 and 24 storey diagrid structure with exterior diagrid tube plan as 30 \* 30 m with a bay length of 10 m, and the inner frame plan is 15 \* 15 m, and story height is 3.6m. The diagonal angle from 55 to 71 with twist rate of 1 floor gives satisfactory results for 60 storeys twisted diagrid. 24 storeys twisted diagrid the angle lies in lower range. The torsional deformation of twisted diagrid increases as the diagonal angle increases. The research showed that twisted diagrid structure with asymmetric diagonal angles shows larger lateral stiffness than the symmetric case.

## 1. Module And Building Configuration

### CONCENTRIC DIAGRID SYSTEM (CDS)

In the first Model, a diagrid of one-story module reinforced concrete frame building Situated in zone III is taken for study. The plan area of the building is 40 x 40 m for G+30 story and G+40 story with 3m as the height of each typical story. It consists of 5 bays in X-direction and 5 bays in Y-direction. The total heights of the buildings were 96 and 126 m.

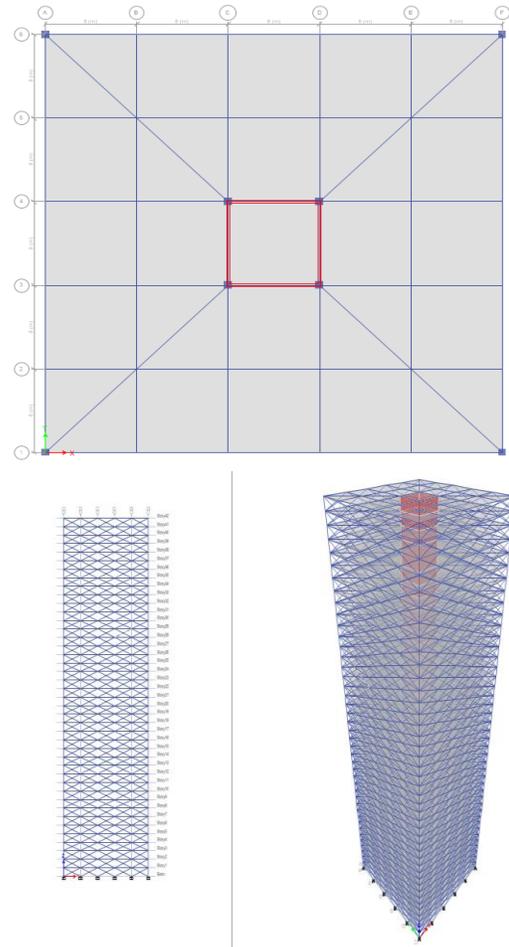


Figure 1: Elevation Views and Isometric view of concentric diagrid system (CDS) G+30 & G+40 Buildings

### ECCENTRIC DIAGRID SYSTEM (EDS)

In the Second Model, eccentric diagrid system (EDS) building situated in zone III is taken for study. The plan area of the building is 40x40 m for G+30 story and G+40 story with 3m as the height of each typical story. It consists of 5 bays in X-direction and 5 bays in Y-direction. The total heights of the buildings were 96 m and 126 m.

