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Analysis of Multi-Storey Building with and without Diagrid System Using ETABS

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***Abstract*- The diagrid structural system has been widely used for recent tall buildings due to the structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. This project presents a stiffness-based design methodology for determining preliminary member sizes of R.C.C. diagrid structures for a G+14 story building using ETABS 2015. The methodology is applied to the diagrid to determine the optimal grid configuration of the diagrid structure and further its comparison with conventional R.C.C structure. Analysis of G+14 story building with perimeter diagrid of 630,660,690 is carried out by Equivalent Static Method. The comparison of analysis of results in terms of top story displacement, story drift, story stiffness, story overturning moment are presented.**

1. INTRODUCTION

1.1 GENERAL

The rapid growth of urban population and consequent pressure on limited space have considerably influenced the residential development of city. The high cost of land, the desire to avoid a continuous urban sprawl, and the need to preserve important agricultural production have all contributed to drive residential buildings upward. As the height of building increase, the 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 steel buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system.

Diagrid has good appearance and it is easily recognized. 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. Perimeter “diagrid” system saves approximately 20 percent of the structural steel weight when compared to a conventional moment-frame structure.

The diagonal members in diagrid structural systems can carry gravity loads as well as lateral forces due to their triangulated configuration. Diagrid structures are more effective in minimizing shear deformation because they carry lateral shear by axial action of diagonal members. Diagrid structures generally do not need high shear rigidity cores because lateral shear can be carried by the diagonal members located on the periphery. Hence, the diagrid, for structural effectiveness and aesthetics has generated renewed interest from architectural and structural designers of tall buildings.

1.2 OPTIMAL ANGLE

As in the diagrids, diagonals carry both shear and moment. Thus, the angle of diagonals is highly dependent upon the building height. Since the optimal angle of the columns for maximum bending rigidity is 90 degrees and that of the diagonals for maximum shear rigidity is about 35 degrees, it is expected that the optimal angle of diagonal members for diagrid structures will fall between these angles and the building height increases, the optimal angle also increases. Usually adopted range is 60-70 degree.

2. LITERATURE REVIEW

Narsireddy (2018) in this study five models are considered, one is conventional steel frame and other four are diagrid frames in which diagrid is connecting to one, two, three storeys. All models are of G+ 25 storeys. They are modelled and analyzed in seismic and wind load conditions using ETABS 2013, for seismic analysis zone 4 is considered, wind speed of 44 m/s is considered in wind analysis. The five models are analysed and the parameters like storey displacement, story drift, time period, axial force, bending moment are compared. Finally, it is concluded that model 3 gives the better results for all above parameter. From the study it is concluded the Diagrid structure is gives better results in seismic and wind analysis than conventional steel structure. The storey displacement is minimum in Diagrid structure as compared to conventional frame. In different seismic and wind load analysis the model 3 gives the better results, in storey displacement, storey drift, bending moment, axial force conditions.

Tejesh R (2018) In the present study 15 storey steel structure of height 45m (3m each storey) was considered. The structure was designed as per IS 800:2007 code with dead load, live load earthquake load combinations and wind load combinations. Dynamic analysis (response spectra) was performed using ETABS software assuming response reduction factor as 5, importance factor as 1, seismic zone II and type of soil is 2. The analysis was performed according to IS 1893.The analysis was performed for building without bracing, with X bracing and V-bracing. The results were compared and studied. It was found that displacement of the structure was more in the structure without bracing than other models. It was also observed that lateral loads were more in the case of X-bracing. Finally, it can be concluded that X-bracing is better for wind loading and V-bracing is better for earthquake loading.

Hyun‑Su Kim (2018) In the present paper, the diagrid structure is proposed with control devices. A genetic algorithm was proposed by taking an example of 60 storey building. The loads such as wind and earthquake are artificially induced. A system is adopted by using tuned mass dampers with magneto rheological damper. The 5 different objectives are used for the multi-objective genetic algorithm includes a response reduction due to dynamic nature, damping and additional stiffness, capacity of MR damper and mass of STMD. From the proposed technique, an integrated optimal designs of diagrid structure and STMD were obtained. It is found from the numerical method too that the STMD provides good control performance in reducing wind and seismic responses on the structure.

