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COMPARATIVE STUDY OF DIAGRID STRUCTURAL SYSTEM WITH VARYING STOREY HEIGHTS

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ABSTRACT
A natural hazard like Earthquake causes damage or collapse of a building if not designed for lateral loads resulting due to Earthquake and wind forces. Hence for Seismic and Wind resistance for high rise structures it is important to provide exclusive Lateral Load Resisting System (LLRS) which will supplement the behavior of moment resisting frames in resisting the lateral load. A well-designed system of Shear walls in a building frame improves its seismic performance significantly. Steel bracings are also one of the successful lateral load resisting system. The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance.A building square in plan 42m x 42m having 60 stories with varying story heights as 3m, 3.3m & 3.6m with Diagrid system as Lateral load resisting system is considered in the present study. The modelling is done to examine the effect of different cases along with different story heights on seismic parameters like Base shear, lateral displacements and lateral drifts. The design of all the members for the steel building is done as per IS 800:2007.

1. INTRODUCTION

1.1 GENERAL

Advances in construction technology, materials, structural systems and analytical methods for analysis and design facilitated the growth of high rise buildings. The rapid growth of urban population and consequent pressure on limited space have considerably influenced the residential development of the cities. The high cost of land, the desire to avoid a continuous urban sprawl, and the need to preserve important agricultural production have all contributed to drive residential buildings upward. Major advancements in structural engineering paved the way for development of different structural systems for high rise buildings. As the height of the building increases, the lateral load resisting system (LLRS) becomes more important than the structural system that resists the gravity loads.The lateral load resisting system that are widely used are the following: rigid frames, shear wall, wall frame, braced tube system, outrigger system and tubular system. The dual structural system consisting of special moment resisting frame (SMRF) and concrete Shear wall has better seismic performance due to improved lateral stiffness and lateral strength. Steel bracings are also one of the successful lateral load resisting system. Recently in some high-rise structures, apart from the standard bracing systems,some high-rises have been constructed with triangulated exterior structural members. This system is known as the “Diagrid system”.

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The Diagrid works as an effective lateral load resisting system.

1.2 DIAGRID STRUCTURAL SYSTEM:

The term "Diagrid" is a blending of the words "diagonal" & "grid" and refers to a structural system that is single-thickness in nature and gains its structural integrity through the use of triangulation. Diagrids has good appearance and it is easilyrecognized. The diagonal members in diagrid structural systems can carry gravity as well as lateral loads due to their triangulated configuration. Diagrids are more effective in minimizing shear deformation because they carry lateral shear by axial action of diagonal members. The difference between conventional exterior braced frame structure and current diagrid structures is that, for diagrid structures, almost all the conventional vertical columns are eliminated. The structural efficiency of diagrid system also helps in avoiding interior and corner columns, therefore allowing significant flexibility with the floor plan. In short, the diagrid configuration allows for no exterior vertical element and promises good structural efficiency & strength.Due to its structural elements that are mostly located at the exterior of the building, a diagrid system resembles a tube system. The lateral stiffness of diagrid structures is desirable not only for linear static loads but also for dynamic loads which are generated due to Wind and seismic actionwhich generate responses in both the wind-ward and across wind directions. The structures have to be checked for seismic & wind loads in order to determine which method dominates the lateral load resistance. Some of the Diagrid structures are shown in Figures 1.1 to 1.4:

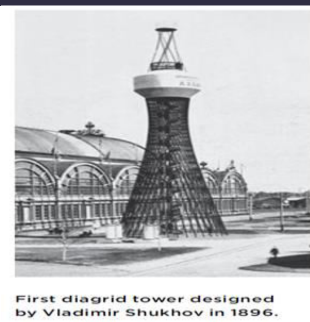

Fig 1.1 SHUKHOV Tower


Fig 1.2: HEARST Tower (New york,U.S.A)


Fig 1.3: SWISS RE LONDON (United Kingdom)


Fig 1.4: Aldar Headquarters (Abu Dhabi)

2. LITERATURE REVIEW

Khushbu Jani, Paresh V.Patel (Elsevier, 2013): A 36-story building was considered for analysis of the Diagrid system when subjected to seismic, dynamic along wind and across wind loads.Alongside, analysis and design of 50, 60, 70& 80 story diagrids is carried out from the study it was found 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.

Jatin B.Tank, Ashwin G.Hansora (IJSRD, 2016): A regular floor plan of 40m x 40m was considered for 80-story diagrid structure. Equivalent static method and dynamic wind load analysis was conducted to study the lateral load resistance of the diagrid system. It was found that as the diagrid angle become steeper towards the corner, its lateral stiffness increases and corresponding lateral displacement decreases.

