

Design Analysis of Outrigger and Hexagrid System in High Rise Building

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Abstract:

The innovation of high strength structural materials as well as the introduction of predominant development methods gave a lift in the development of tall structures. As the height of the structure increases, they become progressively vulnerable to wind load and seismic load. The opposition of tall structures to lateral loads is the fundamental determinant in the formulation of new basic structural frameworks that develop by the constant endeavours of structural engineers to go on increasing the building height while keeping the deflection inside worthy points of confinement and limiting the measure of materials. In this proposed work an analytical study will be consider on such systems like outrigger system with core shear wall and hex grid systems, so as to determine their structural efficiency in transferring the lateral loads safely to the ground. A comparison of outrigger system with core shear wall and a hex grid system wise made on a 20-storey building reinforced concrete building by using standard package ETABS by comparing different parameters such as Maximum Storey Displacement, Maximum Storey Drift, Forces, Moment and Storey Shear.

Keywords: Structural Analysis, Forces, Deflection, Lateral Forces, Etabs

1. Introduction

Outrigger in Building

Outriggers are interior lateral structural systems provided to improve the overturning stiffness and strength of high-rise buildings. It is a lateral load resisting system that is located within

the building. The whole system consists of a core structure connected to the perimeter columns of the building by means of structural members called outriggers. The outriggers can be in the form of horizontal beams, truss, or walls(see fig.1).

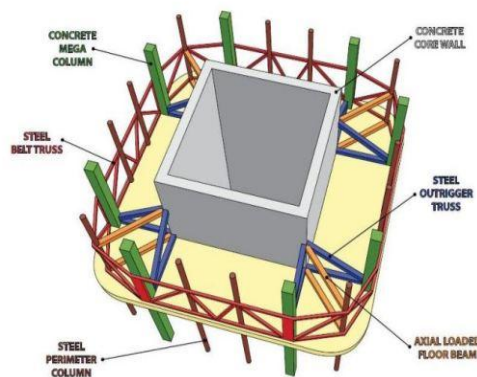


Fig.1: Outrigger Structural System

Outriggers are categorized as interior structural systems that can work efficiently for up to 150 floors. It is one of the successful and stable configurations used in high-rise construction.

Outrigger structural system is popular in construction since the 1980s due to its unique combination of architectural flexibility and structural efficiency.

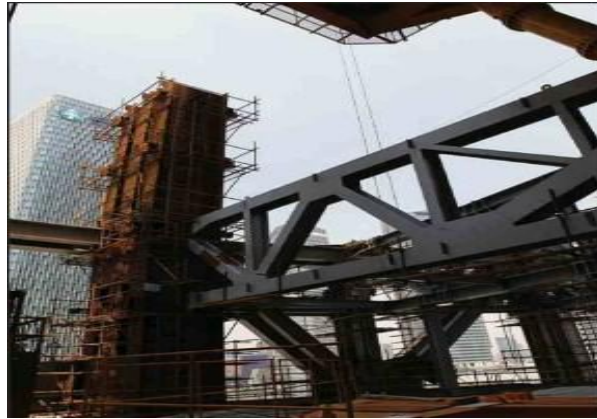


Fig 2: Outrigger Truss Connected to Perimeter Columns

Outrigger Structural Systems

An outrigger structure functions in a high-rise building by tying together two systems (see Figure-2), namely,

1. Core system
2. Perimeter system

As shown in Figure-1, the core structure is the most critical unit of a high-rise building. It is a combination of units like lifts, staircases, ducts, etc. Whereas the perimeter system is a combination of mega columns. The core system and mega columns located in the perimeter are connected using outriggers. Figure-2 shows a truss type outrigger connected to the perimeter column. Other than outriggers, the structure is accompanied by belt trusses around the perimeter to provide extra lateral resistance.

Both the core and perimeter systems together with the outrigger control the behaviour of the whole building. This is performed by the positive interaction between the core and the perimeter system through outriggers.

The main objectives of this project is to study the seismic behaviour of building by using IS 1893:2002, to analyse the 20 stories Diagrid building in zone V seismic condition, to compare the results of storey drift, shear force, bending moment, building torsion of buildings, to study the multi storey buildings in ETABS in Response spectrum analysis and to compare the results of models namely bare frame model, Diagrid model and outrigger model.

