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A Seismic Study on Diagrid Structure

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***Abstract**: A Comparative study of 8 storey bare frame building and a diagrid building is presented. A 'C' shaped floor plan of 16 m × 16 m size was considered. ETABS was used in modeling and analysis of structural members. All structural members were designed as per IS 456:2000, load combinations such as dead load, live load and design earthquake loads were considered for analysis and design of the structure. Later both bare frame and diagrid structural systems were compared; the comparative study of diagrid structural system shows an increase in the responses like storey shear, storey stiffness and decrease in the responses like storey displacement and storey drift.*

Key Words: Conventional structural system, diagrid structural system, high-rise building, storey drift, storey shear, storey stiffness and top-storey displacement.

I. INTRODUCTION

The rapid growth of urban population and limitation of available land, the taller structures are preferred now a day. So when the height of structure increases then the consideration of lateral load is very much important. Lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are rigid frame, shear wall, wall frame, braced tube system, outrigger system and tubular system. Recently the diagrid – diagonal grid structural system is widely used for tall buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. Hence the diagrid, for structural effectiveness and aesthetics has created renewed interest from architectural and structural design of tall buildings.

Diagrid structural system is a type of exterior structure which is a framework of diagonally intersecting metal, concrete or wooden beams that is used in the buildings. Recently diagrid structural system is adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Compared to closely space vertical columns in framed tube, diagrid structure consists of inclined columns on the exterior surface of building. Inclined columns the present lateral loads are resisted due to axial action of the diagonal compared to bending of vertical columns in framed tube structure. diagrid structures generally do not require core because lateral shear can be carried by the diagonals on the periphery of building.

The difference in exterior - braced conventional frame structural pattern and the diagrid structural pattern is that these buildings do not use conventional vertical columns. The previous earthquakes in India show that not only non-engineered structures but engineered structures need to be designed in such a way that they perform well under seismic loading.

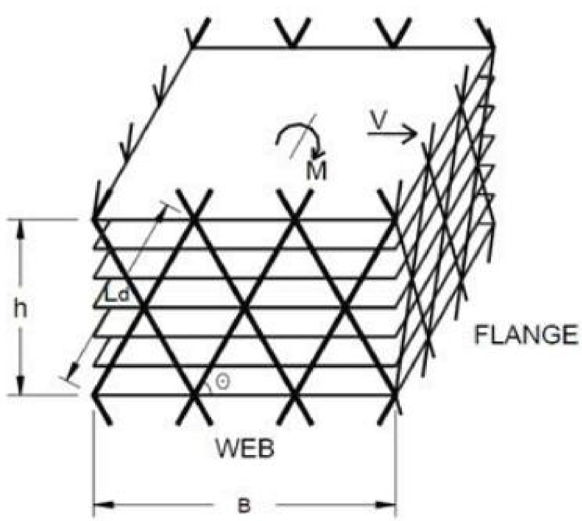

Fig.1. Typical Diagrid module

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To increase the structural performance to lateral loading and to perform well under seismic loading diagrid can be provided. diagrids allow the system to obtain a great increase in lateral stiffness and they increase the natural frequency and usually reduces the lateral drift.

Diagrid has good appearance and is easily visible. The configuration and efficiency of a diagrid system reduce the number of structural element required on the façade of the buildings, therefore less obstruction to the outside view. The structural efficiency of diagrid system also helps in avoiding interior and corner columns, therefore allowing significant flexibility with the floor plan. The diagonal members in diagrid structural systems can carry gravity loads as well as lateral forces due to their triangulated configuration, However the major disadvantage of diagrid system are that still not completely explored, this construction needs a skilled labor and the present crew has no idea or the experience in installing diagrids. The common language of floor to floor design is effected as a single diagrid stacks over 2 to 6 floors in it. Only high-rise buildings can install diagrids, it affects economy and safety of the structure when not properly designed. An early example of the diagrid structure is the IBM building in Pittsburgh built in the early 1960s, with its 13-storey building height. Another famous examples of diagrid structure all around the world are the Hearst Tower in New York, Capital Gate Tower in Abu Dhabi, Cyclone Tower in Asan (Korea) and new World Trade Centre in New York.