Femy Thomas, Binu M.Issac (Intl conf. on S & T, 2015):In this paper the concept of steel

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diagrid structural system is studied by conducting Linear static method of seismic analysis for various plan configurations and for varied diagrid angles. After the analysis results the optimum diagrid was found to be 67.38°.Square and circular diagrid buildings perform almost equally better than rectangular diagrid buildings. Circular diagrids perform better than all the considered configurations.

3.METHODOLOGY

3.1 METHODS FOR DETERMINATION OF DESIGNLATERAL LOADS

Earthquake and its occurrence, measurements and its vibrations effect and structural response have been studied for past many years. Since then structural engineers have tried procedures with an aim to counter the complex dynamic effect of seismically induced forces in structures, for designing of earthquake resistant structures in a refined and easy manner. Various approaches to seismic analysis have been developed to determine the lateral forces. However according to IS 1893(Part 1):2002 following methods have been recommended to determine design lateralloads,

1. Equivalent Lateral ForceMethod
2. Response SpectrumMethod
3. Time HistoryMethod

The Response spectrum Method is carried out in our present study and the Equivalent Lateral Force is used for adjusting the scale factor.

3.2 Wind Load Analysis

Concept of Wind Load Analysis:

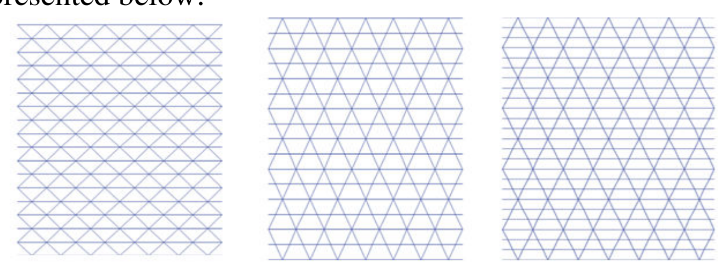
Buildings are subject to horizontal loads due to wind pressure acting on the buildings. Wind load is calculated as per IS 875(Part III)-1987. The horizontal wind pressures act on vertical external walls and exposed area of the buildings. Some of the pressure acting on exposed surfaces of structural walls 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 terrace transfers the wind loads to the surface slab by cantilever action. For simplicity, the wind loads acting on exposed surfaces of a given story are idealized to be supported by upper and lower floors.Wind forces acting on a given surface is equal to the wind pressures multiplied by the affected area.

4. RESULTS AND DISCUSSIONS

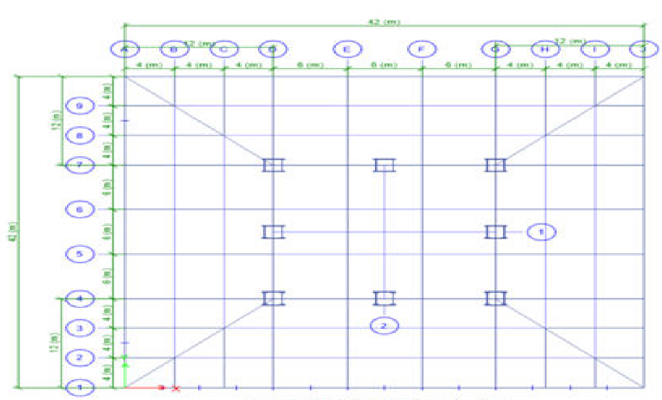
Different models that are considered for analysis are given below:

2-story module with 3m story height
2-story module with 3.3m story height
2-story module with 3.6m story height
4-storey module with 3m story height
4-story module with 3.3m story height
4-story module with 3.6m story height
6-story module with 3m story height
6-story module with 3.3m story height
6-story module with 3.6m story height

The Diagrid modules and plan dimensions are presented below:



2-Story Diagrid module **4-Story Diagrid module** **6-Story Diagrid module**



STRUCTURAL PLAN

LOADINGDATA:

DEAD LOAD DATA:ETABS itself takes the self-weight of slabs, beams and columns.

IMPOSED LOADS DATA:

The imposed loads are taken from Table-1 of IS 875 (part-1,2) 1987 as below

Floor finishes + additional Dead load = 3.25 kN/m^2

Live load = $3kN/m^2$

Considering the total structure is cladding with glass around the building. Since the glass load is very less it is neglected.

Grade of steel = Fe250 & Fe345.