2. LITERATURE REVIEW

Rohit Kumar Singh (2014), studied comparison of analysis results in terms of storey drift, node to node displacement, bending moment, shear

forces, area of reinforcement, and also the economical aspect is presented. Drift in Diagrid building is approximately half to that obtained in conventional building. In these steel reinforcement used in Diagrid structure is found to be 33% less compared to conventional building. It is observed that due to diagonal columns in periphery of the structures, the Diagrid structure is more effective in lateral load resistance. They concluded that the diagrid buildings show structural performance, material saving property, better resistance to lateral loads, aesthetic look.

Kyoung Sun Moon (2014), studied structural system design option for tilted tall building and their performances. Tilted tall buildings are designed with various structural system, such as braced tubes, diagrid and outrigger system, and their structural performances are studied. Structural design of today's tall buildings built with higher strength material is generally governed by lateral stiffness. Tilted towers are deformed laterally not only by lateral loads but also by dead load and live load due to their eccentricity. The impact of tilting tall building on the gravity and lateral load resisting systems is studied. Comparative evaluation of structural system for titled tall building is presented.

Khushbu Jani (2015), studied comparison of analysis results in terms of time period, top storey displacement and inter-storey drift. ETABS software is used for modelling and analysis of structural members. All structural members are designed as per IS 800:2007 considering all load combinations. Dynamic along wind and across wind are considered for analysis and design of the structure. Load distribution in dia grid system is

also studied for 36 storied building. Similarly, analysis and design of 50, 60, 70 and 80 storied dia grid structures is carried out.

Raghunath D. Deshpande (2015) compared conventional and dia grid structural systems. ETABS software is used for modelling and analysis of structural members. Dynamic along wind and across wind are considered for analysis and design of the structure. Diagrid performs better across all the criterions of performance evaluation, such as, efficiency, expressiveness and sustainability. Structure has comparatively less deflection; structural weight is reduced to greater extent, due to this structure has more resistance to lateral forces, cost effective and eco-friendly, diagrid uses 11247 tonnes of steel which is 28% less compared to the conventional orthogonal building which uses 15255 tonnes. Compared to Conventional Structure, Diagrid Structure has more opening area, less deflection, 28% less steel usage.

Femy Maria Thomas (2015), studied the concept of steel diagrid structural system by conducting literature review, then optimum configuration for building and optimum angle for diagrid is found out comparing square, rectangular and circular building with same plan area using ETABS software. Square and circular Diagrid buildings perform almost equally better than rectangular diagrid buildings and circular Diagrid buildings perform better than square diagrid buildings.

Sree Harsha J (2017), studied the comparison of 24-storied diagrid structural system with different uniform angles. The 24 storied diagrid structural systems with different angles are modeled and analyzed by using ETABS Software. Now a day the nonlinear analysis is essential for a tall building, in this present study the nonlinear analysis is carried out for the considered diagrid structural system. The comparison of analyzed results is in terms of top storey displacement, time period, storey shears and mode shapes is presented here.

Nishith B. Panchal (2018), studied the comparison of 20-storey simple frame building and diagrid structural system building. The comparison of analysis of results in terms of top storey displacement, storey drift, steel and concrete

consumption is presented here. ETABS 9.7.4 software is used for modeling and analysis of structure. Analysis results like displacement, storey drift and storey shear are presented here. Also design of both structures is done and optimum member sizes are decided to satisfy the code criteria.

Ravish Khan (2018), studied 20 storey diagrid structures in comparison with exterior braced frame structure. Analysis results and design of both the models are presented in terms of storey shear, displacement, drift and summary of lateral and gravity forces. From the study, it is concluded that the diagrid structure resists approximately the same amount of lateral loads as compared to the exterior braced structure; despite all the vertical columns being eliminated in the periphery of the diagrid structure. Diagrid structure provides more efficiency than braced structure. Also, less amount of storey shear is seen in diagrid structure than to the braced frame structure. The top storey drift of diagrid structure is less by 30.7% than in the exterior frame structure. The top storey displacement of diagrid structure is less by 46.7% than in the exterior frame structure. All these factors make the diagrid structure more resistant than the braced frame structure. Diagrid structure gives more aesthetic look and gives more of interior space due to less columns and façade of the building can also be planned more efficiently.