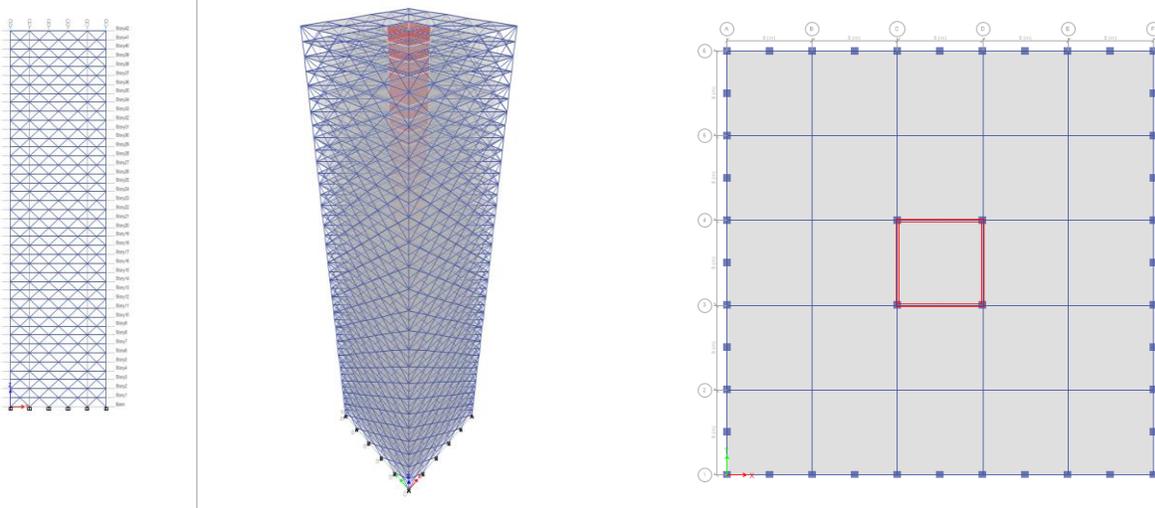


Figure 2: Elevation view and Isometric Views of eccentric diagrid system (EDS) For G+30 & G+40

FRAME TUBE STRUCTURE

Model 3: In the Third Model, the FRAME TUBE Structure situated in zone III is taken for study. The plan area of the building is 40x40 m for G+30 story and G+40 story with 3m as the height of each typical story. It consists of 5 bays in X-direction and 5 bays in Y-direction. The total heights of the buildings were 96 m and 126 m

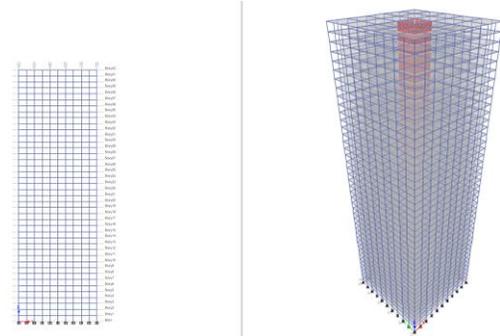
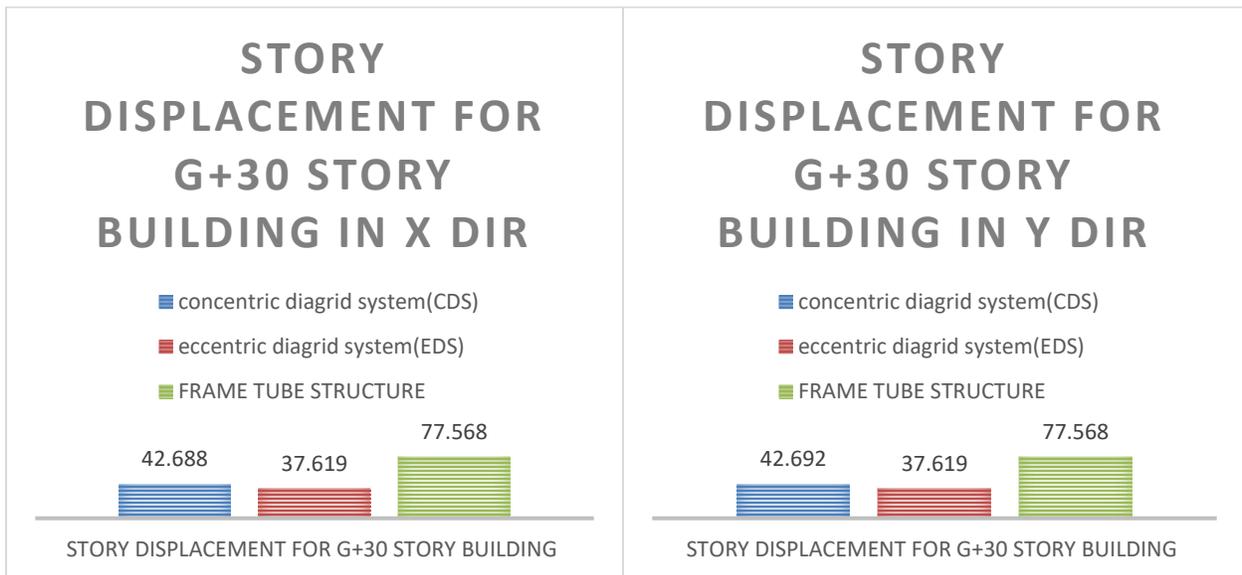


