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Analysis of Tall buildings with Different Structural Systems

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Abstract

The concept for the development of new structural system is based on the stiffness & lightness of tall buildings under evolution. Structural systems are more efficient now and this is significantly influenced by its geometrical configuration. With the aspect of efficiency in structure & architectural planning flexibility, diagrid structural system in tall building is a tool implemented with ease. And diagrid system is evolution of braced tube structure. As a resistance by means of stiffness for the lateral forces acting on the structures, outrigger structural system gives the best outcome. 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 range of angles in diagrid and optimum position of outrigger studied with the outcome that regular diagrid structure proofs effective than regular outrigger structure.

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

I. INTRODUCTION

Nowadays due to the limitation of available land & growth of urban population, taller structures are preferred. The evolution structural system of tall building based on new structural concepts with construction methods & newly adopted materials with more strength have been towards the parameters of "stiffness" and "lightness". Structural systems are becoming lighter and stiffer. Various types of structural forms are there which provides stability to tall structure, but it's really difficult to decide which type of structural form will be suitable to any particular building type. 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.

A. Diagrid Structural system

Diagrid are configurations of structural perimeter which are implemented both in resistance of lateral loading & gravity characterized by a narrow grid of diagonal members. In most applications, buildings that are non- rectilinear, adapting well to highly angular buildings and curved forms, diagrid provide structural supports. The purest form of diagrid without participation of a basic structural core is capable of sustaining all the lateral loads & gravity loads on the structure. This permits unique deviations from structural types that are dependent on core for stability.

B. 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

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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. The columns of the structure connected to outrigger resist the rotation of central core subjected to horizontal loads hence lateral deflection & moments in the core becomes quite small with respect to the core alone resisting the loading. In usual cases, the outrigger located at (1/n+1), (2/n+2) upto (n/n+n) of height gives the satisfactory outputs.

II. MODELLING

The two structural systems i.e. the diagrid and the outrigger structural system are considered for study. 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 I
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	ISMB_350
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

A. Model considered for analysis

The 3D models and the plan of a building with different positions of outrigger and different inclination angles of diagrid structure are to be considered. Here the building with 2 outriggers @ H/3 & 2H/3 and diagrid module (35.45° inclination) are presented in the figure given below. The detailed plan of both structural system is shown in below figure.

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Fig. 1 Plan of Diagrid building

Fig. 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

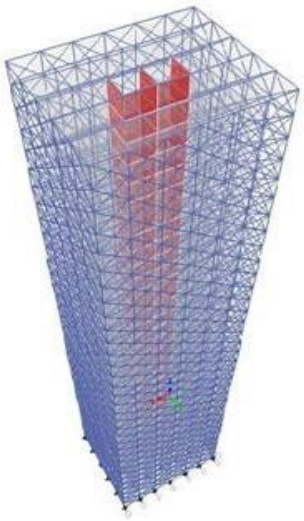

Fig. 3 3D Model with diagrid module(35.45° inclination) @ H/3 and 2H/3

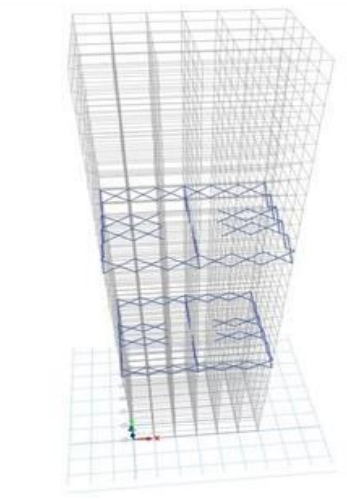

Fig. 4 3D Model with 2 Outriggers

III. LITERATURE REVIEW

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

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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. For modelling and analysis of structural members E-TABS software was implemented. For analysis and design of structure, wind loads were considered. 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 were 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.