Fig.2. (i) Hearst Tower, (ii) IBM Building

II. OBJECTIVE OF PROPOSED STUDY

A. Introduction

In this paper, a comparative study of 8-storey RC bare frame building and a diagrid structural system building with same configuration is presented here. A simple floor plan of 16m x 16m size was considered. The analysis was carried out for 8-storey building with floor height of 3.5m and the results were obtained in terms of displacement, storey drift, storey shear, and storey stiffness are presented.

the present study evaluation of seismic response of the G+7 storey RC frame structure by using diagrid is discussed. A simple computer based modelling in ETABS software was performed for equivalent static method (ESM) subjected to earthquake loading.

B. Objectives

1) To understand the behaviour of RC framed structure with diagrids
2) The objective of this study is to evaluate the response of bare frame and frame with diagrid structure subjected to seismic loads and to identify the suitable arrangement for resisting the seismic load efficiently
3) To evaluate the performance of diagrid structures subjected to equivalent static loads.
4) To find the base shear, storey displacements and storey drifts for RC bare frame and RC frame with diagrid structure.
5) To understand the behaviour of RC bare frame, RC frame with diagrids for Zone II, Zone III, Zone IV and Zone V.

The analysis was performed for the seismic zone II, III, IV and V by equivalent static method (ESM). The results for above mentioned parameters are presented in tables and graphs.

C. Methodology

1) A thorough literature review to understand the seismic behaviour of building structure
2) The dead load and live load is applied on frame and design earthquake load is considered as per IS 1893-2002 (part-1) for analysis
3) Both RC bare frame and RC diagrid frame were analysed using of ETABS 2015 ultimate 15.0.0
4) Equivalent Static analysis is adopted for analysis
5) The response of frame was studied for comparison.

III. ANALYSIS OF 8-STOREY BUILDING

A. Building Configuration

The 8-storey building is having 16m x 16m plan dimension and 28m total height of building, the storey height between each floor is 3.5m, the typical plan and elevation are shown in figure 3. There are two models for comparative study, one is RC bare frame building and another is diagrid structure, the building is kept same for both models, the beam size and column sizes are taken as 230 x 300 and 400 x 400 respectively with M25 grade concrete and Fe 415 HYSD bars as reinforcement, the slab thickness is 150mm. The diagonal member's (diagrid) size is 400mm x 400 mm for diagrid structure and it is at the angle of 60°15'18" for simple frame building. The design dead load and live load on terrace level are 3.97kN/m^2 and .75kN/m^2 respectively and for typical floor slab is 4.75kN/m^2 and 2.5kN/m^2. The design earthquake load is computed based on the zone factor, for soil type II, with importance factor, response reduction as per IS-1893-2002(Part 1). The design earthquake load is considered as per the IS-1893-2002(Part 1) that is, 25% of the live load is considered in seismic analysis. The a/l ratio for the building was considered and is well above the specified limits and modelling, analysis and design of diagrid structure are carried out using ETABS 2015 ultimate 15.0.0 software. The end condition for diagrid is assumed as hinged, the support conditions are assumed as fixed and the design of member is as per IS-456-2000.