3. METHODOLOGY USED

RESPONSE SPECTRUM METHOD

The representation of maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. This analysis is carried out according to the code IS 1893-2002 (part1). Here type of soil, seismic zone factor should be entered from IS 1893-2002 (part1). The standard response spectra for type of soil considered is applied to building for the analysis in ETABS 2013 software. Fig.3 shows the standard response spectrum for medium soil type and that can be given in the form of time period versus spectral acceleration coefficient (S_a/g).

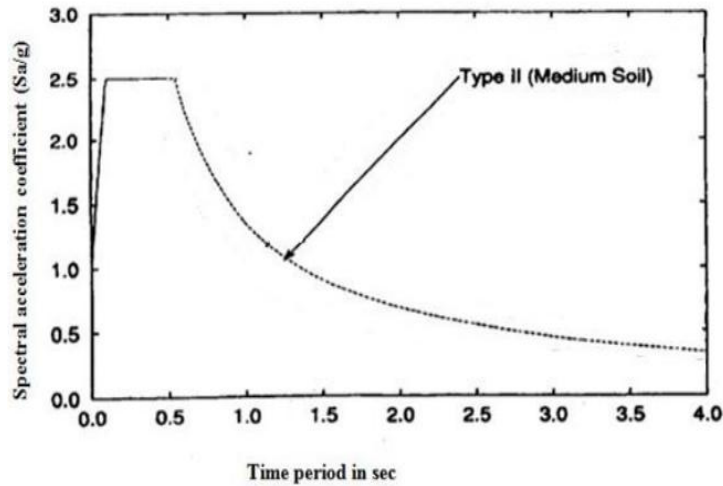


Fig.3: Response spectrum for medium soil type for 5% damping

This approach permits the multiple modes of response of a building to be taken in to account (in the frequency domain). This is required in many building codes for all except very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the “harmonic” computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

- absolute - peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) - a method that is an improvement on SRSS for closely spaced modes

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum.

In cases where structures are either too irregular, too tall or of significance to a community in disaster response, the response spectrum

approach is no longer appropriate, and more complex analysis is often required, such as non-linear static analysis or dynamic analysis.

4. Modelling of building

Problem statement

In the present study, analysis of G+20 storied building in Zone V seismic zone is carried out in ETABS.

Basic parameters considered for the analysis are.

1. Grade of concrete : M30
2. Grade of Reinforcing steel : HYSD Fe500
3. Dimensions of beam : 450mmX450mm,
4. Dimensions of columns :600mmX450mm
5. Diagrid RCC beam section :350mmX350mm
6. Angle of Diagrid : 5 degrees
7. Dimensions of column : 500mmX500mm
8. Thickness of slab : 150mm
9. Height of bottom storey : 3m
10. Height of Remaining storey : 3m
11. Live load : 2.5 KN/m²
12. Floor load : 1.5 KN/m²
13. Density of concrete : 25 KN/m³
14. Seismic Zone : Zone 5
15. Site type : II
16. Importance factor : 1.5
17. Response reduction factor : 5
18. Damping Ratio : 5%
19. Structure class : B
20. Basic wind speed : 39m/s
21. Risk coefficient (K1) : 1.08

- 22. Terrain size coefficient (K2) : 1.14
- 23. Topography factor (K3) : 1.36
- 24. Wind design code : IS 875: 1987 (Part 3)
- 25. RCC design code : IS 456:2000
- 26. Steel design code : IS 800: 2007
- 27. Earth quake design code : IS 1893: 2002 (Part 1)

Three types of models have been developed using etabs in this study.

