Comparative Analysis of Tall buildings with Diagrid and Outrigger structural systems

Harinam k. Jaybhaye
SITS student
Saket P. Naik
SITS student

Raviranjan N. Mishra
SITS student
Snehal T. Sanap
SITS Asst. Professor

Bhushan G. More
SITS student
Indrajeet M. Jain
SITS Asst. Professor

Abstract:

The development of new structural system concepts for the evolution of tall building have been towards stiffness and lightness. Structural systems are more efficient now and this is significantly influenced by its geometrical configuration. Recently diagrid structural system is adopted in tall building due to its structural efficiency and flexibility in architectural planning. And diagrid system is evolution of braced tube structure. The provision of outrigger structural system is benefitted to give adequate stiffness against such lateral forces to the structure. A review paper is presented discussing the effectiveness of diagrid structural system over outrigger structural system. A 32 storey building of floor plan 30×25m with diagrid and outrigger structural system is presented. Diagrid structural system having uniform angle and optimum position of outrigger are studied. Resulting diagrid structure and outrigger structure are assessed under gravity, earthquake and wind loads Lastly, analysis result like displacement, storey drift, storey shear and time period of all models are compared. Optimum diagrid angle range and optimum position of outrigger is discussed and depicted that regular diagrid structure is better than regular outrigger structure.

Keywords: *Diagrid structural system, High rise building, Lateral loads, Outrigger structural system, Structural design, Tall buildings.*

1. Introduction:

The rapid growth of urban population and limitation of available land the taller structure are preferable nowadays. The evolution of tall building structural system based on new structural concepts with newly adopted high strength materials and construction methods have been towards "stiffness" and "lightness". Structural systems are becoming lighter and stiffer. Various types of structural forms are there which provides stability to tall structure, but its really difficult to decide which type of structural form will be suitable to any particular type of building. While choosing any particular structural form of building we need to consider different factors like aesthetics, safety, municipal rules, and regulations, feasibility, advantages and disadvantages of chosen structural form and ultimately everything is related to economy of the structure. So we have considered different structural system and on the basis of various parameters we should further suggest which system will be appropriate.

1.1 Diagrid Structural system: Diagrid are perimeter structural configurations characterized by a narrow grid of diagonal members which are involved both in gravity and in lateral load resistance. In most applications, diagrid provide structural supports to buildings that are non-rectilinear, adapting well to highly angular buildings and curved forms. The diagrid in its purest form is capable of resisting all the gravity loads and lateral loads on the structure without assistance of a traditional structural core. This permits unique deviations from structural types that are dependent on core for stability.

1.2 Outrigger structural system: Outriggers are the stiff beams connected between the core and external column which helps in keeping the column in their position by reducing the lateral drift. Outriggers are the beams of single or double floor depth, which are provided between core and peripheral columns. They can be provided in one or both directions. They can be provided either in the form of R.C.C. beams or in the form of truss. When the structure is subjected to horizontal loads, the columns connected to outrigger resist the rotation of central core hence moments and lateral deflection in the core becomes lesser as compared to core alone set apart resisted the loading. Generally the outrigger located at 1/n+1, 2/n+2 upto n/n+n of height to achieve satisfactory results.

2. Modelling:

In the present study we have considered two structural system i.e diagrid and outrigger structural system. The various models with these structural systems is modelled and analysed by using E-TABS software and results are compared.

Building Configuration:
No of stories: 33
Height of storey: 3.5m
Height of structure: 115.5m
Plan dimension: 30×25

Material Properties:
Grade of concrete: M30
Grade of steel sections: Fe345

Structural parameters:

Table 2.1: Structural Parameters

Parameters	Diagrid	Outrigger
Floor level column	ISMB 500	ISMB 500
Ground level column	ISMB 500	ISMB 500
Floor level beam	ISMB 350	ISMB 350
Plinth beam	ISMB 350	ISMB350
Slab Type	Filled	Filled
Slab thickness	Deck slab(150mm thick)	Deck slab(150mm thick)
Core wall thickness	300 mm thick RCC wall	300 mm thick RCC wall
Section	Steel tube 400mm outer diameter & 25 mm thickness	ISMB 300
Diaphragm	Rigid	Rigid

Loading data:
Floor finish: 1.5 kN/m²
Live load: 4 kN/m²
Super dead load: 1.5 kN/m²
Basic wind speed: 50 m/s
Terrain Category: 2
Zone factor: 0.36
Soil Type: II

2.1 Model considered for analysis:
The 3D models and the plan of a building with different location of outrigger and different angle of inclination of diagrid structure are to be considered. Here the building with diagrid module (35.45° inclination) and building with 2 outriggers @ H/3 &2H/3 are presented in the figure given below. The below figure shows the detailed plan of both structural system.