3. OBJECTIVES

- To study the concept of diagrid and without diagrid (bare frame) structural system on a high rise structure.
- To study the comparative behavior of Diagrid and Without diagrid (bare frame) structures subjected to Static and Dynamic earthquake loading.
- To compare the behavior of structural elements in diagrid building with different angle of diagrid. Such as 630 660 and 690.
- To determine the optimum configuration for buildings using ETABS 15.2.2 software.
- Comparison of results in terms of Max storey drift, max storey displacement, overturning Moment and Max storey stiffness in seismic case.
- Finally, the analysis will be concluded based on the behaviour for diagrid and without diagrid (RC bare frame) structures system.

4. METHODOLOGY

The present study is an effort towards analysis of the structure located on a flat ground during the earthquake. An ordinary moment resisting building of G+14 storey’s located over a medium soil is considered. The number of bays will be kept as 6 along both direction and the bay size will be kept as 4m with the storey height being 3m. The building will be analysed considering zone III by static equilibrium method using ETABS 2015 software.

The details of models are given as follows

- Plan dimention-20mx20m
- Number of stories-15
- Floor to floor height-3m
- Number of bays in X-direction-6
- Number of bays in Y-direction-6
- Depth of slab-150mm
- Diagrid angle-630 660 690

Beam and column dimentions

B 200mmx450mm

C 300mmx700mm

Material Properties

Young's Modulus (E)for M25 Concrete = 25x106kN/m2
Density of Concrete = 25kN/m3
Density of Masonry Unit = 20kN/m3
Poisson's Ratio = 0.2
Member Properties
Slab thickness = 150mm
Column Size from Level (0) to Level (15) = 300mmx700mm (M25)
Beam Size = 200mmx450mm (M25)
Masonry Wall Thickness = 230mm
Diagrid Beam Size = 200mmx450mm
Support Type = Fixed
Loads Considered
Wall Load = 9.18kN/m
Parapet Load = 1.8kN/m
Live Load = 3.00kN/m2
Live Load on Roof = 1.50kN/m2
Floor Finish = 1.5kN/m2
Seismic Data
Zone Factor = 0.16 (Zone III)
Importance factor = 1
Response Reduction Factor = 5
Soil type = II
Load Combination
1) 1.5 (DL + LL)
2) 1.2 (DL + LL ± EL)
3) 1.5 (DL ± EL)
4) 0.9DL ± 1.5EL