1. Bare Frame Model
2. Diagrid Model
3. Outrigger model

The details are shown in Fig. 4(a-

Building models in ETABS

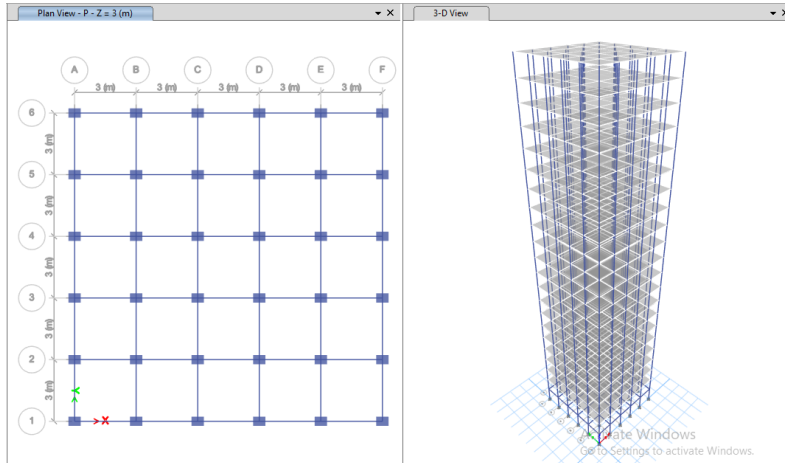


Fig 4(a). Bare frame model

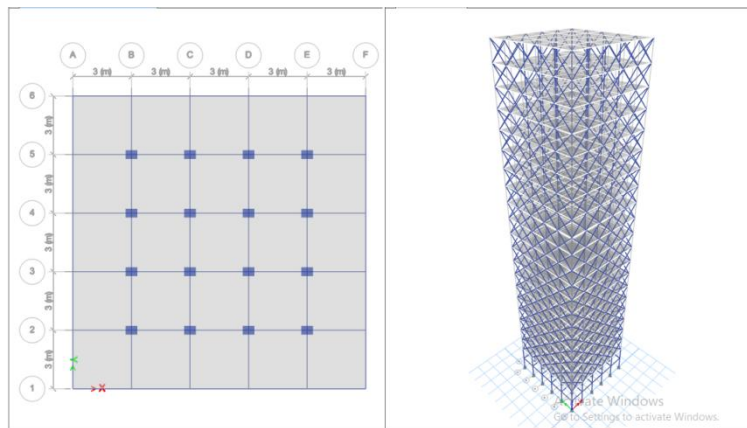


Fig 4(b). Diagrid model

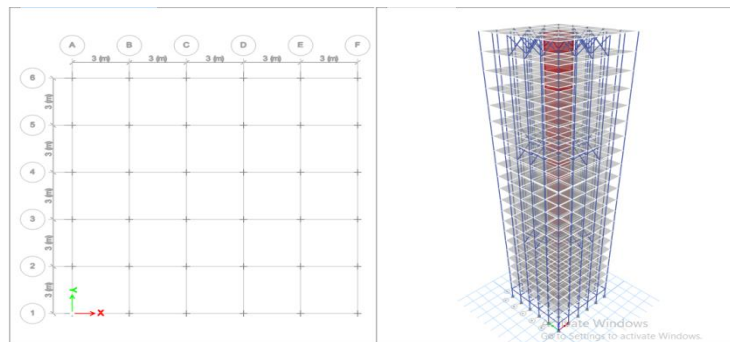


Fig 4(c). Outrigger model

5. RESULTS AND ANALYSIS

5.1 Storey drift

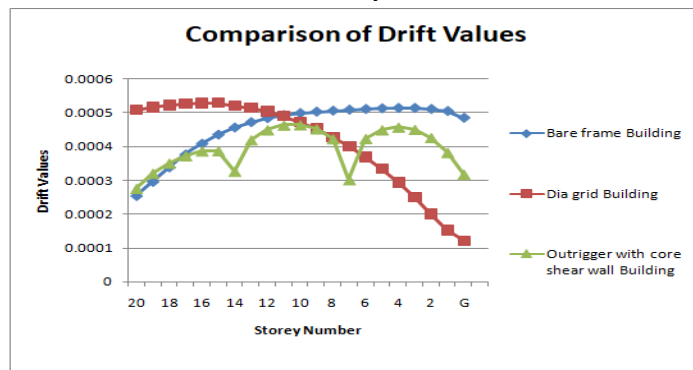


Fig 5(a). Variation of Drift in X-Direction

From the above results it was observed that the values of storey drift increasing in case of bare frame building from top storey to bottom (20th to Base), where as in case of Diagrid structures the

values are decreasing from top storey to bottom storey (20th to Base) and by using out triggers in the structure we can observe the increasing and decreasing variations of drift values.