Figure 2.1 Plan of Diagrid building

Figure 2.2 Plan of outrigger Building

Nomenclature of models:
Scheme 1: Models with different uniform angle along the height.
Model 1: Diagrid with 35° inclination
Model 2: Diagrid with 50° inclination
Model 3: Diagrid with 64° inclination
Model 4: Diagrid with 70° inclination
Model 5: Diagrid with 74.28° inclination

Scheme 2: Models with varying position of outrigger.
Model 6: Without outrigger
Model 7: Outrigger at H/5
Model 8: Outrigger at H/3
Model 9: Outrigger at H/3 and 2H/3
Model 10: Outrigger at H/5 and top

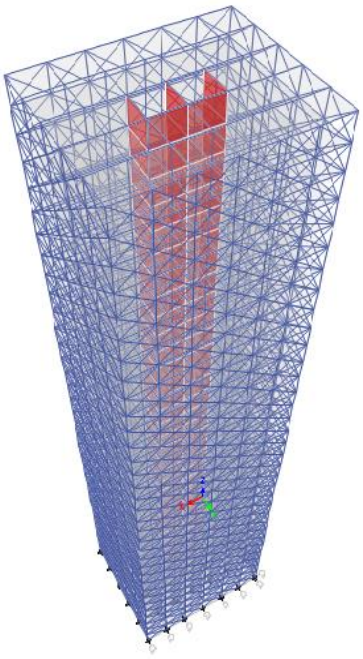

Figure 2.3 3D Model with diagrid module(35.45° inclination)

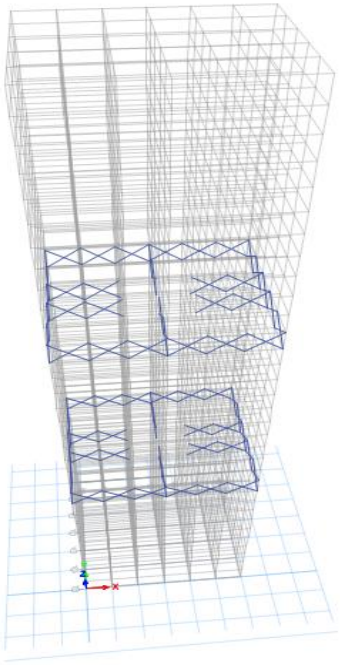

Figure 2.4 3D Model with 2 Outriggers @ H/3 and 2H/3

3. Literature Review:

Kyoung Soon Moon(2011) studied structural performance of diagrid system employed for complex shaped tall building. Taller building behave more like bending beams and should be designed to have more bending deformation than shorter building that behave like shear beam.

Parekh M. M.(2016) described deflection control by effective utilization of belt truss and outrigger for 40, 60, 80 storey building. The various models have been analysed on varying position of outrigger i.e at top, mid height & 2/3 height. The model was analysed in FEM using SAP 2000. After analysing the model it was found that the deflection of outrigger at top and 2/3 height was lesser. The model without outrigger system was having maximum deflection at top.

Varsani H., Pokar N. Gandhi(2016) analysed 24 storey building using diagrid structural system and conventional structural system. A regular floor plan of 36×36m was considered. This study was carried out using E-TABS software and all the structural members were considered as per IS 800:2007. The dynamic load was also considered for analysis and result was calculated on the basis of storey shear, drift,etc.

Jani k., Paresh V. Patel(2013), considered a regular floor plan of 36×36m size. E-TABS software is used for modelling and analysis of structural members. The wind loads were considered for analysis and design of structure. Load distribution in diagrid system is also studied for 36 storey building. It was observed that the storey shear and inter storey drift in x-direction and y-direction due to dynamic wind load is higher as compared to earthquake load. Hence to increase the stability of building various models of diagrid were studied by varying angle of inclination of inclined peripheral columns.

Panchal N. B., Patel V. R.(2014), studied a comparison of analysis of 20 storey simple frame building and diagrid structural building in terms of top storey displacement, storey drift and material consumption. 20 storey building having 18×18m plan and 72 m height is studied. The design was carried out using E-TABS software and the loads was assigned to both the structures with all load combinations. This study conclude that diagrid provide more resistance in the building which gives suitable stability for building against lateral loads. Diagrid also provide more economy in terms of consumption of material as compared to other.

