COMPARATIVE STUDY OF THE PERFORMANCE OF TALL STRUCTURES WITH DIAGRID AND SHEAR WALL SYSTEMS SUBJECTED TO SEISMIC LOADING

Nischay J[1], M.R.Suresh[2]

[1]*Post Graduate Student, Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka, India*
[2]*Associate Professor, Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka, India*

Abstract - *The essential objective of the project was to study the behavior of the tall structures with the diagrid systems as the major lateral load resisting part of the structure. Hence three distinct shapes of the plans were considered they are Square, octagon and circular. All the three models are symmetric in plan. For each shape three storey heights are modeled that is 30 stories, 45 stories and 60 stories. From the past researches it was found the optimum angle for diagrid is around 70 degrees. Using this data we have modeled the diagrid with an angle of 69.67 degrees. For comparative purpose the shear wall system is included as an external lateral load resisting system. For the same plans and storey heights we have used shear walls in place of diagrid. Thus we will have three models in each plan geometry with diagrids only in the exterior on the buildings adding to nine models. And nine models with shear wall in the exterior of the buildings. Both the diagrid and shear wall system models with not have any columns at the building boundary. E.TABSv2015 is the software used for the analysis. The parameters like storey drift, lateral displacement, storey stiffness, base shear and time period are considered for the investigation.*

Key Words: Diagrid, shear wall, seismic loads, lateral load resisting system, lateral displacement, stiffness, time period.

1.INTRODUCTION

The development of tall structures associates numerous complex aspects such as economics, scientific knowledge, aesthetics, government policies. The financial factor will be the primary determining factor. Tall structures demand a lot of technical support without which its emergence is not possible. As the height of the structure is increased the lateral forces acting on the structure also rapidly increases. Hence the lateral load resisting systems becomes very critical. Over the years the structural engineering saw the development of many lateral resisting systems. The twentieth century saw dramatic changes in the structural systems since the decline of traditional rigid frame as primary type of structural system for concrete or steel structures. The economic demands and technological development of realistic structural analysis and design empowered by the arrival of high speed digital computers. The new era of tall structures gave rise to innovative structural systems like core and outrigger system, diagrid system, tube system, mixed concrete systems.

1.1 Diagrid system

The adoption of diagonals elements termed as diagrid at the building outlines is advantageous structurally as well as aesthetically. In diagrid structures, the intersecting diagonal elements structurally operates as a supporting system instead of the vertical columns. The elimination of vertical members and establishment of diagonal members at the building perimeter gives an additional aesthetical elegance to the structure. The efficiency of the diagrid system to resist lateral loads with the added aesthetical grace has made it one the most popular choice of structural engineers and architects for tall buildings.

Fig -1: Diagrid modules

The diagonal elements of the diagrid system forms triangulated arrangement in a uniform dissipation manner

which effectively carry both gravity load and lateral loads. This ability of diagrid has made it possible to eliminate the perimeter columns. Structurally the performance of diagrid and traditional braced systems are comparable as they both systematically resist lateral loads axially with their diagonal bracing elements. At the same time the bending resistance in braced system is provided by vertical columns, the diagonal elements provide both bending and shear rigidity as they are composed of only diagonal members.

1.2 Shear wall system

The RCC walls in a structure provided mainly to resist the horizontal forces is known as shear walls. Major portion of lateral seismic and wind forces are taken up by these walls. The behavior of shear wall is similar to the action of a cantilever deep beam. The shear walls as fixed at the base and free at the top behave as cantilever beam. The length of these wall are usual high hence visualized as a deep beam under the action of lateral forces.