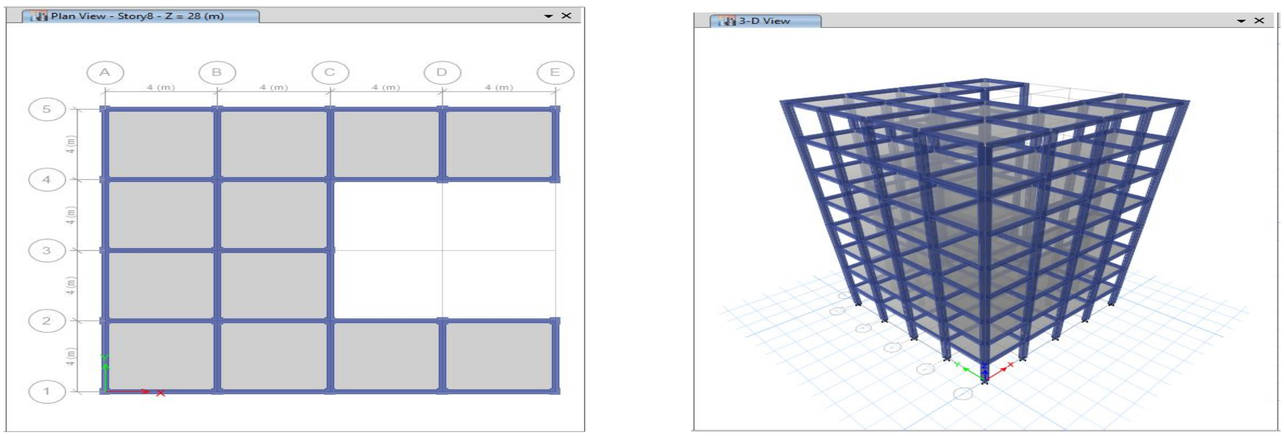

Fig.3 Plan and 3-D view of the RC bare frame

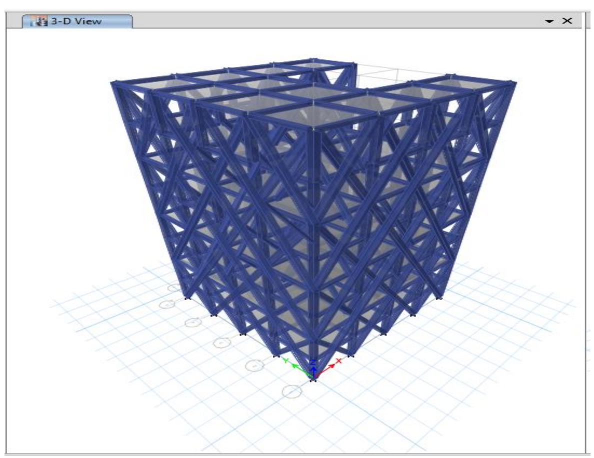

Fig.4. 3-D view of the RC Diagrid frame

IV. RESULTS AND DISCUSSIONS

Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. The current version of the IS 1893(Part 1): 2002 requires that practically all multi-storied buildings be analysed as three-dimensional systems. In the present study the performance evaluation of RC buildings with diagrid. The study as a whole makes an effort to evaluate the effect of diagrid on RC buildings, in terms of dynamic characteristics and identifies the influencing parameters which can regulate the effect on storey displacement, storey drift, and storey shear & storey stiffness

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This paper presents results of seismic analysis carried out on G+7 storied C shaped 3-D RC bare frame and frame with diagrid in outer periphery. The analysis is performed by taking into account of earthquake loads in EQX and EQY directions. The response obtained from the analysis is storey displacement, storey drift and storey shear. The results presented are discussed in detail with reference to relevant Tables and Figures.

A. Phase 1: A. Results in Zone-V.

1) *Storey displacement:* A storey displacement value were obtained from the static linear analysis has been studied by considering G+7 storey reinforced concrete building. Storey displacements of G+7 storey building models subjected to earthquake loads in EQX direction are listed below. Table-1 shows a Storey displacement values. Similarly Fig-5 shows the plot of storey displacement versus number of storey subjected to earth quake loads in x direction

Table 1. Storey displacement of C-shaped RC frame & diagrid frame models in Zone-V at each floor level subjected to EQX

Storey Displacement along X-direction		
Storey No	RC Bare frame(mm)	Frame with diagrid(mm)
8	97.54	3.0045
7	93.36	2.885
6	85.83	2.3466
5	75.01	2.5
4	61.41	1.6164
3	45.57	1.461
2	28.16	0.8309
1	10.76	0.1666

