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Diagrid High Rise Steel Structure and Comparison of analysis Using E-tab

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Abstract
Diagrid buildings are emerging as structurally efficient as well as architecturally significant assemblies for tall buildings. Recently the diagrid structural system has been widely used for tall buildings due to the structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. Generally, for tall building diagrid structure steel is used. Lateral load resistance of the structure is provided by interior structural system or exterior structural system. Due to inclined columns lateral loads are resisted by axial action of the diagonal in diagrid structure compared to bending of vertical columns in conventional building
Comparison of analysis results in terms of time period, storey displacement, storey shear and storey drift with conventional building. And concrete diagrid structure is analysed and compared with conventional concrete building. Structural design of high-rise buildings is governed by lateral loads due to wind.
Keyword: *RCC Frame structure, Bracing, Lateral displacement, Wind Analysis.*

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I. INTRODUCTION

The origins of diagrid typology lie at the crossroads of engineering and architecture. Initial explorations were done by the Russian Er. Vladimir shukhov. It is significant that Norman Foster has referenced the work of Shukhov as an inspiration for his diagrid exploration. This affirms the role of Shukhov's tower as a precedent for building such as the Swiss Rey tower and the Hearts Magazine Tower.

In India, a building greater than 75ft (23m), generally 7 to 10 stories, is considered as high-rise steel building. Also, a building is considered to be high rise when it extends higher than the maximum reach available to fire fighters. According to the building code of India, a tall building is one with four floors or more or a high-rise building is more than 15m height. Most of the tall building are in commercial capital Mumbai. More than 2500 high rise building are already constructed. In addition, more than mid rises exists already in the city. Mumbai is undergoing a massive construction boom, with thousands of tall buildings and about 15 high rise structures are under construction. Delhi and its surrounding regions are witnessing huge construction activities with the 1500 already constructed high rises.

A Diagrid structure provides great structural efficiency without vertical columns have also opened new aesthetic potential for tall building architecture. Diagrid has a good appearance and it is easily recognized. The configuration and efficiency of a diagrid system reduces the number of structural elements 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, and therefore allowing significant flexibility with the floor plan. "Diagrid" system around perimeter saves approximately 20 percent of the structural steel weight when compared to a conventional moment- frame structure. The diagonal members in diagrid structural systems carry gravity loads as well as lateral forces due to their triangulated configuration. Diagrid can save up to 20% to 30% the amount of structural steel in a high- rise building.

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. And wind speed is necessary to take in consideration to reduce lateral forces on structure.

1.1. What is Diagrid: -Diagrid is the combination of words - 'Diagonal' and 'Grid' = Diagrid.

Diagrid is formed by Intersecting the diagonal and horizontal components. Diagrid buildings are widely used for tall steel buildings due to its **structural efficiency and aesthetic potential** provided by the unique geometric configuration of the system. A diagrid structure is a form of a space truss which is effective in reducing shear deformation, as they carry the lateral load by an axial action of diagonal members. Diagrid structure consists of perimeter grid made up of series of triangulated truss system. Diagrid structural system that is single- thickness in nature and gains its structural integrity through the use of triangulation. Perimeter diagrid normally carry the lateral and gravity loads of the building and are used to support the floor edges.

II. LITERATURE REVIEW

In recent trends, the construction development has been rapidly increasing towards tall building structures. For "stiffness" and "lightness" to structural system has been evaluated based on new structural concept with newly adopted high strength materials and construction methods. Recently different structural system like braced tub structure, spaced truss, Diagrid structural system, etc. Area adopted in tall building due to its structural efficiency and flexibility in architectural planning. Diagrid structure consists of inclined columns on the exterior surface of building, compared to closely spaced vertical columns in framed tube

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2.1. TECHNICAL PAPER: -

2.1.1 Kyoung Sun Moona: - In this paper author investigate that, Diagrid structures have been prevalently used for tall buildings worldwide. The unique compositional characteristics of diagrids provide great structural efficiency and aesthetic potential as an accentuating element in any existing urban context generally composed of buildings of orthogonal components. This paper presented structural performance and constructability issues of diagrid structures employed for complex-shaped tall buildings such as twisted, tilted and freeform towers. Though widely used today, application of diagrid structures for tall buildings is relatively new.