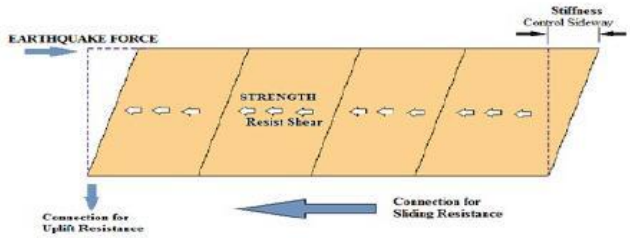


Fig -2: Shear wall action

2. MODELLING AND ANALYSIS

The essential objective of the project was to study the behaviour of the tall structures with the diagrid systems and the major lateral load resisting part of the structure. Hence three distinct shapes of the plans were considered they are Square, octagon and circular. All the three models are symmetric in plan. For each shape three storey heights are modelled that is 30 stories, 45 stories and 60 stories. From the past researches it was found the optimum angle for diagrid is around 70 degrees. Using this data we have modelled the diagrid with an angle of 69.67 degrees.
For comparative purpose we have used shear wall system as an external lateral load resisting system. For the same plans and storey heights we have used shear walls in place of diagrid. Thus we will have three models in each plan geometry with diagrids only in the exterior on the buildings adding to nine models. And nine models with shear wall in the exterior of the buildings. Both the diagrid and shear wall system models with not have any columns at the building boundary.

A. MATERIAL PROPERTIES

- CONCRETE - M30
- REINFORCEMENT- Fe500
- STEEL- Fe345

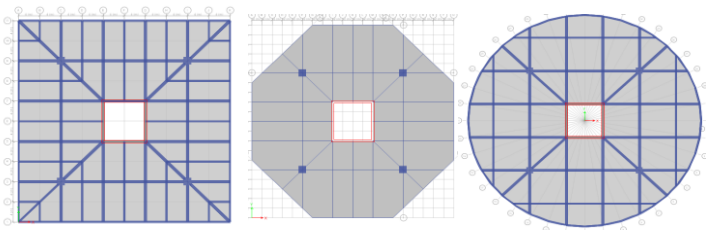
B. SECTIONAL PROPERTIES

- Columns -1500*1500mm
- Beam1 -500*1000mm
- Beam2 -300*700mm
- Diagrid - 500mm dia and 25 mm thick pipe
- Slabs -125mm thick
- Shear wall -500mm thick

C.LOADINGS

- Super dead load -2 KN/m^2
- Live load -3KN/m^2
- Zone factor - 0.24
- Soil Type - II
- Importance factor- 1
- Response reduction factor-5

The analysis was done using E.TABSv2015. The beams at the edge of the plan are assigned as B2.



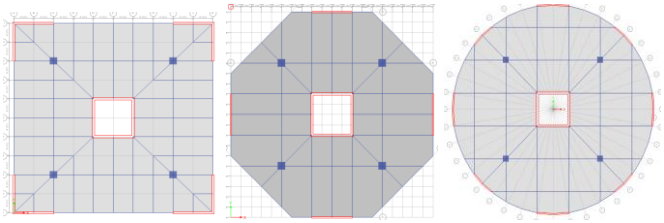
A B C

Fig -3: Structural plans for diagrid system **A**. square, **B**. Octagon, **C**. Circular

- The square plan dimension is 40*40m modeled for 30, 45 and 60 storey
- The octagon plan of sides 20 m modeled for 30, 45 and 60 storey.
- Circular plan of diameter 50.95 m modeled for 30,45 and 60 storey

The grid spacing is kept constant at 4m center to center for all the models.

Fig -4: 3D models of diagrid system for 30, 45 and 60 storey



A B C

Fig -5: Structural plans for shear wall system **A**. square, **B**. Octagon, **C**. Circular

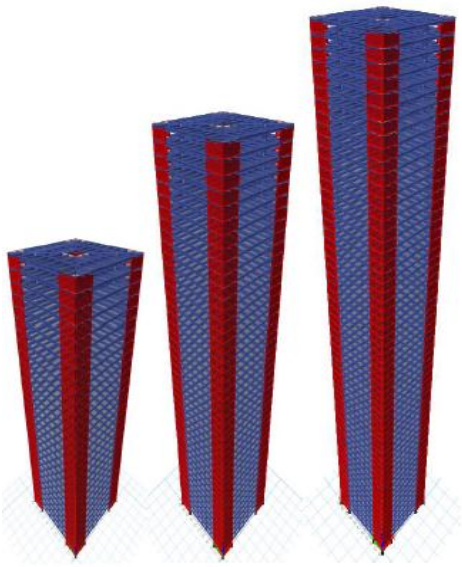


Fig -6: 3D models of shear wall system for 30, 45 and 60 storey

3. RESULTS AND DISCUSSION

In this part the dynamic analysis results are discussed. The parameters selected for the discussion are lateral displacement, base shear and time period.