Plan Elevation and 3D View of Different Models Considered

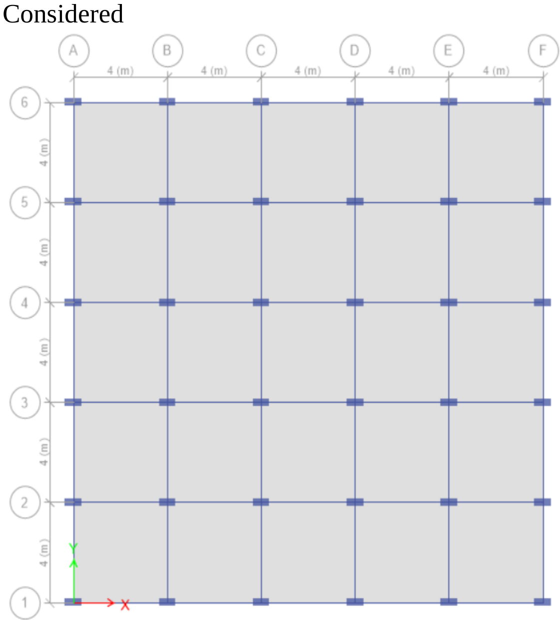

Figure Plan of bare frame

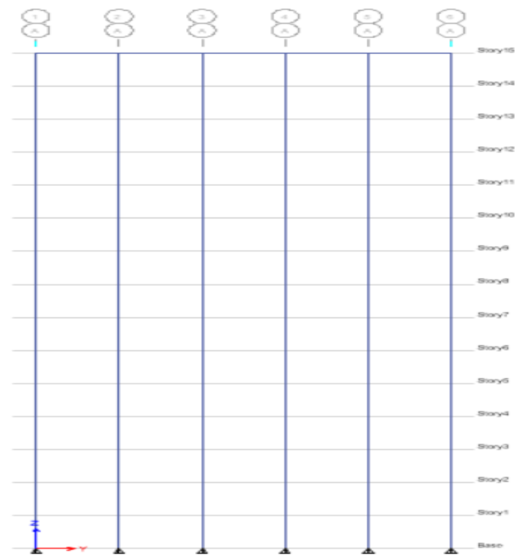

Figure Elevation of bare frame

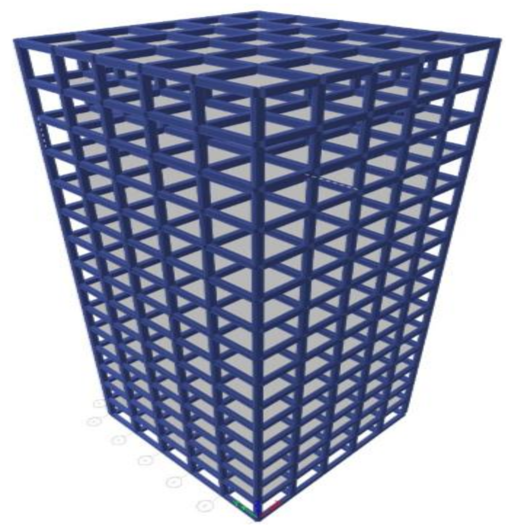

Figure 3D view of bare frame

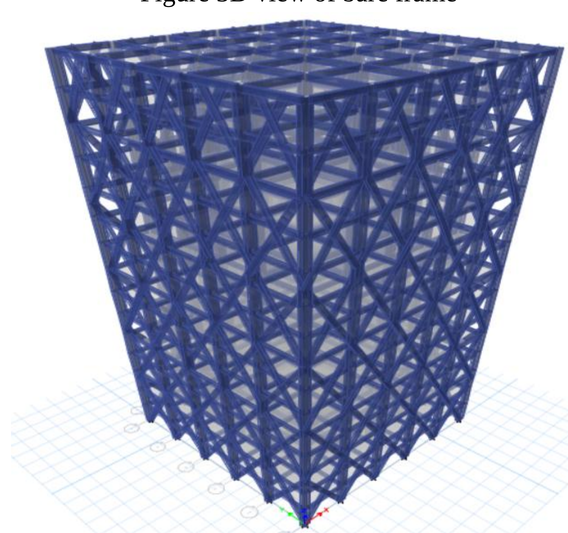

Figure 3D view of Diagrid at 630

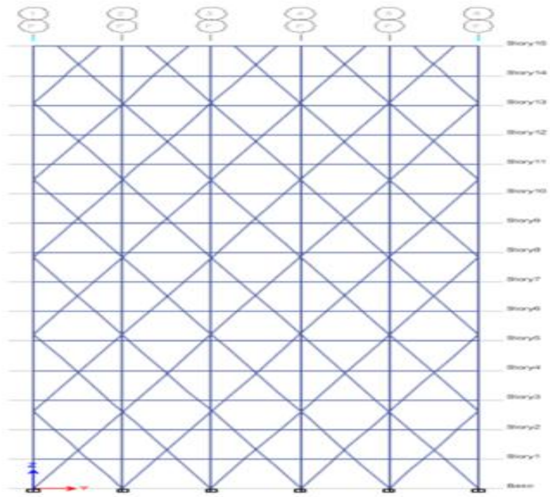

Figure Elevation of Diagrid at 630

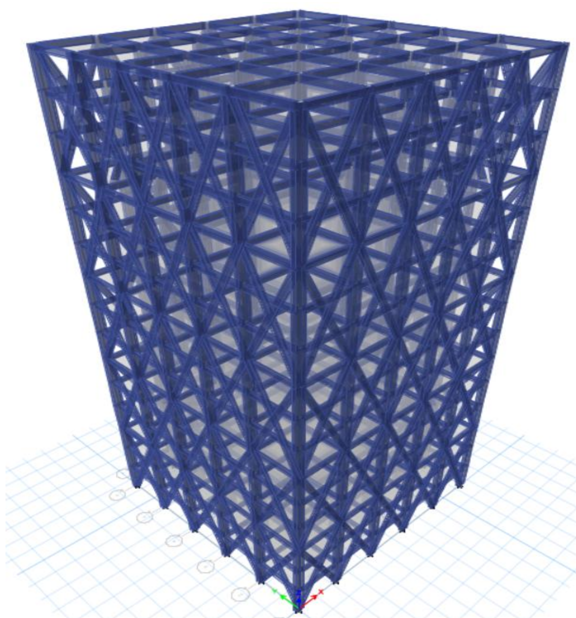

Figure 3D view of Diagrid at 660

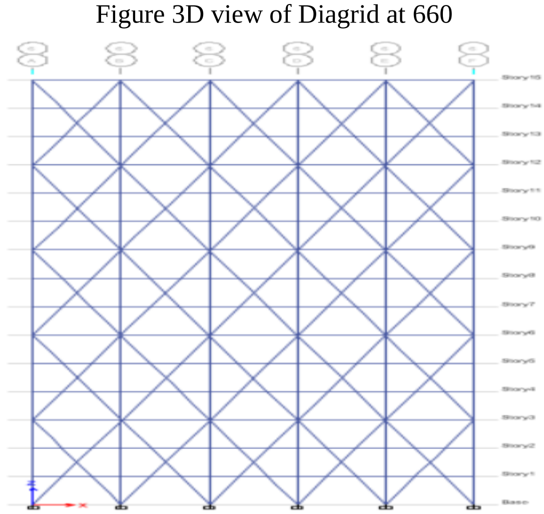

Figure Elevation of Diagrid at 660

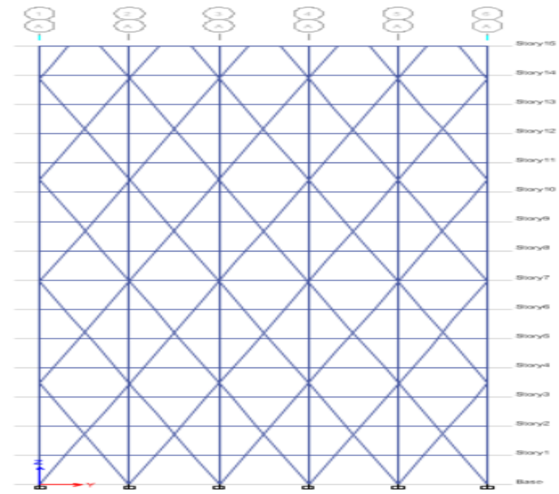

Figure Elevation of Diagrid at 690

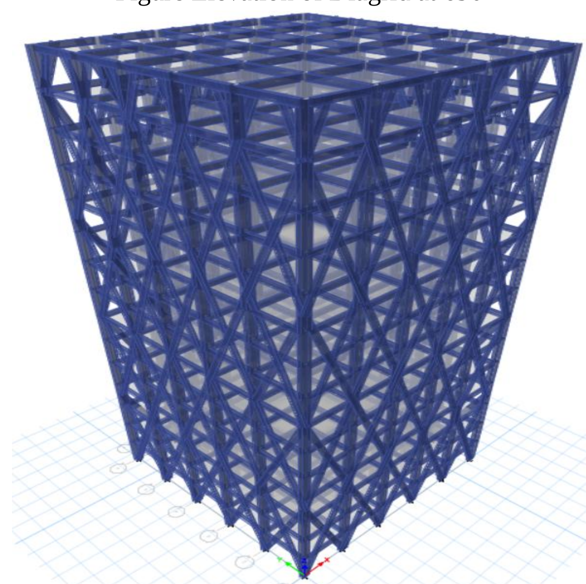

Figure 3D view of Diagrid at 690

5. RESULTS AND DISCUSSIONS

Storey Displacement