4. Results and Discussions:

4.1 Analysis of Diagrid and Outrigger:

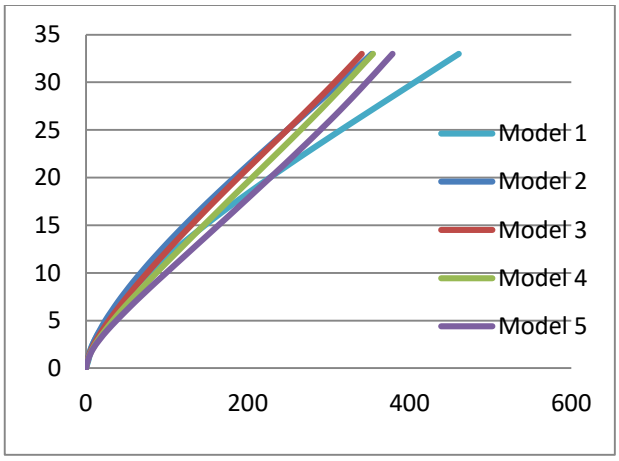

Figure 4.1: Maximum storey displacement for different angles of diagrid

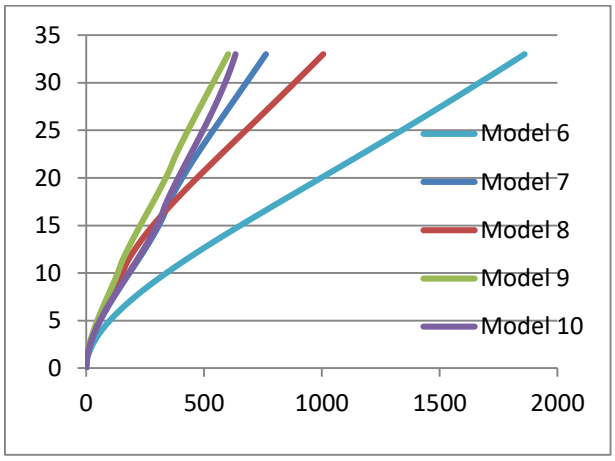

Figure 4.2: Maximum storey displacement for different positions of outrigger

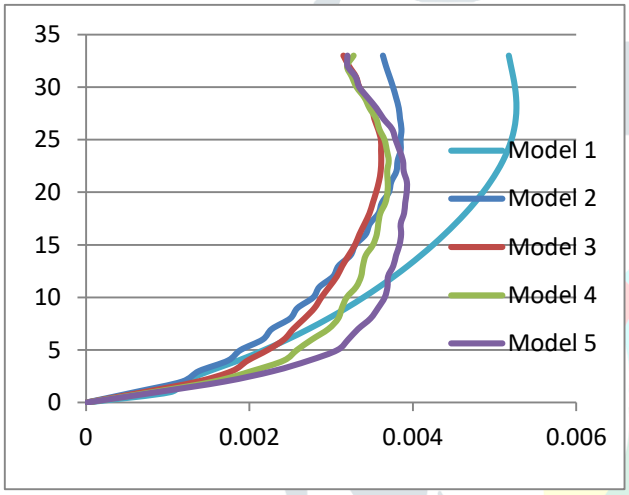

Figure 4.3: Maximum storey drift for different angles of diagrid

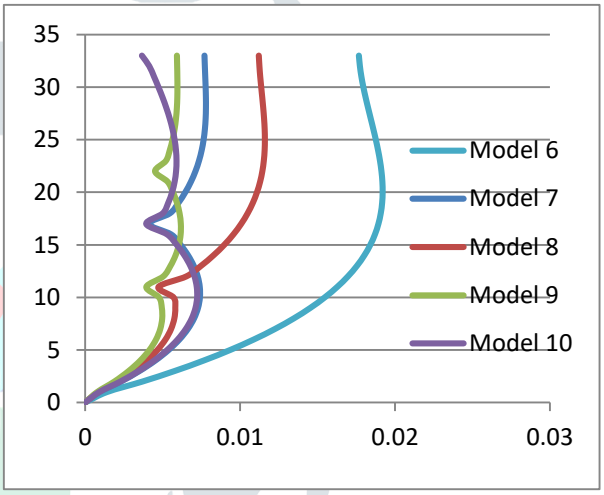

Figure 4.4: Maximum storey drift for different positions of outrigger

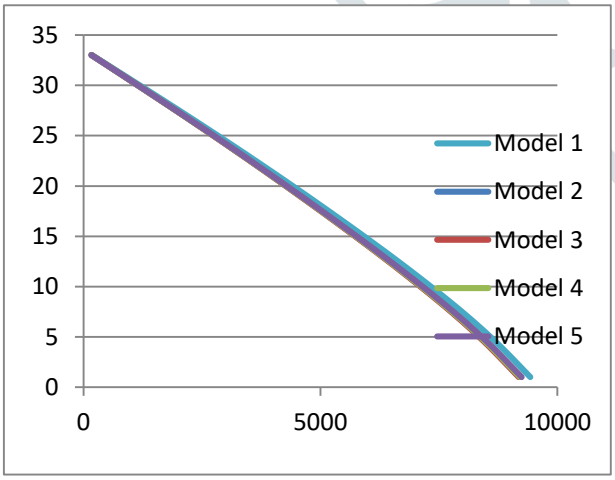

Figure 4.5: Maximum storey shear for different angles of diagrid

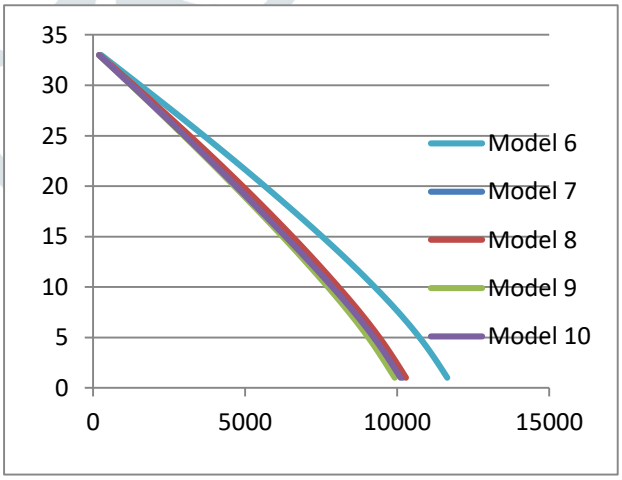

Figure 4.6: Maximum storey shear for different positions of outrigger

Table 4.1: Maximum storey displacement for different angles of diagrid

Structural Systems	Top Storey Displacement(mm)
Model 1	461.1
Model 2	353.2
Model 3	341
Model 4	354.8
Model 5	378.9

Table 4.2: Maximum storey displacement for different position of outrigger

Structural Parameters	Top storey displacement(mm)
Model 6	1860.475
Model 7	763.07
Model 8	1005.602
Model 9	602.634
Model 10	634.402

Table 4.3: Maximum storey drift for different angles of diagrid

Structural Parameters	Maximum storey drift
Model 1	0.00495
Model 2	0.003737
Model 3	0.003583
Model 4	0.003692
Model 5	0.003928

Table 4.4: Maximum storey drift for different position of outrigger

Structural Parameters	Maximum storey drift
Model 6	0.015476
Model 7	0.007415
Model 8	0.005713
Model 9	0.00478
Model 10	0.007227

Table 4.5: Maximum storey shear for different angles of diagrid

Structural parameters	Maximum storey shear(kN)
Model 1	9426.4097
Model 2	9197.2683
Model 3	9186.7169
Model 4	9210.6233
Model 5	9247.8477