IV. RESULTS AND DISCUSSIONS

A. *Analysis of Diagrid and Outrigger*

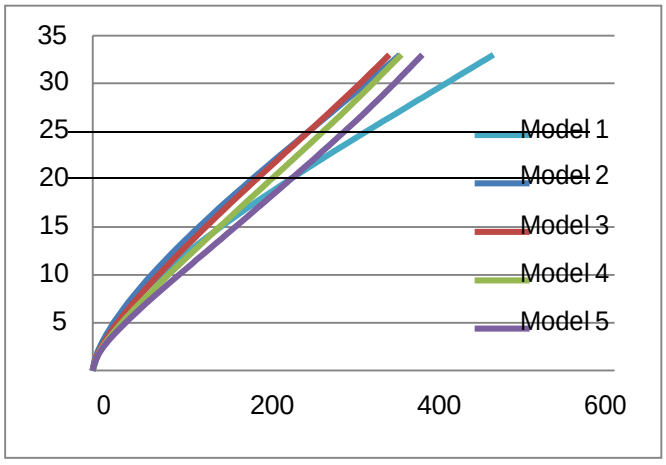

Fig. 5 Max storey displacement for different angles of diagrid

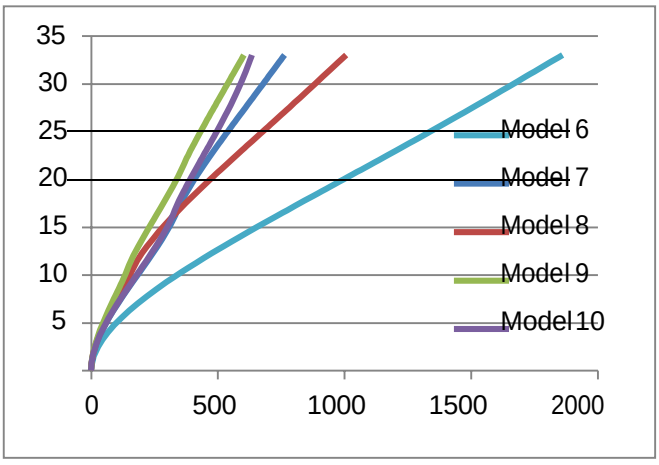

Fig. 6 Max storey displacement for different positions of outrigger

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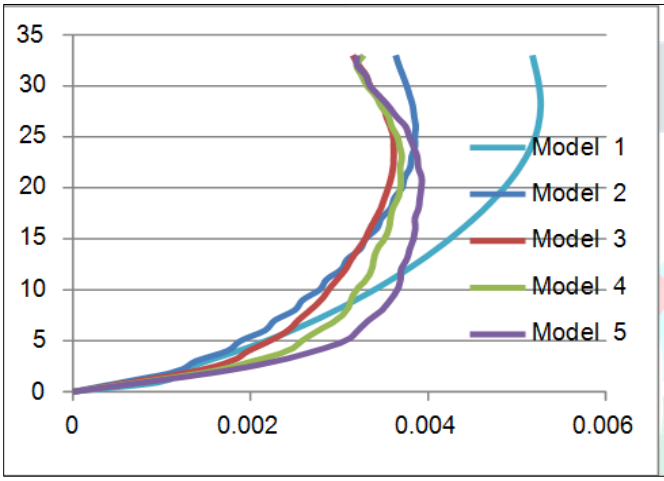

Fig. 7 Max storey drift for different angles of diagrid

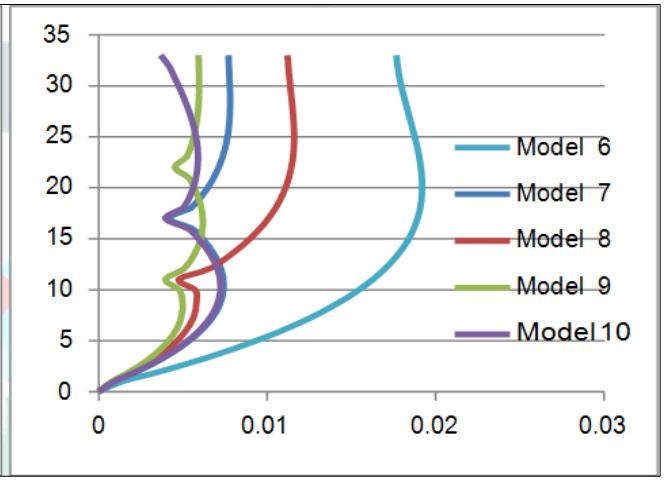

Fig. 8 Max storey drift for different positions of outrigger

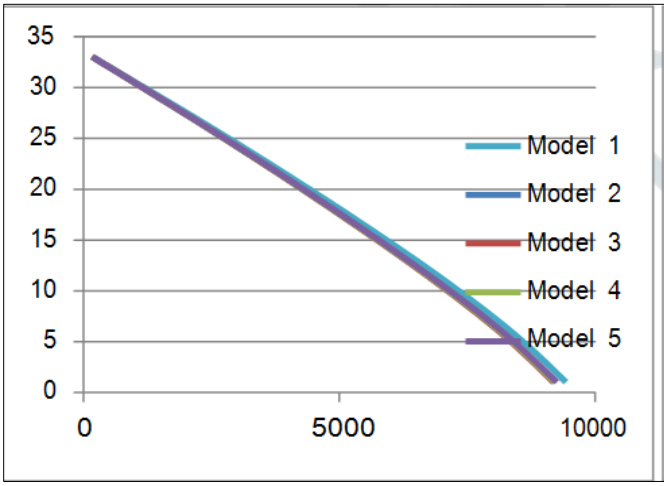

Fig. 9 Max storey shear for different angles of diagrid

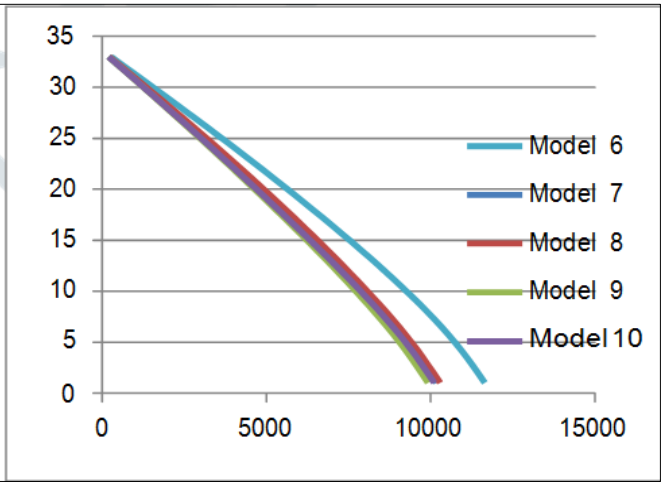

Fig. 10 Max storey shear for different positions of outrigger

TABLE II
MAX 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 III
MAX STOREY DISPLACEMENT FOR DIFFERENT ANGLES OF DIAGRID

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 IV
MAX STOREY DRIFT FOR DIFFERENT ANGLES OF DIAGRID

TABLE V
MAX STOREY DRIFT FOR DIFFERENT POSITION OF OUTRIGGER

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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

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 VI
MAX 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 VII
MAX 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

V.

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VI. 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 discussions 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.

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