SEISMIC PARAMETERS:

The following seismic parameters are considered as per IS 1893 (part-1) 2002 of analysis of all the structures:

Zone factor (Z) (Seismic zone 5 – Table-2 Cl.6.4.2) = 0.36

Importance Factor (I) (Table-6 Cl.6.4.2) = 1.0

Response Reduction Factor (R) (Table-7 Cl.6.4.2) = 5.0

Structural Soil (SS) (Fig.2 Type-1 Rock or Hard soil) = 1.0

Damping Ratio (D_{mp}) = 0.02(2%)

Discussions on Story Displacements

Table: Final values of maximum story displacements

MAX. STORY DISPLACEMENTS								
2 STORY 3m	4 STORY 3m	6 STORY 3m	2 STORY 3.3m	2 STORY 3.6m	4 STORY 3.3m	4 STORY 3.6m	6 STORY 3.3m	6 STORY 3.6m
150.781	93.669	101.866	195.825	251.288	131.76	181.035	146.954	205.984
			max = 251.288		min = 93.669			

The maximum story displacements of all the models after the analysis are presented in the table and their respective graphs are shown. The top story displacements for 2-story, 4-story & 6-story modules are found to be 150.781, 93.67 & 101.866 respectively which are less than the Permissible limits i.e. H/500 = 360mm (where H = Total height of the building=180m, 196m, 216m; least was considered).When the height of the buildings is varied to 3.3m & 3.6m it is found that thetop story displacements further increase.The Maximum and Minimum top story displacements for 180m tall buildings are found to be 150.781mm and 93.67mm for 2-story & 4-story modules where the percentage decrease is 37.876%. In case of 196m tall buildings the maximum and minimum displacements are 195.825mm and 131.76mm where the percentage decrease is 32.71%. Lastly in the case of 216m tall buildings the maximum and minimum displacements are 251.288mm and 181.035mm where the percentage decrease is 27.97%. The top story displacement for 4-story 3m module building is reduced by 62.74% when compared to the 2-storey 3.6m module building.The displacements for both 3.3m & 3.6m story height buildings got increased when compared to the 3m buildings.

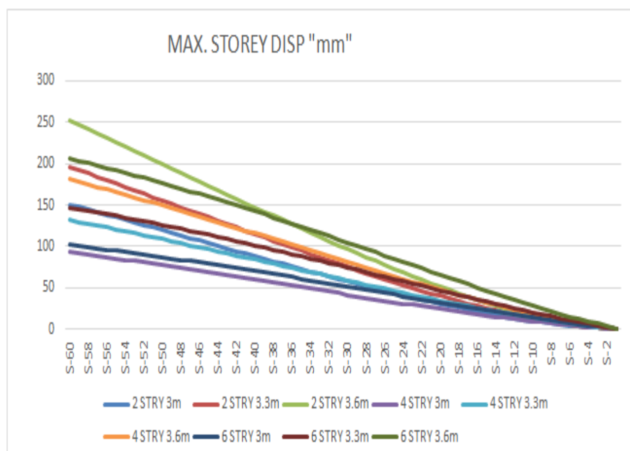


Fig: Comparison between Max. Story Displacements

Discussions on Story Drifts

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		MAX. STORY DRIFTS						
2 STOREY 3m	4 STORE Y 3m	6 STOREY 3m	2 STOREY 3.3m	2 STOREY 3.6m	4 STORE Y 3.3m	4 STOREY 3.6m	6 STOREY 3.3m	6 STOREY 3.6m
0.0010 48	0.000 602	0.00065 2	0.00123 7	0.00145 5	0.0007 7	0.00096 9	0.00085 5	0.001098
			max = 0.001455		min = 0.000602			

Table: Final values of Maximum Story Drifts

The maximum story drifts of all the models after the analysis are presented in the above table and their respective graphsare shown from Figure. The maximum story drifts for 2,4,6-story module buildings are found to be 1.48mm, 0.602mm & 0.652mm respectivelywhich are less than the permissible limits i.e. 0.004 x story height (3m, 3.3m & 3.6m) = 12mm, 13.2mm & 14.4mm. (cl.7.11.1, IS 1893:2002).When the height of the buildings is varied to 3.3m & 3.6m, it is observed that the story drifts further increase.The maximum and minimum story drifts for 180mtall buildings are found to be 1.048mm & 0.602mm with maximum drift occurring at story no.46. In case of 196m tallbuildings the maximum and minimum story drifts are 1.23mm and 0.77mm with maximum drift occurring at story no.46. Lastly in case of 216m tall buildings the maximum and minimum drifts are 1.45mm and 0.96mm with maximum drift occurring at story no.46. The maximum story drift for 4-story 3m module building is reduced by 41.374% when compared to 2-story 3.6m module building.The story drifts for both 3.3m & 3.6m story heights got increased when compared to the 3m story height.The drifts for 2,4, & 6-storey modules are found to be maximum for story no: 46,37 &25 respectively.