5.2 Storey shear

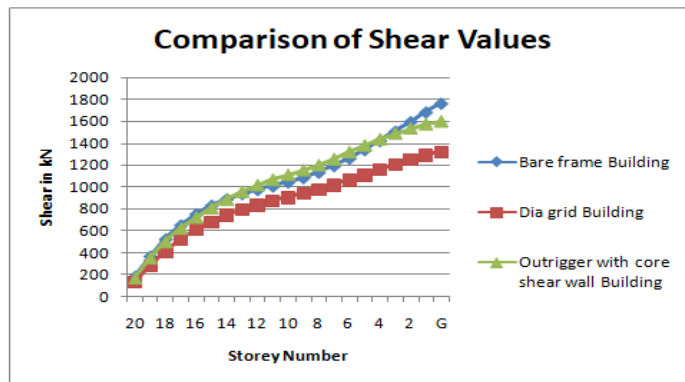


Fig 5(b). Comparison of Shear Values

From the above results it was observed that the values of shear are increasing from 20th to base in all the structures namely bare frame, Diagrid and outrigger buildings, the intensity of shear has less

values for the building model made with outrigger case because of more contact surface area in the out trigger building the intensity of shear is decreasing.

5.3 Storey Bending

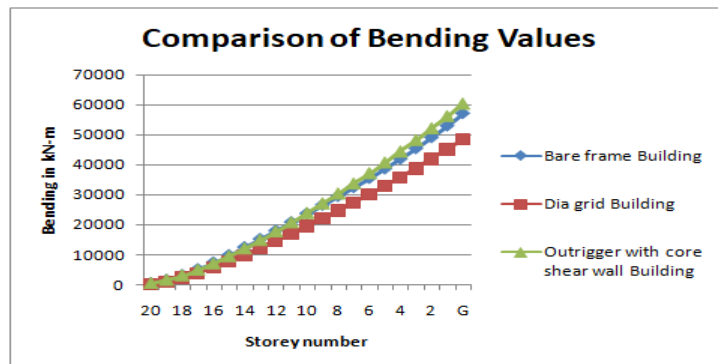


Fig 5(c). Comparison of Bending Values

From the above results it was observed that the values of bending are increasing from 20th to base in all the structures namely bare frame, Diagrid and outrigger buildings, the intensity of shear has

less values for the building model made with outrigger case because of more resistance for outrigger building the intensity of bending is decreasing.

5.4 Storey Torsion

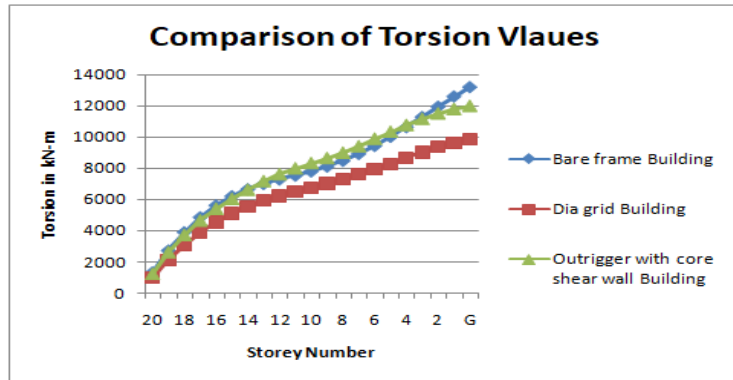


Fig 5(d). Comparison of Torsion Values

From the above results it was observed that the values of torsion are increasing from 20th to base in all the structures namely bare frame, Diagrid and

outrigger buildings, the intensity of shear has less values for the building model made with outrigger case because of more resistance for outrigger building the intensity of torsion is decreasing.