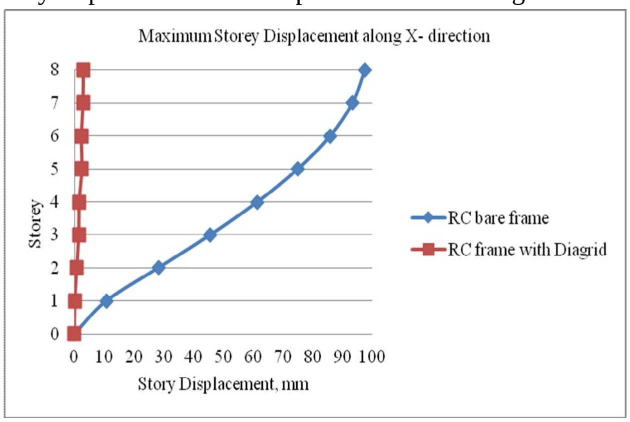

Fig 5. Maximum storey displacement of C-shaped RC frame & diagrid frame models in Zone-V at each floor level subjected to EQX

From results it was observed that storey displacement is maximum for RC bare frame and minimum for RC diagrid frame. From the Table-1 and Figure-5 further it can be seen that the maximum storey displacement for RC bare frame occurs at the top storey and the minimum storey displacement occurs at the base. It can be seen that storey displacement has reduced by 96.91% for RC diagrid frame in comparison with RC bare frame.

2) *Storey Drift:* Storey drift is nothing but difference of displacement in higher storey to displacement in lower storey. Drift is defined as the ratio of storey drift to the total height of the structure.

The storey drift values were obtained from the static linear analysis has been studied by considering G+7 storey reinforced concrete building. Storey drift of G+7 RC building models subjected to earthquake loads in EQX direction for the two models are listed in Table-2; similarly fig-6 shows the plot of storey drift versus number of storey for earthquake loads in x direction.

Table 2. Storey drift of C-shaped RC frame & diagrid frame models in Zone-V at each floor level subjected to EQX

Storey Drift along X-direction		
Storey No	RC Bare frame	Frame with diagrid
8	0.00119	6.80E-05
7	0.00215	9.50E-05
6	0.00452	8.30E-05
5	0.00388	0.00015
4	0.00452	0.000134
3	0.00492	0.000282
2	0.00497	0.00019
1	0.00300	4.80E-05

Fig 6 Maximum storey drift of C-shaped RC frame & diagrid frame models in Zone-V at each floor level subjected to EQX

B. Comparative Study of Storey drift With RC Diagrid Model.

From results it was observed that storey drift is maximum for RC bare frame and minimum for RC frame with diagrid. From the Table-2 and Figure-6, further it can be seen that the maximum storey drift for RC bare frame occurs at the storey-1. It can be seen that maximum storey drift is reduced by 94.26% for RC diagrid frame in comparison with RC bare frame.

C. Storey Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (V) depend on soil conditions at the site and proximity to potential sources of seismic activity.(such as geological faults)

A storey shear values were obtained from the static linear analysis and has been studied by considering G+7 storey C-shaped reinforced concrete building. Storey Shear of G+7 storey building model is subjected to earthquake loads in EQX direction for the two models are listed in Table-3; similarly fig-7 shows the plot of storey drift versus number of storey for earthquake loads in x direction.

Table.3. Storey shear of C-shaped RC frame building models in Zone-V at each floor level subjected to EQX

Storey Shear in X-Direction in kN		
Storey No	RC Bare frame(kN)	Frame with diagrid(kN)
8	222.7332	378.4921
7	520.4023	622.2711
6	766.1592	832.7592
5	967.9904	1008.333
4	1133.882	1261.058
3	1271.822	1472.353
2	1389.795	1638.288
1	1495.788	1741.272

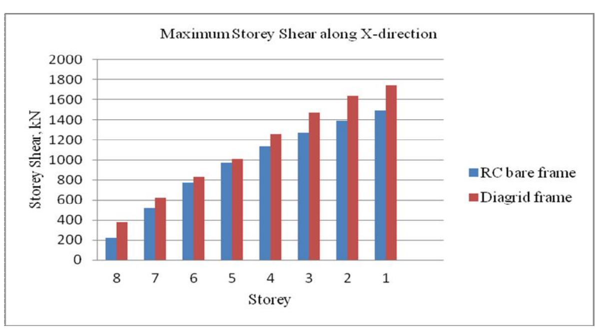

Fig 7. Maximum storey Shear of C-shaped RC frame & diagrid frame models in Zone-V at each floor level subjected to EQX

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D. Comparative Study of Storey Shear with rc Diagrid Model.

