DIA-GRID STRUCUTURES

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Abstract – *One of the evocative structural design solutions for tall buildings is recently embraced by the diagrid (diagonal grid) structural system. In tall buildings, the main problem that governs the design is lateral loads, instead of the gravitational loads in shorter building. Thus, systems that are more efficient in achieving stiffness against lateral loads are considered better options in designing tall buildings. The diagrid system is one of the most efficient lateral resisting systems, and this feature is caused by its triangular configurations. The diagrid structural system has been widely used for recent tall buildings due to the structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. This paper presents a stiffness-based design methodology for determining preliminary member sizes of R.C.C. diagrid structures for a G+36 story building. The methodology is applied to the diagrid to determine the optimal grid configuration of the diagrid structure and further its comparison with conventional R.C.C structure.*

A regular floor plan of 36 m × 36 m size is considered for the structures. ETABS 9.7.4 software is used for modelling, analysis and design of structural members. All structural members are designed as per IS 456:2000 and load combinations of seismic forces are considered as per IS 1893(Part1):2002 considering all load combinations. Dynamic load along wind and across wind are considered for analysis for the structure as per IS 875-1987 (part 3). Analysis of G+36 story building with perimeter diagrid is carried out by Response spectrum method. The comparison of analysis of results in terms of top story displacement, story drift, story shear, time period, steel and concrete consumption, base reactions for seismic and wind forces is done.

Key Words: Simple structure, Diagrid structure, ETABS analysis.

1. INTRODUCTION

The rapid growth of urban population and consequent pressure on limited space have considerably influenced the residential development of city. 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. As the height of building increase, the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are: rigid frame, shear wall, wall-frame, braced tube system, outrigger system and tubular system. Recently, the diagrid – Diagonal Grid – structural system is widely used for tall steel buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system.

Diagrid has good appearance and it is easily recognized. The configuration and efficiency of a diagrid system reduce the number of structural element 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, therefore allowing significant flexibility with the floor plan. Perimeter "diagrid" system saves approximately 20 percent of the structural steel weight when compared to a conventional moment-frame structure.

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. Hence, the diagrid, for structural effectiveness and aesthetics has generated renewed interest from architectural and structural designers of tall buildings.

2. METHODOLOGY

A diagrid structure is modelled as a vertical cantilever beam on the ground, and subdivided longitudinally into modules according to the repetitive diagrid pattern. Each module is defined by a single level of diagrids that extend over multiple stories. The stiffness based design methodology is used for determining preliminary member sizes of RCC diagrid structures for tall buildings. The methodology is applied to G+36 story structure to determine the optimal grid configuration. A regular floor plan of 36 × 36 m size is considered for the structures. ETABS 9.7.4 software is used for modelling, analysis and design of structural members. All structural members are designed as per IS 456:2000 and load combinations of seismic forces are considered as per IS 1893(Part1):2002 considering all load combinations. Dynamic along wind and across wind are considered for analysis of the structure as per IS 875-1987 (part 3). Analysis of 36 story building with perimeter diagrid with different story module is carried out by Response spectrum method. The comparison of results of analysis in terms of top story displacement, story drift, story shear, time period, angle of diagrid, base shear and story shear for seismic and wind forces is done and these properties are compared with conventional structure to determine the effectiveness of diagrid structure.

2.1 Stiffness based design methodology:

This methodology is adopted here for determining the member sizes such that the storey drift and the top story displacement is within permissible limits.

Storey drift < h/250

Top storey displacement < H/500

Where, h = Inter storey height

H = Total height of building.

2.2 ETABS Modelling And Analysis

Basic Parameters Considered For Design			
Sr. No	Parameters	Simple Structure	Diagrid Structure
1.	Plan Area	36m X 36m	36mX 36m
2.	Storey Height	3.6m	3.6m
3.	Grade of Steel	Fe500	Fe500
4.	Grade of concrete	M40	M40

Sr. No	Parameters	Simple Structure	Diagrid Structure
5.	Wall Thickness	0.23m	0.23m
6.	Live Load	2.5KN/m²	2.5KN/m²
7.	Floor Finish Load	2.5KN/m²	2.5KN/m²
8.	Density Of Concrete	25KN/m³	25KN/m³
9.	Density Of Masonry Wall	20KN/m³	20KN/m³
10.	Parapet Height	1.2m	1.2m

Sectional Properties			
Sr. No	Members	Simple Structure (mm)	Diagrid Structure (mm)
1.	Slabs at each floor	150	150
2.	Beams at each floor	300 X 800	300 X 900
3.	Columns at each floor	600 X 600	1600 X 1600
4.	Diagrids	-	500 X 500