Table 4.6: Maximum storey shear for different positions of outrigger

Structural parameters	Maximum storey shear(kN)
Model 6	11649.65
Model 7	10185.95
Model 8	10288.83
Model 9	9924.357
Model 10	10114.36

5. Conclusion:

In this paper 2 different schemes were adopted for diagrid and outrigger structural system under various loads. The schemes adopted are as follows: Scheme 1: Models with different uniform angle along the height, Scheme 2: Models with varying position of outrigger.

The results were analysed in terms of displacement, storey drift and storey shear. Based on results and discussion following conclusions are drawn from the present study:

1. Model 3 gives optimum value of displacement, storey drift and storey shear as compared to other models of scheme 1 for given G+32 building.
2. Hence we can conclude that model 3 with 64° inclination behaves as optimum angle model in diagrid structural system.
3. Model 9 gives optimum value of displacement, storey drift and storey shear as compared to other models of scheme 2 for given G+32 building.
4. Hence we can conclude that model 9 behaves as optimum position model in outrigger model.
5. The top storey displacement of model 3(64° inclination) is about 44% less as compared to model 9(two outriggers @ H/3 and 2H/3).
6. The storey drift of model 3(64° inclination) is about 25% less as compared to model 9(two outriggers @ H/3 and 2H/3).
7. The storey shear of model 3(64° inclination) is about 8% less as compared to model 9(two outriggers @H/3 and 2H/3).

Hence we can conclude that diagrid structural system is more capable of resisting the lateral loads as compared to outrigger structural system.

6. References :

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