From results, it was observed that a storey shear decreases with respect to increase in height of the building. Storey shear is minimum for RC bare frame and maximum for RC frame with diagrid. It is observed from Table-3 and Figure-7 that, the maximum storey shear for the two models occurs at the storey-1. It can be seen that storey shear is increased by 14.09% for RC diagrid frame in comparison with RC bare frame.

E. Storey stiffness: The storey stiffness value were obtained from the static linear analysis has been studied by considering G+7 storey reinforced concrete building. Storey stiffness of G+7 storey building models subjected to earthquake loads in EQX direction for the two models is listed below. Table-4 shows a storey displacement values. Similarly Fig-8 shows the plot of storey stiffness versus number of storey subjected to earth quake loads in x direction.

Table 4. Storey stiffness of C-shaped RC frame building models in Zone-V at each floor level subjected to EQX

Storey Stiffness in X-Direction in kN/m		
Storey No	RC bare frame(kN/m)	Frame with diagrid(kN/m)
8	52221.847	150609.56
7	68207.108	156373.62
6	70204.344	166624.16
5	70732.466	227502.95
4	71260.784	256023.14
3	72779.744	656392.91
2	79612.240	944998.76
1	139868.000	997382.71

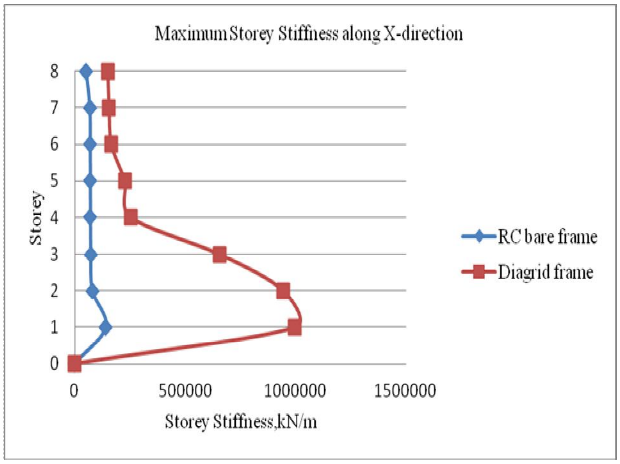


Fig 8. Maximum storey stiffness of C-shaped RC frame & diagrid frame models in Zone-V at each floor level subjected to EQX

F. Comparative Study of Storey stiffness With RC Diagrid Model

It is observed that a storey stiffness decreases with respect to increase in height of the building. Storey stiffness is minimum for RC bare frame and maximum for RC frame with diagrid. From the Table-4 and Fig-8, it can be seen that the maximum storey stiffness for the two models occurs at the storey-1. It can be seen that storey stiffness is increased by 85.97% for RC diagrid frame in comparison with RC bare frame.

G. Discussion

1) From Table-1 and Figure-5, it is noted that the lateral displacement is decreased by 96.91% for RC diagrid frame in comparison with RC bare frame. Hence, RC frame with diagrid is effective in reducing displacement.

2) As per Clause 7.11.1 of IS 1893 (Part I): 2002, the storey drift should not exceed 0.004 times the storey height, for a storey height of 3.5m the storey drift limit would be 14mm. From table-2 and Fig-6 it is noted that the lateral drift is decreased by 94.26% for RC diagrid frame in comparison with RC bare frame. Hence, RC frame with diagrid is effective in reducing storey drift.

3) From Tables-3 it is noted that RC frame with diagrid has a maximum storey shear at base and it has increased by 14.09% as compared to RC bare frame model. Therefore from serviceability criteria RC frame with diagrid is more effective in increasing storey shear.

4) From Tables-4 it was noted that RC frame with diagrid has maximum storey stiffness at base and RC bare frame has stiffness of only 85.97% compared to with diagrid. Therefore from serviceability criteria RC frame with diagrid is more effective in increasing storey stiffness in turn reduces displacement. From results, it is observed that a storey shear increases in all other Zones of the building. Further from the observations it can be seen that the maximum storey shear for all the Zones occurs at the storey-1. The maximum magnitude of storey shear occurs at the Zone-V but there is a decrease in shear in Zone IV as compared to Zone III. It is observed that storey shear in RC frame with diagrid has increased by 27.72% for Zone-II and Zone-III but the storey shear has increased by 26.90% from Zone-IV to Zone-V.