2.1.2 Khushbujani: - In this paper, analysis and design of 36 Storey diagrid steel building is presented in detail. A regular floor plan of 36 m ×36 m size is considered. ETABS software is used for modeling and analysis of structure. All structural members are designed using IS 800:2007 considering all load combinations. Load distribution in diagrid system is also studied for 36 Storey building. Also, the analysis and design results of 50, 60, 70 and 80 Storey diagrid structures are presented. From the study it is observed that most of the lateral load is resisted by diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns. So, internal columns need to be designed for vertical load only. Due to increase in lever arm of peripheral diagonal columns, diagrid structural system is more effective in lateral load resistance. Lateral and gravity load are resisted by axial force in diagonal members on periphery of structure, which make system more effective.

2.1.3 Dongkyu Lee: - The diagrid structural system is a new architectural trend for free formed tall buildings, in which high performance steel with tensile stress of 800 MPa (i.e., HSA800) can be applied. The DSDI TRIZ procedure results in new structural details of the existing diagrid in structural design of mega structures such as tall buildings, and TRIZ can be also applied to architectural or civil design. TRIZ is a problem-solving, analysis and forecasting tool derived from the study of patterns of inventions in the global patent literature. This study confirms that the TRIZ process can be a strong idea generation tool for developing structural details to improve the behaviours of existing structures. Finally, the author conclude that effectiveness of the new structural diagrid detail information is presented using actual non-linear static pushover analysis,

2.1.4 Nishith B. Panchal: - In this paper, comparative analysis and design of 20-storey diagrid structural system building and simple frame building is presented here. A regular floor plan of 18m x 18m size is considered. ETABS 9.7.4 software is used for modeling and analysis of structure. Analysis results like displacement, Storey drift, storey shear is presented in this paper. Also design of both structures is done and optimum member sizes are decided to satisfy the code criteria. Author concludes from the study that, As the lateral loads are resisted by diagonal columns, the top storey displacement is very much less in diagrid structure as compared to the simple frame building. The storey drift and storey shear are very much less for diagrid structural system. Diagrid structure system provides more economy in terms of consumption of steel and concrete as compared to simple frame building.

2.1.5 Giovanni Maria montuori: - The authors aim was to explore both uniform and non-uniform diagrid patterns and defining adequate design criteria. In particular in this paper,8 alternative geometrical patterns of diagrid structures have been generated, design, optimized and comparatively assessed from the structural point of view by author. The author states that, being diagrids inherently efficient systems, the simplified procedures let the designer guess with a reasonable confidence what to expect from more rigorous and sophisticated analyses, and take the designer 90% of the way towards an optimized solution.

III. METHODOLOGY

With the help of traditional method by calculating forces acting on structures seismic and wind analysis performed on the E-TAB software using static method of structural analysis. Using wind analysis member is

3.1. Wind Analysis:

Buildings are subjected to horizontal load due to wind pressure acting on the buildings. Wind load is calculated as per IS 875(Part 3):1987. The horizontal wind pressures act on vertical external walls and exposed area of the buildings. Some of the pressure acting on exposed surfaces of structural walls and columns is directly resisted by bending of these members. The infill walls act as vertical plate supported at top and bottom by floor beams, thus transferring the loads at slab level. The parapet wall is at the terrace transfers the wind loads to the surface slab by cantilever action. For simplicity, the wind loads acting on exposed surfaces of a given storey are idealized to be supported by upper and lower floors.

3.1.1. Design Wind Speed (Vz):

The basic wind speed map of India is applicable to 10m height of building above mean ground level for different zones of country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean height above ground level in an open terrain (Category 2). Basic wind speeds presented in map have been worked out for 50-year return period. Basic wind speed for some important cities/town is also given in Appendix A and shall be modified to include the following effect to get design wind velocity at height (Vz) for chosen structure:

a. Risk level, b. Terrain roughness, height and size of structure and, c. Local topography.

It can be mathematically expressed as follows;

$$V_z = V_b \times k_1 \times k_2 \times k_3 \quad \text{Were,}$$

V_z = Design wind speed at height z in m/s k_1 = Probability factor (risk coefficient) k_2 = Terrain, height and structure size factor k_3 = Topography factor

3.1.2. Basic wind speed (Appendix A of IS 875.Part 3-1987):

IS : 875 (Part 3) - 1987

APPENDIX A

(*Clause* 5.2)