A. Lateral displacement:

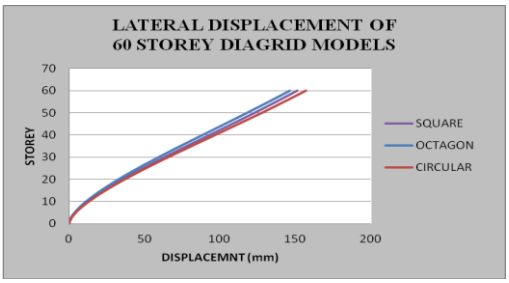


Chart -1: Lateral displacement of 60 storey diagrid models

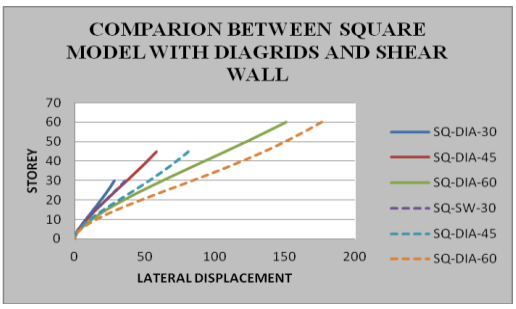


Chart -2: Diagrid and shear wall in square(displacement)

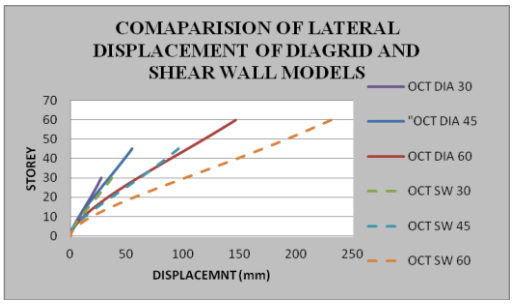


Chart -3: Diagrid and shear wall in octagon(displacement)

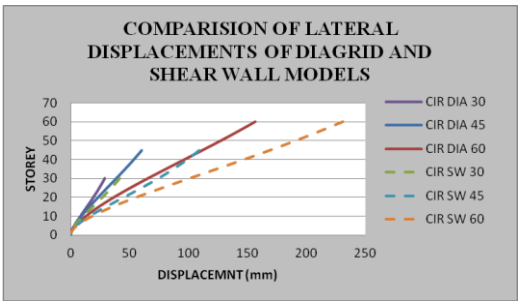


Chart -4: Diagrid and shear wall in circular(displacement)

The lateral displacements of the models for various lateral load resisting systems and heights are shown in the charts. From chart1 we see that comparatively the lateral displacement in the octagon model is less than square and circular models. From chart 2, chart 3 and chart 4 it is observed that the lateral displacement is always less in diagrid system compared to shear wall system for all the three type of plan and storey height.