H. Discussion

From the observations it was noted that the storey shear has increased in Zone-II to Zone-III. The lateral drift in Zone-II has decreased by 70.27% in comparison with Zone-III, but the storey drift has decreased by 14.63% in Zone-IV to Zone-V. The decrease in storey shear in Zone-IV as compared to Zone-III can be attributed to the fact that the ductility factor has an influence on storey drift in Zone-IV while the ductility factor is not considered in Zone-III, which results in higher value of storey shear in Zone-III than Zone-IV. The frames are designed as Moment Resisting frames for Zone II and Zone III whereas for Zone IV and Zone V it is designed as Special Moment Resisting frames resulting in ductile detailing.

V.CONCLUSION

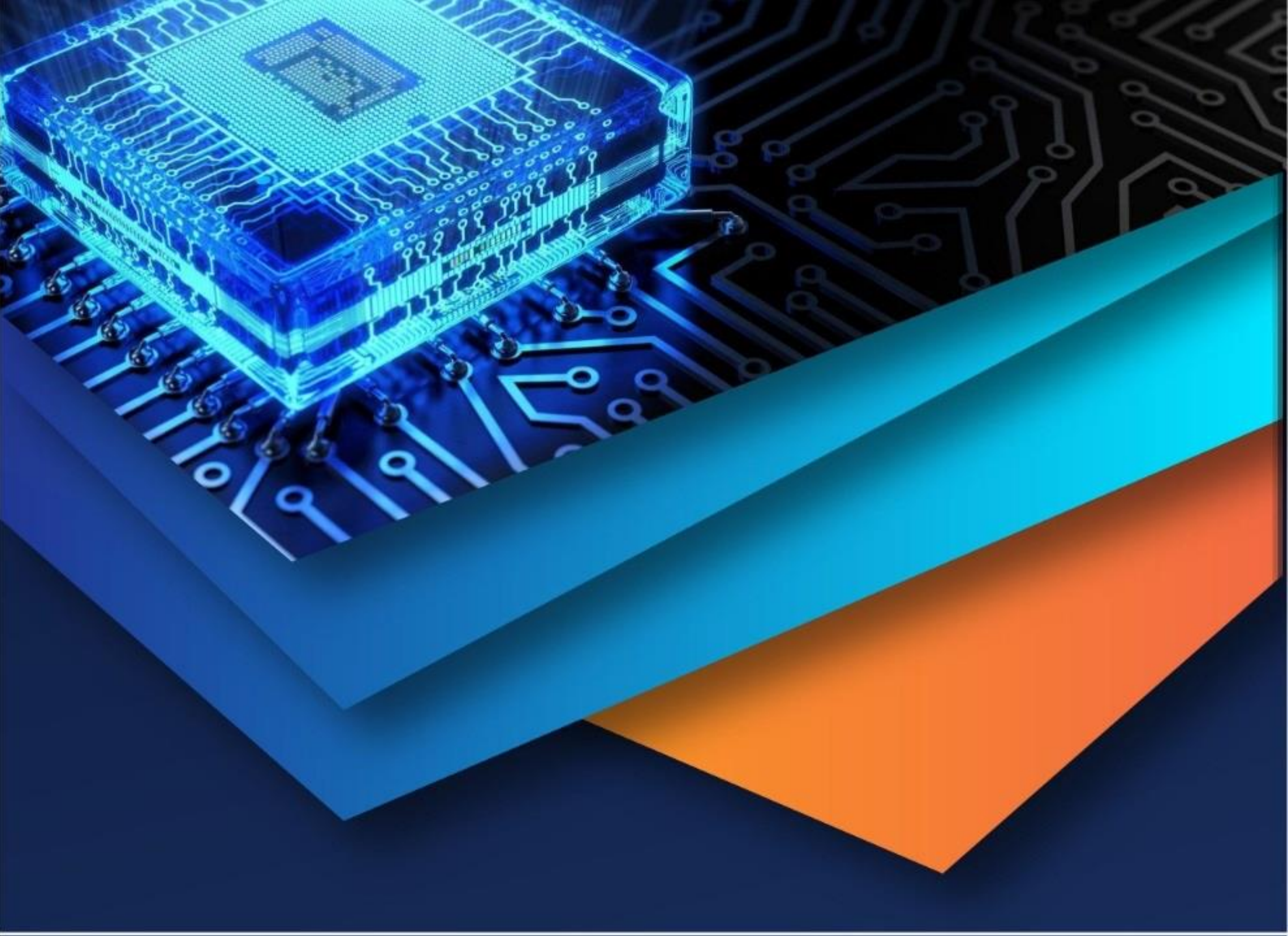
The fact that the, lateral resistance of frame can be significantly improved by the addition of a diagrid system. The potential advantage of diagrid system is that there is small increase in mass and it is easy to construct.