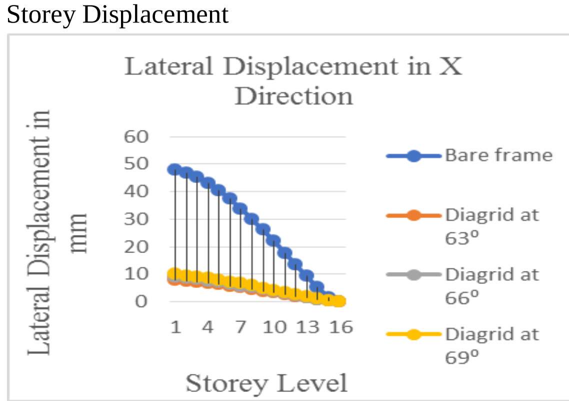

Figure Lateral Displacement in X Direction Due to EQX Load

From the above figure it is observed that the storey displacement is reduced to greater extent for the diagrid building at an angle 63^0, while displacement is maximum in RC bare frame building compare to all the RC diagrid building at an angle 63^0, 66^0 and 69^0.Theses patterns are observed due to increased stiffness in diagrid building while compared to RC bare frame building. The top roof displacement for RC diagrid building with different diagrid angle such as (63^0, 66^0 and 69^0) is reduced by 83.32%, 81.499% and 79.11% respectively when compared to without diagrid (bare frame) building.

Storey Drift

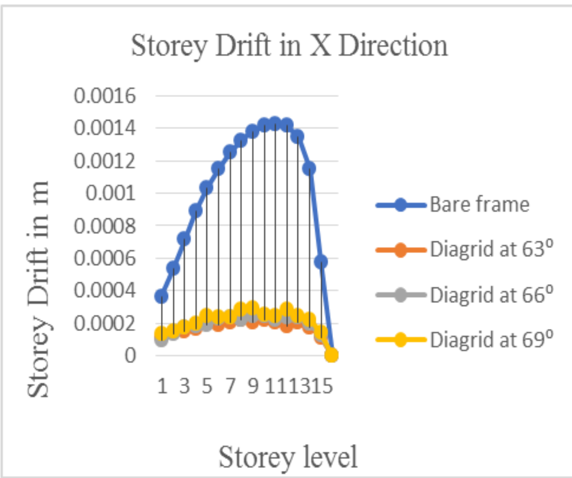

Figure Storey Drift in X Direction Due to EQX Load

The storey drift values of diagrid building models and bare frame building models are compared under EQ X load case. And it is observed that the storey drift under EQ X load case the storey drift values are found to be increase from lower up to 6 storey for both type of buildings. The maximum storey drift value of bare frame building is found to be more than that of diagrid building models. Maximum storey drift value of of bare frame building model is found to be 0.00138 and diagrid building models with different angle such as 630, 660 and 690, is found to be 0.000222, 0.000248 and 0.000288 respectively. The storey drift for all diagrid building models i.e (630, 660 and 690) is reduced by 83.91%, 82.01% and 79.13% respectively when compared to bare frame (without diagrid) buildings.