BASIC WIND SPEED AT 10 m HEIGHT FOR SOME IMPORTANT CITIES/TOWNS

City/Town	*Basic Wind Speed* (m/s)	*City/Town*	*Basic Wind Speed* (m/s)
Agra	47	Jhansi	47
Ahmadabad	39	Jodhpur	47
Ajmer	47	Kanpur	47
Almora	47	Kohima	44
Amritsar	47	Kurnool	39
Asansol	47	Lakshadweep	39
Aurangabad	39	Lucknow	47
Bahraich	47	Ludhiana	47
Bangalore	33	Madras	50
Barauni	47	Madurai	39
Bareilly	47	Mandi	39
Bhatinda	47	Mangalore	39
Bhilai	39	Moradabad	47
Bhopal	39	Mysore	33
Bhubaneshwar	50	Nagpur	44
Bhuj	50	Nainital	47
Bikaner	47	Nasik	39
Bokaro	47	Nellore	50
Bombay	44	Panjim	39
Calcutta	50	Patiala	47
Calicut	39	Patna	47
Chandigarh	47	Pondicherry	50
Coimbatore	39	Port Blair	44
Cuttack	50	Pune	39
Darbhanga	55	Raipur	39
Darjeeling	47	Rajkot	39
Dehra Dun	47	Ranchi	39
Delhi	47	Roorkee	39
Durgapur	47	Rourkela	39
Gangtok	47	Simla	39
Gauhati	50	Srinagar	39
Gaya	39	Surat	44
Gorakhpur	47	Tiruchchirrappalli	47
Hyderabad	44	Trivandrum	39
Imphal	47	Udaipur	47
Jabalpur	47	Vadodara	44
Jaipur	47	Varanasi	47
Jamshedpur	47	Vijaywada	50
		Visakhapatnam	50

3.1.3. Risk Coefficient (IS 875.Part 3-1987):

The risk coefficient k1 takes in to account the degree of reliability required and the expected life of structure.

a. All general buildings (Design life 50 years), b. Temporary sheds (Design life 5 years), c. Less important buildings (Design life 25 years), d. Important buildings (Design life 100 years)

TABLE 1 RISK COEFFICIENTS FOR DIFFERENT CLASSES OF STRUCTURES IN DIFFERENT WIND SPEED ZONES

(*Clause* 5.3.1)

Class of Structure	Mean Probable Design Life of Structure in Years	k_1 Factor for Basic Wind Speed (m/s) of					
		33	39	44	47	50	55
All general buildings and structures	50	1·0	1·0	1·0	1·0	1·0	1·0
Temporary sheds, structures such as those used during construction operations (for example, formwork and falsework), structures during construction stages and boundary walls	5	0·82	0·76	0·73	0·71	0·70	0·67
Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0·94	0·92	0·91	0·90	0·90	0·89
Important buildings and structures such as hospitals communication buildings / towers, power plant structures	100	1·05	1·06	1·07	1·07	1·08	1·08

Coefficients For Different Classes of Structures in Different Wind Speed Zones

3.1.4. Terrain, height and structure size factor (IS 875.Part 3-1987):

It depends of terrain category and building class/size of structure. Four terrain categories are specified by the code defending on the availability of obstruction to the flow of wind.

Category 1: Refers to no obstruction available to the building.

Category 2: Refers to open terrain with scattered obstruction of 1.5m to 10m height. Category 3: Refers to areas of closed spaced buildings of height up to 10m.

Category 4: Refers to area with highly closed building of large heights.

Class A: Maximum of l, b, h < 20m
Class B: Maximum of l, b, h – 20m to 50m, Class C: Maximum of l, b, h > 50m

3.1.5. Factors to obtain design wind speed variation with height in different terrain for different classes of buildings/structures

TABLE 2 k_2 FACTORS TO OBTAIN DESIGN WIND SPEED VARIATION WITH HEIGHT IN DIFFERENT TERRAINS FOR DIFFERENT CLASSES OF BUILDINGS/STRUCTURES

(*Clause* 5.3.2.2)