A. Conclusions on Comparison of rc Bare Frame And rc Frame with Diagrid System in Zone-v.

1) The Storey displacement and story drift is maximum for RC bare frame and minimum for RC frame with diagrid.
2) RC diagrid frame has the displacement which is 96.91% less as compared to RC bare frames.
3) RC diagrid frame has the drift which is 94.26% less as compared to RC bare frames.
4) Maximum story shear is observed at the base in the two models.
5) Storey shear is minimum for RC bare frame and maximum for RC frame with diagrid.
6) Storey shear is increased by 14.63% from RC bare frame to RC frame with diagrid.
7) RC diagrid frame has the storey shear which is 14.63% high as compared to RC bare frames.
8) Storey stiffness is minimum for RC bare frame and maximum for RC frame with diagrid.
9) RC diagrid frame has the stiffness which is 85.97% high as compared to RC bare frames.

REFERENCES

[1] Kyoung S. Moon, "Diagrid Structures for Complex-Shaped Tall Buildings", Published by Elesevier Ltd., International Journal of High-Rise Buildings December 2016,Vol5,No4,243-250
[2] Nishith B. Panchal, Vinubhai R. Patel " Diagrid Structural System: Strategies to Reduce Lateral Forces on High-Rise Buildings", Applied Mechanics & Structural Engineering Department, Faculty of Technology & Engineering, The M. S. University of Baroda, Vadodara, Gujarat, Indi
[3] Khushbu Jani , Paresh V. Patel, "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings", Department of Civil Engineering, Nirma University, Ahmedabad 382481, India Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference on Engineering (NUiCONE-2012)
[4] Rohit Kumar Sing, Vivek Garg, Abhay Sharma, "Analysis and Design of Concrete Diagrid Building and it's Comparison with Conventional Frame Building", Vol 2,6 August2014 (VER II),september 2014
[5] Raghunath .D. Deshpande, Sadanand M. Patil, Subramanya Ratan, "Analysis and Comparison of Diagrid and Conventional Structural System" Dept of Civil Engineering, Gogte Institute of Technology Belagavi, Karnataka, India, International Research Journal of Engineering and Technology,june 2015
[6] Kyoung S. Moon, Jerome J. Connor and John E. Fernandez, "Diagrid Structural Systems for Tall Building: Characteristics and Methodology For Preliminary Design", Willey Interscience Publication
[7] Khushbu Jani and Paresh V. Patel, "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings", Published by Elesevier Ltd.
[8] Mir M. Ali and Kyoung S. Moon, "Structural Developments in Tall Buildings: Current Trends and Future Prospects", Architectural Science Review Vol50.3, pp 205-223.
[9] Kyoung S. Moon, "Diagrid Structures for Complex-Shaped Tall Building", Published by Elesevier Ltd.
[10] IS: 456-2000. Plain and Reinforced Concrete- Code of Practice (Fourth Revision), Bureau of Indian Standard, New Delhi.
[11] IS: 1893(Part-I)-2002, Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standard, New Delhi.
[12] IS: 875(Part-I, II, III)-1987, Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Bureau of Indian Standard, New Delhi



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