B. Base shear:

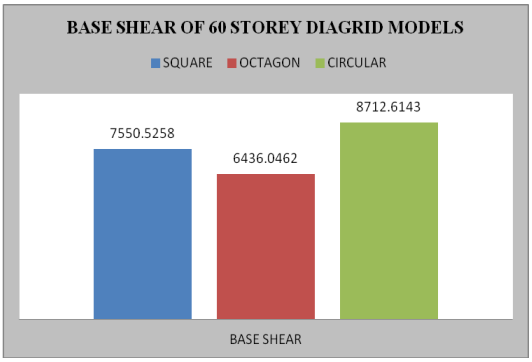


Chart -5: Base shear for different plan shapes

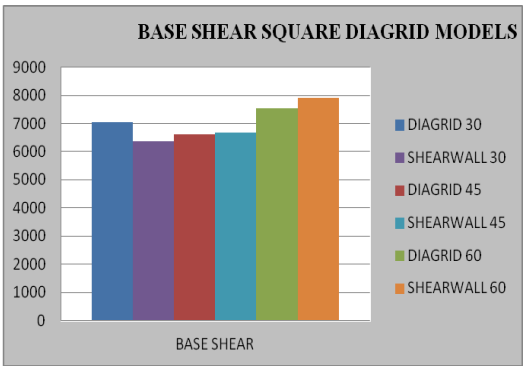


Chart -6: Base shear for square models

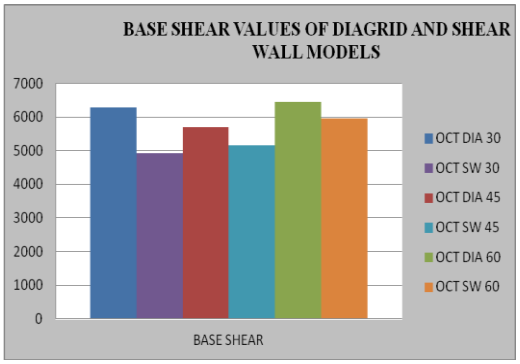


Chart -7: Base shear for octagon models

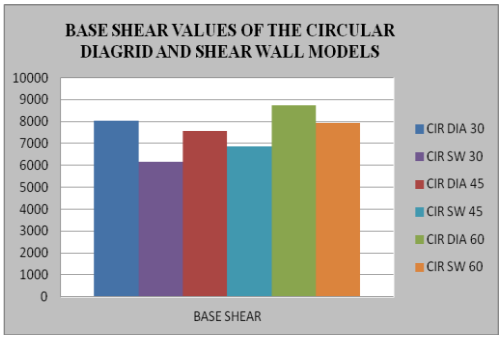


Chart -8: Base shear for circular models

The base shear values is higher for circular plan and lesser for the octagon plan as shown in chart5. This shows that lesser seismic forces is acting on the octagon model. From charts 6, 7 and 8 we see that for octagon and circular models the base shear values are comparatively lesser for shear wall models than diagrid models. The base shear values for 45 storey in both circular and octagon models are lesser than 30 and 60 stories.

C. Time period:

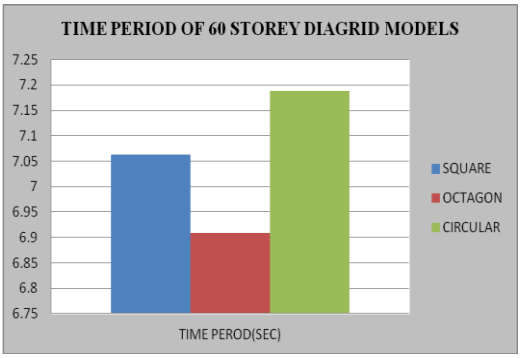


Chart -9: Time period for different plan shapes

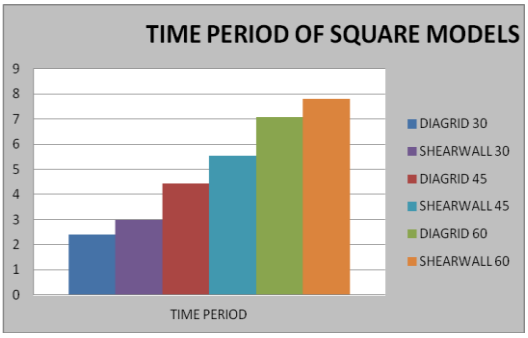


Chart -10: Time period for square plan models

The time period values of the octagon model was the least and circular model was highest of the three models as shown

in chart-9. From the above observation it is found that octagon models have higher stiffness compared to square and circular models. From chart 10 we observed that the time period is higher in shear wall models than diagrid models.