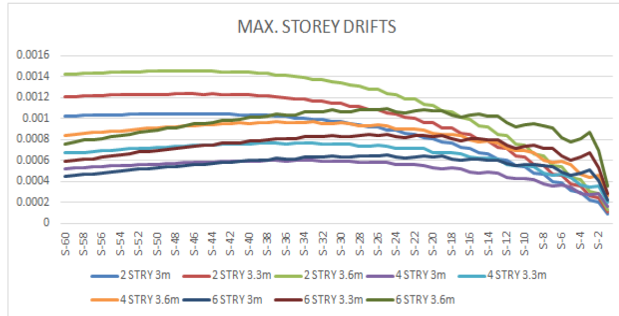

Fig: Comparison between Max. Story Drifts

Discussions on Story Shears:

		MAX. STORY SHEAR "KN"						
2 STORY 3m	4 STORY 3m	6 STORY 3m	2 STORY 3.3m	2 STORY 3.6m	4 STORY 3.3m	4 STORY 3.6m	6 STORY 3.3m	6 STORY 3.6m
21692.34 85	21690.5 985	21690. 6057	24200.4 981	26742.94 75	24200.4 981	26742.94 73	24200.50 86	26742.9 62
			Max = 26742.962		Min = 21690.5985			

Table: Final values of maximum story shears

The maximum story shears of all the models after the analysis are presented from the above table and their respective graphis shown. The maximum Base shears for 2,4,6-story module buildings are found to be 21692.348, 21690.598 & 21690.605KN respectively.After the comparison of Base shears for all the models it is observed the buildings with similar story heights displayed equal base shears.The buildings with 3.3m & 3.6m as story heights have greater base shears than the 3m story height. The maximum and minimum story shearsare found to be 26742.962kN & 21690.598kN for 6-story 3.6m module & 4-story 3m module buildings respectively. The maximum base shear of 6-story 3.6m module is 23.29% (i.e. 123.29% of minimum base shear) more than the minimum base shear model.For all the models the wind load base shear is critical over seismic base shear.After summing up the lateral load on all

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elements of a building it is found that the Diagrid structure is predominant in lateral load resistance and the magnitude of its resistance ranges from 82-87% of the total lateral load resistance. The gravity load is resisted by both the internal columns and peripheral diagonal columns.

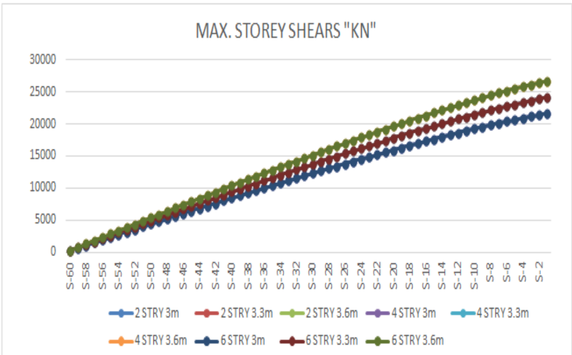

Fig:Comparison between Max. Story Shears

5.CONCLUSIONS

1) From the analysis results of Lateral loads, it was concluded that the Wind load is critical over seismic load.

2) The maximum base shear of wind loads was found to be 26742.962kN while forResponse spectrum it was found to be 13160.52kN which implies that the base shear of wind load exceeds the seismic load by approximately 2 times.

3) The Maximum top story displacementsare found to be 150.7mm, 93.6mm and 101.8mm for180m tall building in which the 4-story module represents the most optimum. In the case of 196m tall buildings, the top story displacements are found to be195.8mm, 131.7mm and 146.9mmfor which the 4-story module represents the most optimum.Similarly, in the case of 216m tall buildings, the top story displacement is found to be 251.2mm, 181mm and 205.984mm for which the 4-story module represents the most optimum.

4) From all the cases considered for Diagrids structures, the 4-story module building was found to be the most optimum.(w.r.t displacements, drifts and shears)

5) 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. The diagrids of all the models account for approx. 82-87% of total lateral load resistance.

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