5.4 Time period

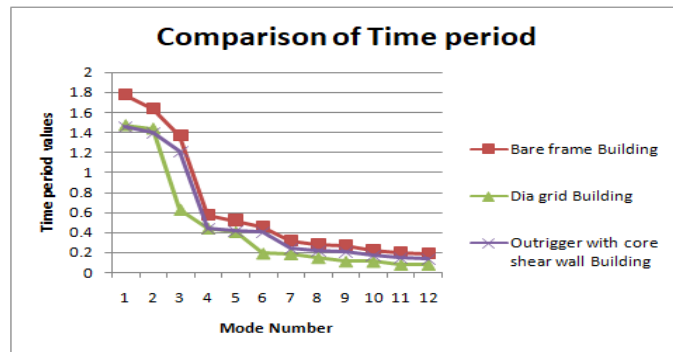


Fig 5(e). Comparison of Time Period

The intensity variation of time period is shown in the above plot from the above observation it was concluded that the intensity of time period

decreases from the mode 1 to mode 12 for all the three cases of building and the model made with Diagrid case has less intensity of time period when we compared with other building models.

5.5 Frequency

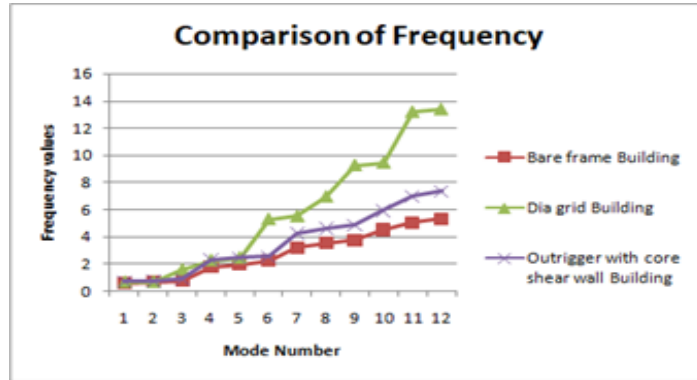


Fig 5(f). Comparison of Frequency

The intensity variation of frequency is shown in the above plot from the above observation it was concluded that the intensity of time period increases from the mode 1 to mode 12 for all the

three cases of building and the model made with bare frame case has less intensity of time period when we compared with other building models.

5.6 Base shear

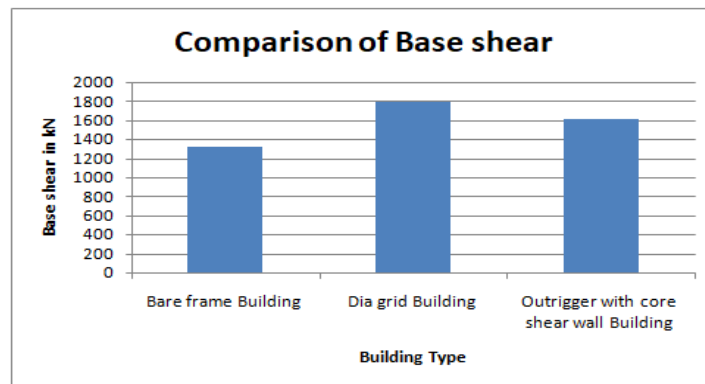


Fig 5(g). Comparison of Base Shear

From the above results it was concluded that the base shear values are having less intensity for the bare frame when we compared with other building models namely Diagrid, and outrigger case,

because of the less own (self-weight) intensity of weight from the bare frame model it is having less bare frame than other models.