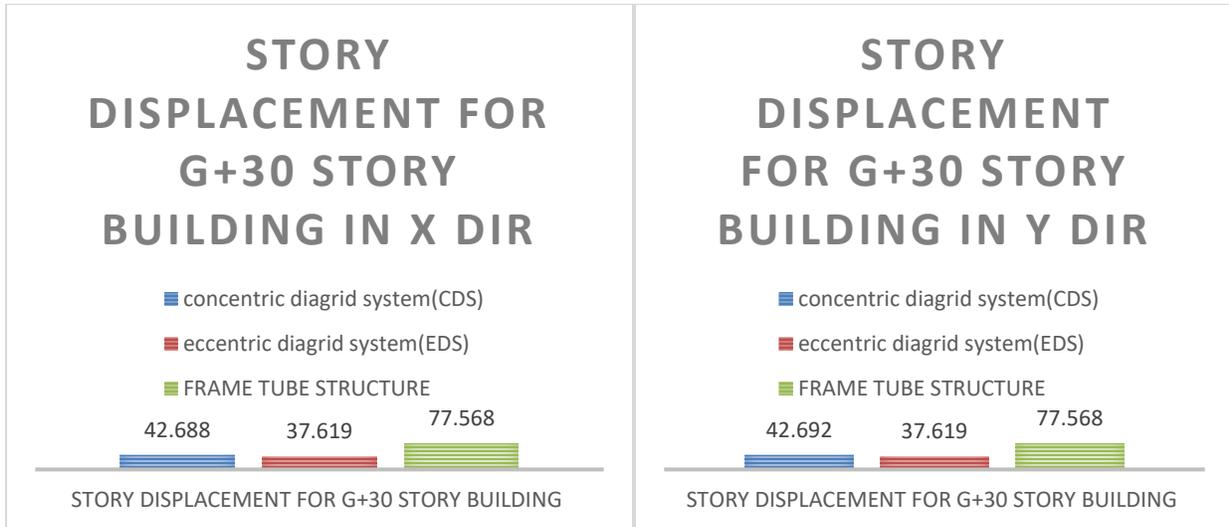
Figure 3: Elevation View and Isometric Views of Framed Tube Structure for G+30 & G+40