HEIGHT	TERRAIN CATEGORY 1 CLASS			TERRAIN CATEGORY 2 CLASS			TERRAIN CATEGORY 3 CLASS			TERRAIN CATEGORY 4 CLASS		
m	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	1·05	1·03	0·99	1·00	0·98	0·93	0·91	0·88	0·82	0·80	0·76	0·67
15	1·09	1·07	1·03	1·05	1·02	0·97	0·97	0·94	0·87	0·80	0·76	0·67
20	1·12	1·10	1·06	1·07	1·05	1·00	1·01	0·98	0·91	0·80	0·76	0·67
30	1·15	1·13	1·09	1·12	1·10	1·04	1·06	1·03	0·96	0·97	0·93	0·83
50	1·20	1·18	1·14	1·17	1·15	1·10	1·12	1·09	1·02	1·10	1·05	0·95
100	1·26	1·24	1·20	1·24	1·22	1·17	1·20	1·17	1·10	1·20	1·15	1·05
150	1·30	1·28	1·24	1·28	1·25	1·21	1·24	1·21	1·15	1·24	1·20	1·10
200	1·32	1·30	1·26	1·30	1·28	1·24	1·27	1·24	1·18	1·27	1·22	1·13
250	1·34	1·32	1·28	1·32	1·31	1·26	1·29	1·26	1·20	1·28	1·24	1·16
300	1·35	1·34	1·30	1·34	1 32	1·28	1·31	1·28	1·22	1·30	1·26	1·17
350	1·37	1·35	1·31	1·36	1·34	1·29	1·32	1·30	1·24	1·31	1·27	1·19
400	1·38	1·36	1·32	1·37	1·35	1·30	1·34	1·31	1·25	1·32	1·28	1·20
450	1·39	1·37	1·33	1·38	1·36	1·31	1·35	1·32	1·26	1·33	1·29	1·21
500	1·40	1·38	1·34	1·39	1·37	1·32	1·36	1·33	1·28	1·34	1·30	1·22

NOTE 1 — *See* **5.3.2.2** for definitions of Class A, Class B and Class C structures.

NOTE 2 — Intermediate values may be obtained by linear interpolation, if desired. It is permissible to assume constant wind speed between 2 heights for simplicity.

3.1.6. Topography Factor (IS 875.Part3-1987):

It depends on the topography i.e., hill region, cliffs and ridges.

If the upward slope 0 ≤ 30, value of k3 shall be taken 1.0.

For 0 > 3, value of k3 lies between 1.0 to 1.36.

3.1.8. Design Wind Pressure (Pz):

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$P_z = 0.6 \times V_Z^2$$

Were,

P_z = Design wind pressure in N/m2 at height z and

V_z = Design wind speed velocity in m/s at height z.

3.2. Analysis on E-TAB:

First of all, shape of analysing structure is finalized to compare in different condition such as providing column without bracing, diagonal bracing with and without column.

The models are prepared in E-TABs with an equal interval as shown in diagram

Load applied such as self-weight of a structure gravitational load, seismic load as per zone 4 and the properties beam, column, slab and bracing applied in the model.

3.3. The properties of model are as follows:

All Model: Geometry- size Length –4mx5m=20m, width: 5m x6=30m, Floor to Floor height: 3.65m, total height:11x3.65m= 40.15m (total stories:11)

Member properties- column = 900mm x 900mm, beam = 500mmX 600mm, slab thickness: 150mm, bracing ISMB: 450mm

Earthquake Analysis-Zone: 4

Important factor = 1.5

type of soil: II (medium)

time period =Tdx= 0.010, Tdz: 1.0122

Wind Analysis- zone (terrain Category): 4

Wind speed- 42m/sec

Material Data-grade of concrete: M30, steel: Fy 500, steel bracing - Fy 250.

IV. MODELLING AND ANALYSIS

4.1. Description of structure:

4.1.1Geometrical Data:

Models that have been prepared for present investigational study along with other parameters for G+10 building for all is represented in the Table No. 1.

Sr.no	Shape	Length in x axis	Length in y axis	Type of structure
1	I	20	30	ONLY WITH COLUMN
2	I	20	30	X BRACING
3	I	20	30	DIAGONAL BRACING