RSA Y Results

5.7 Storey drift

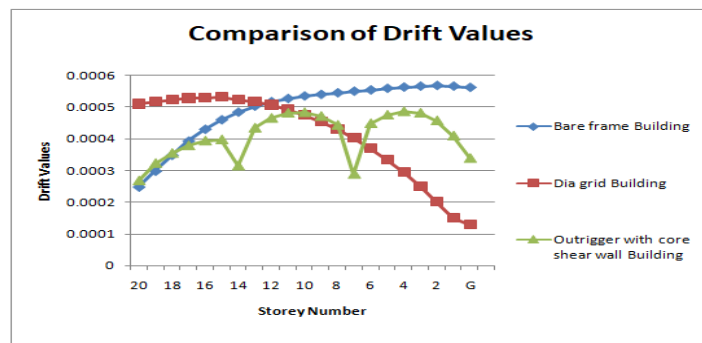


Fig 5(h). Variation of Drift in Y-Direction

From the above results it was observed that the values of storey drift increasing in case of bare frame building from top storey to bottom (20th to Base), where as in case of Diagrid structures the

values are decreasing from top storey to bottom storey (20th to Base) and by using out triggers in the structure we can observe the increasing and decreasing variations of drift values.

5.8 Storey shear

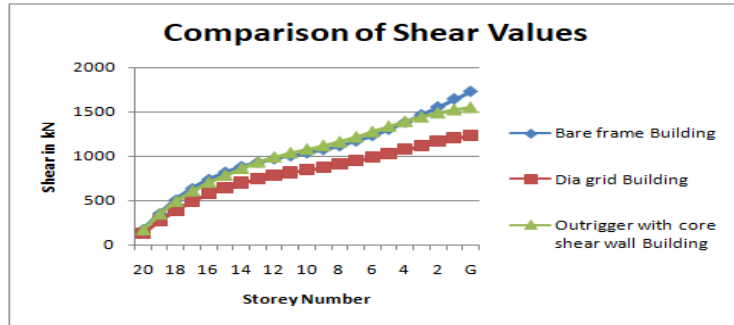


Fig 5(i). Comparison of Shear Values

From the above results it was observed that the values of shear are increasing from 20th to base in all the structures namely bare frame, Diagrid and outrigger buildings, the intensity of shear has less

values for the building model made with outrigger case because of more contact surface area in the out trigger building the intensity of shear is decreasing

5.9 Storey Bending

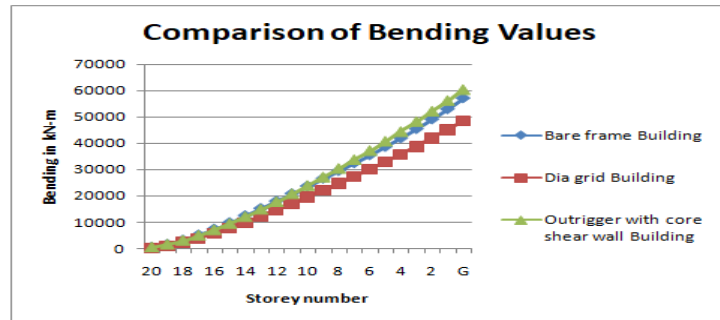


Fig 5(j). Comparison of Bending Values

From the above results it was observed that the values of bending are increasing from 20th to base in all the structures namely bare frame, Diagrid and outrigger buildings, the intensity of shear has

less values for the building model made with outrigger case because of more resistance for out trigger building the intensity of bending is decreasing.

5.10 Storey Torsion

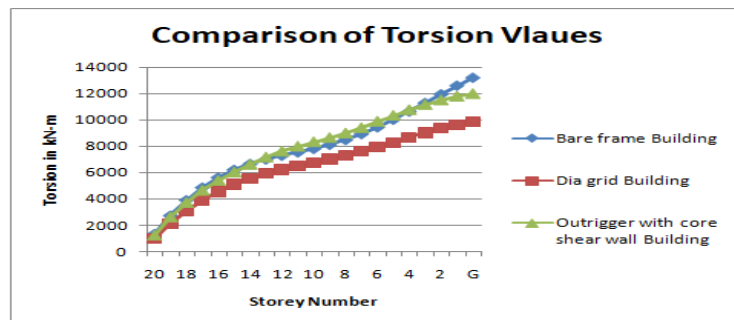


Fig 5(k). Comparison of Torsion Values

From the above results it was observed that the values of torsion are increasing from 20th to base in all the structures namely bare frame, Diagrid and outrigger buildings, the intensity of shear has less

values for the building model made with outrigger case because of more resistance for out trigger building the intensity of torsion is decreasing.