III. RESULTS FOR MODELS

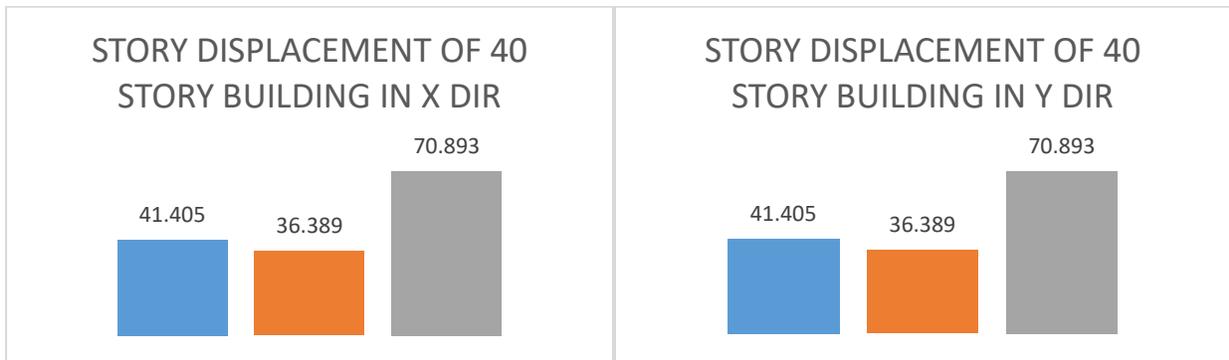
STORY DISPLACEMENT FOR REGULAR MODEL FOR G+30 USING RESPONSE SPECTRUM



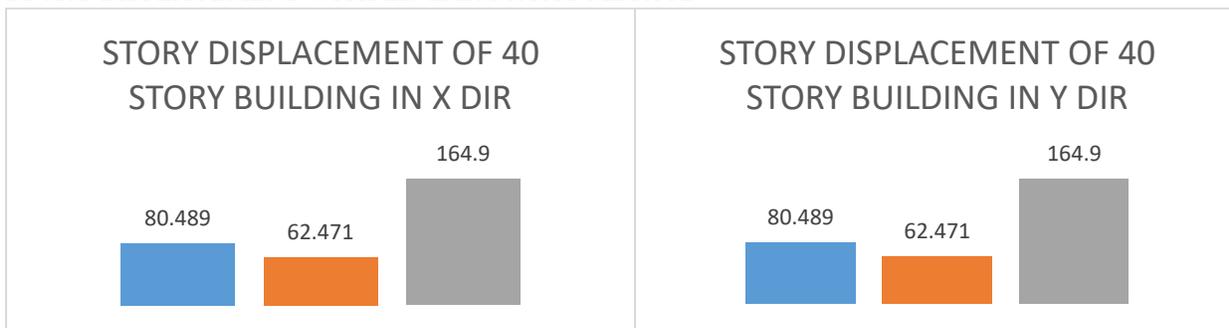
FOR G+30 STORY BUILDING USING LINEAR STATIC METHOD



RESULTS FOR G+40 STORY BUILDING  
STORY DISPLACEMENT WITH RESPONSE SPECTRUM METHOD



STORY DISPLACEMENT WITH LINEAR STATIC METHOD



IV. CONCLUSION

- Complicated system design, analysis and construction in complex, large buildings today are needed. In order to produce higher quality environments, not just architectural but structural and other related performance issues should be considered

holistically. Proper coordination between architects and engineers is important.

- Two-story diagrid structures have better performance in satisfying the stiffness and strength criteria than conventional diagrid systems and framed tube structure. The percentage of reduction in displacement of eccentric diagrid system (EDS) is

12% and 43.9% compared to concentric diagrid system (CDS) and framed tube model.

- As per the results it is found that the displacement of the 1-story diagrid module building is less with response spectrum analysis. The percentage of displacement increases by 37.83 % - 43.4 % from response spectrum to linear static analysis.
- The results showed that for high-rise building the displacements in X directions using the response spectrum analysis are less than their corresponding values obtained using the equivalent static analysis by 48 % and in Y direction the results showed that the displacement using response spectrum analysis are less than corresponding values obtained by using the equivalent static analysis by 48%
- In order to control the seismic response diagrid structure with 2-story module were modelled and the results showed that there is a drastic decrease in storey displacements by 81% and 46% compared to diagrid one story and framed tube structure and storey drifts by 60% and 33% compared to other symmetric building.
- In present work, due to using diagrid structure it gives good ductility and increase in strength carrying capacity and initial stiffness of Rec frame. The reduction of story drift by 40% compared to diagrid 1-story module and framed tube Structure.

#### V. SCOPE OF FURTHER STUDY

- To study the shear lag effect on tall structure, exhibit a considerable degree of shear-lag with consequential reduction in structural efficiency.
- To study the Wind effects on tall building frames-influence of dynamic parameters.
- In the present study, openings were not considered in infills. Presence of opening in infills significantly reduces the stiffness and strength of the infilled frames. Suitability of the proposed strengthening schemes must be verified for Masonry-infilled frames with openings with walls.

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