Overturning Moment

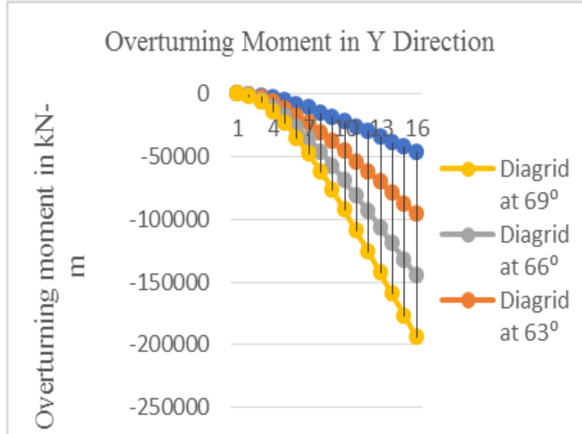

Figure Overturning Moment in Y Direction Due to EQX Load

From the above figure it is observed that the storey overturning moment decreases with respect to increases in the storey height of building. Storey overturning moment is minimum in RC frame with diagrid models and maximum in RC bare frame building and it can be seen that the maximum storey overturning moment for all four models are occurs at the storey1. It can be seen that storey overturning moment for different RC frame with diagrid models of an angle 630,660and 690 is reduced by 4.58%, 4.78% and 4.38% when compare to RC bare frame building.

Storey Stiffness

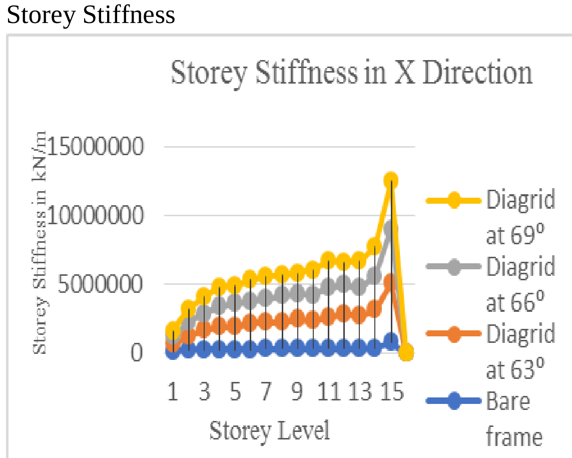

Figure Storey Stiffness in X Direction Due to EQX Load

From the above figure 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 building models and maximum for RC frame with diagrid models and it can be seen that the maximum storey stiffness for the all four models occurs at the storey-1. It can be seen that storey stiffness for different RC frame with diagrid models of different angle at 630, 660 and 690, is increased by 81.60%, 79.77% and 76.79% for RC diagrid frame models in comparison with RC bare frame models.

6. CONCLUSION

1. The Storey displacement and story drift is maximum for RC bare frame and minimum for RC frame with diagrid.
2. Top storey displacement, storey drift and storey overturning moment is less for diagrid system with diagonal angle 63 degree.
3. RC diagrid frame has the displacement which is 78%-84% less as compared to RC bare frames.
4. RC diagrid frame has the drift which is 78%-84% less as compared to RC bare frames.
5. Storey overturning moment is maximum for RC bare frame and minimum for RC frame with diagrid.
6. Storey stiffness is minimum for RC bare frame and maximum for RC frame with diagrid.
7. RC diagrid frame has the stiffness which is 75%-82% high as compared to RC bare frames.

Scope for Further Study

- Higher storey buildings can be studied in R.C.C symmetrical building for diagrid structure.
- The present work is based on the Equivalent static method analysis and the dynamic analysis like Response Spectrum Method can be implemented to check the obtained results.
- In this study, the analysis is carried out on flat ground and hence the results can be verified using sloping grounds.
- In the present study, the Special moment resisting building is considered and the results can be verified using ordinary moment resisting building.
- Asymmetrical building with different angel study for diagrid structure.
- Study With and without outer column for diagrid structure.
- Steel building can also studies diagrid structures.
- Comparative study braced tube system and diagrid structures.

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