4.1.2. Typical Plans of Floor with side view

Structure with only Column

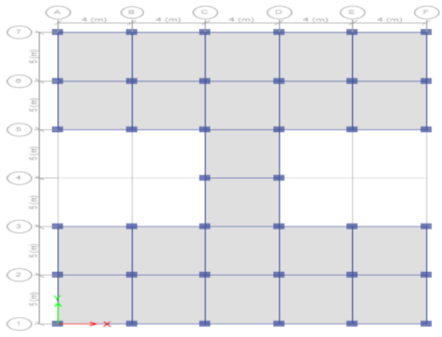


Fig no. 1

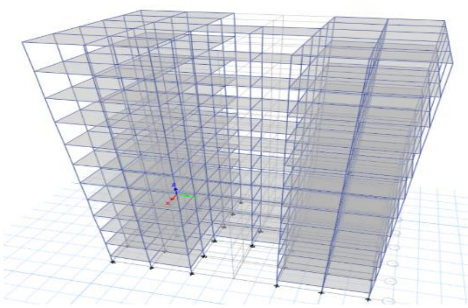


Fig no. 2

Structure with X bracing

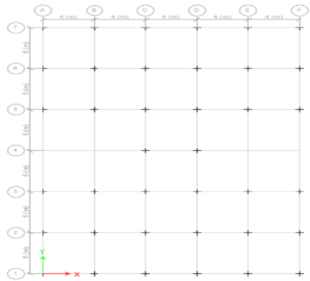


Fig no. 3

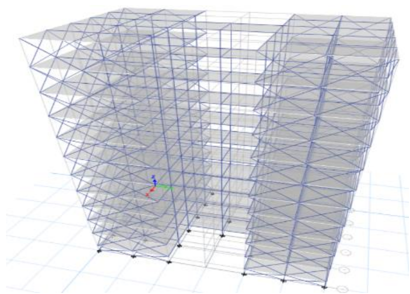


Fig no. 4

Structure with diagonal bracing

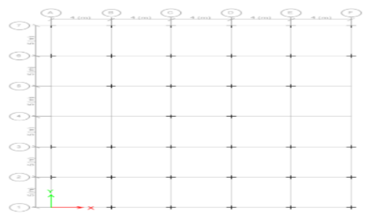


Fig no. 5

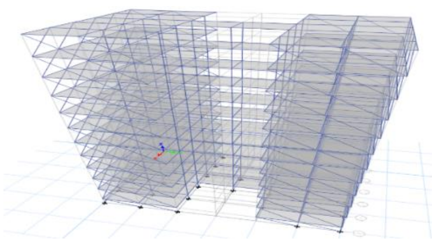


Fig no. 6

4.2. RESULT
4.2.1. MAXIMUM BASE REACTIONS IN ALL STRUCTURE.

Type of Structure	In Wind load (KN)	In Wind load (KN)
	In X-Direction	In Y-direction
Column only	1918.14	1446.43
X Bracing	1918.14	1446.43
Diagonal bracing	1918.14	1446.43

Table no. 2

4.2.2. STORY DISPLACEMENT

4.2.2.1. STORY DISPLACEMENT OF STRUCTURE WITH COLUMN IN WIND LOAD

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	41.65	Top	8.471	8.914

Table no. 3

4.2.2.2. STORY DISPLACEMENT OF STRUCTURE WITH X BRACING IN WIND LOAD

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	41.65	Top	10.83	13.783

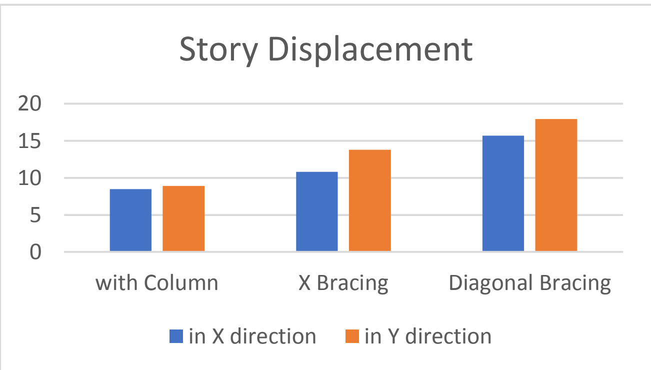
Table no. 4

4.2.2.3. STORY DISPLACEMENT OF STRUCTURE WITH DIAGONAL BRACING IN WIND LOAD

Table no .5

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	41.65	Top	15.687	17.912

4.3. GRAPHICAL CHART
4.3.1. STORY DISPLACMENT GRAPHICLA COMPERISION IN WIND LOAD



All units in mm.

V. CONCLUSION:

1) With the help of I-shape structure we analysed the structure and compared with providing column, x-bracing and diagonal bracing.

2)The base shear in All structure is same in x direction and in y direction with respect to wind.

5)The story displacement Of x-bracing increased by 28.66% in x direction and increased by 54.62% in y direction compared to column structure.

6)The story dispacement of diagonal bracing increased by 85.18% in x direction and 100.94% in y direction compared to column structure.

7)The story drift of all structure pass the criteria of story drift as mention in IS-Code.

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