3. CONCLUSIONS

From the study the conclusions are as follows

- The introduction of diagrid systems in tall structures is found to increase the seismic performance of the structure.
- From the comparison of diagrid system with shear wall system it is found that the lateral displacements in diagrid models is much lesser than the shear wall models.
- The lesser lateral displacements in diagrid shows the enhanced resistance of the buildings against lateral seismic force.
- The base shear values in diagrid models are higher than other models with shows higher seismic forces are acting on the diagrid models.
- The time periods are less in diagrid system models. lesser values of the time period than shear wall models shows that diagrid models are less flexible against seismic vibrations.
- From the comparison of different shapes of plans like square, octagon and circular for diagrid system, the lateral displacement is least in the octagon plan and highest in circular plan.
- From the base shear values it showed that the octagon plan had minimum forces acting on it than the other two plans.
- The octagon plan was less flexible than circular and square plan because of the lesser time periods.
- The 30 storey models by the comparison with diagrid and shear wall systems was highly efficient for circular plan with 30.9 % decrease in lateral displacement values.
- The 45 storey models with diagrid was most efficient for circular model with 44.56% reduction in lateral displacement than shear wall model.
- The most efficient model with diagrid for 60 storey is octagonal shape model with 36.72 % reduction in lateral displacement against shear wall model.

ACKNOWLEDGEMENT

I would like to acknowledge the support of my guide Mr. M.R. Suresh for supporting me and guiding me for this work. I would also thank Dr.AIT for providing me facilities and opportunities. I would also like to extent my thanks to all those who supported me and guided me for this work.

REFERENCES

[1].Analysis of diagrid structure in comparison with exterior braced frame structure, Ravish Khan[1], S.B. Shinde[2], IJRET, pISSN: 2321-7308.

[2]. Optimal diagrid angle to minimize drift in high-rise steel buildings subjected to wind loads, Khalid K. Shadhan, International Journal of Civil Engineering and Technology (IJCIET),Volume 6, Issue 11, Nov 2015, pp. 01-10

[3]. Numerical Modelling and Evaluation of Hybrid Diagrid Structures, Lekshmi Mohan1, C.K.Prasad Varma Thampan2, International Journal of Research in Advent Technology (E-ISSN: 2321-9637), "TASC- 15", 10-11 June 2015.

[4]. Analysis and comparison of diagrid and conventional structural system, Raghunath .D. Deshpande[1], Sadanand M. Patil[2], Subramanya Ratan[3]. IRJET, Volume: 02 Issue: 03 June -2015.

[5]. Comparative Analysis of Diagrid Structural System and Conventional Structural System for High Rise Steel Building, Harish Varsani [1], Narendra Pokar [2], Dipesh Gandhi[3], IJAREST ISSN(O):2393-9877, ISSN(P): 2394-2444,Volume 2,Issue 1, January- 2015..

[6]. Comparison of symmetric and asymmetric steel diagrid structures by non-linear static analysis, Prashant T G[1], Shrithi S Badami[2], Avinash Gornale[3], IJRET, pISSN: 2321-7308.

[7]. Improving the seismic performance of diagrid steel structures using friction mass damper, Garlan Ramadhan[1] and André R. Barbosa[2], Tenth U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering.

[8]. Pushover Analysis of Diagrid Structure, Ravi K Revankar, R.G.Talasadar, IJEIT, Volume 4, Issue 3, September 2014.

[9]. Analysis and design of concrete diagrid building and its comparison with conventional frame building, [1]ROHIT KUMAR SINGH, [2]Dr. VIVEK GARG, [3]Dr. ABHAY SHARMA. ISSN: 2348-4098,VOLUME 2 ISSUE 6 AUGUST 2014 (VER II)

[10]. Optimum Angle of Diagrid Structural System, Nishith B. Panchal, Dr. V. R. Patel, Dr. I. I. Pandya, IETR,ISSN: 2321-0869, Volume-2, Issue-6, June 2014

[11]. The Evolutionary Process of Diagrid Structure Towards Architectural,Structural and Sustainability Concepts: Reviewing Case Studies, Sepideh Korsavi[1] and Mohammad Reza Maqhareh[2], J Archit Eng Tech 2014, 3.2.

[12]. Structural Developments in Tall Buildings: Current Trends and Future Prospects,
Mir M. Ali† and Kyoung Sun Moon, Architectural Science ReviewVolume 50.3, pp 205-223