5.11 Time period

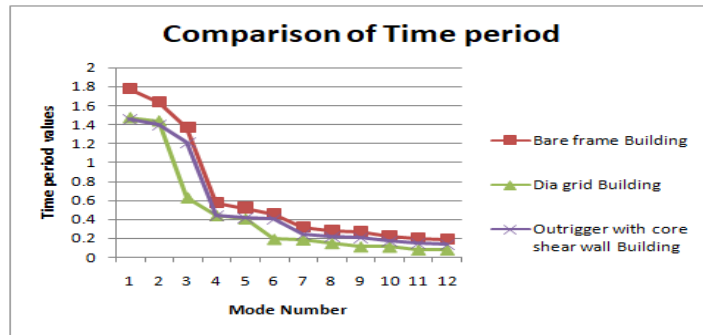


Fig 5(l). Comparison of Time Period

The intensity variation of time period is shown in the above plot from the above observation it was concluded that the intensity of time period

decreases from the mode 1 to mode 12 for all the three cases of building and the model made with Diagrid case has less intensity of time period when we compared with other building models.

5.12 Frequency

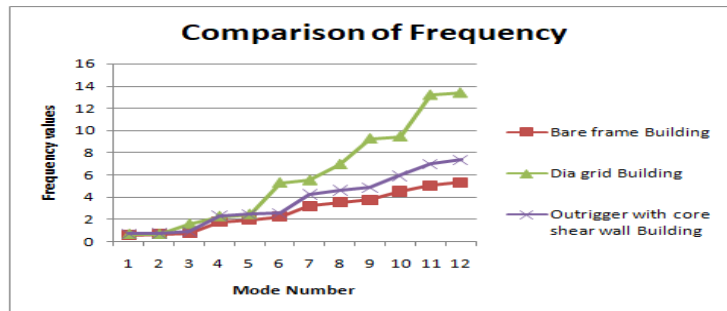


Fig 5(m). Comparison of Frequency

The intensity variation of frequency is shown in the above plot from the above observation it was concluded that the intensity of time period increases from the mode 1 to mode 12 for all the

three cases of building and the model made with bare frame case has less intensity of time period when we compared with other building models.

5.13 Base shear

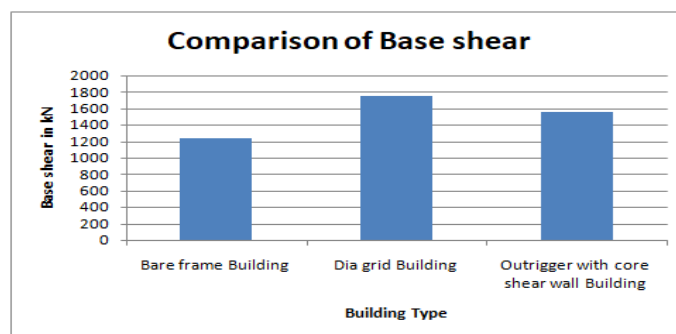


Fig 5(n). Comparison of Base Shear

From the above results it was concluded that the base shear values are having less intensity for the bare frame when we compared with other building models namely Diagrid, and outrigger case, because of the less own (self-weight) intensity of weight from the bare frame model it is having less bare frame than other models.

6. Conclusions

1. From the study it is observed that most of the lateral load is resisted by outrigger or Diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral Diagonal columns.
2. So, internal columns need to be designed for vertical load only. Due to increase in lever arm of peripheral Diagonal columns, outrigger, Diagrid structural system is more effective in lateral load resistance.
3. Lateral and gravity loads are resisted by axial force in Diagonal members on periphery of structure, which make system more effective. Diagrid structural system provides more flexibility in planning interior space and façade of the building.
4. The values of storey drift in X direction and Y direction has higher values for bare frame building model than Diagrid models and outrigger model.
5. The values of shear, bending in X direction and Y direction has higher values for bare frame than Diagrid building and outrigger model in Zone 5 condition.
6. The torsion has higher intensities for bare frame models than the Diagrid building structures and outrigger model.
7. The time period has higher values in case of bare frame model than remaining building structures.
8. Model stiffness has higher values for bare frame structure than Diagrid model or outrigger model.

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