Earthquake Parameters		
Sr. .No	Parameters	Detail
1.	Seismic zone	II
2.	Soil type	II
3.	Response reduction factor	5
4.	Seismic zone factor	0.16
5.	Importance factor	1
6.	Time Period	Program Calculated

Wind Parameters		
Sr.No	Parameters	Details
1.	Wind speed	39 m/s
2.	Terrain category	2
3.	Structure class	B
4.	Risk co-efficient (kl)	1
5.	Topography factor (k3)	1

Load Combinations	
Sr. No	Name of Combinations
1.	1.5(DL + LL)
2.	1.5(DL +/- EQ)
3.	1.5(DL +/- WL)
4.	1.2(DL + LL +/- EQ)
5.	1.2(DL + LL +/- WL)
6.	0.9DL +/- 1.5EQ

Codes Used for Design		
Sr. No	Code Name	Code Number
1.	RCC Design Code	IS 456 - 2000
2.	Earthquake Resistant Design Of Structure	IS 1893 - 2002
3.	Wind Load	IS 875- 1987 (part III)

2.2.1 ETABS Modelling

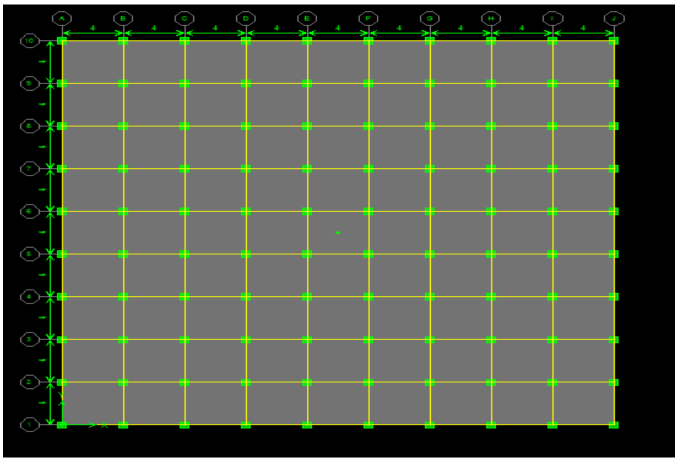

Fig -1: Plan of simple structure

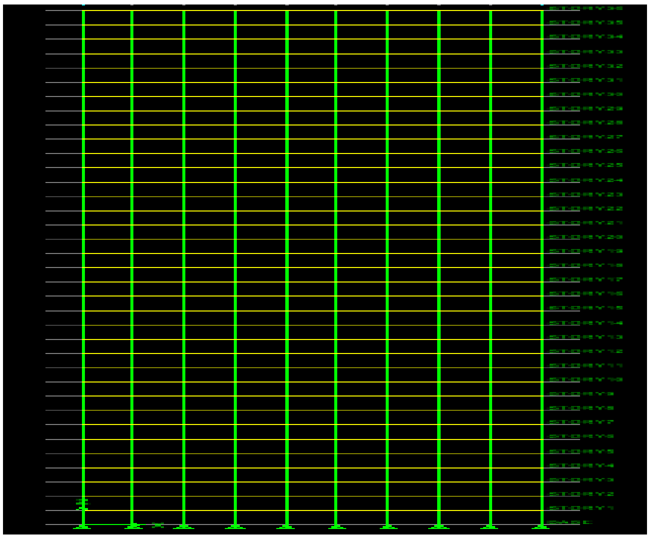

Fig -2: Elevation of simple structure

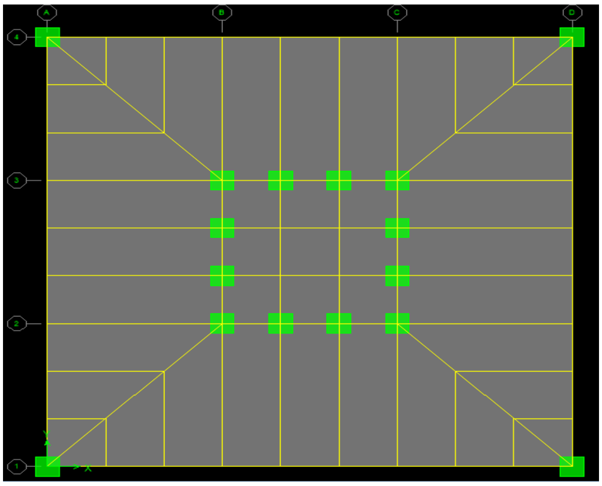

Fig -3: Plan of Diagrid structure

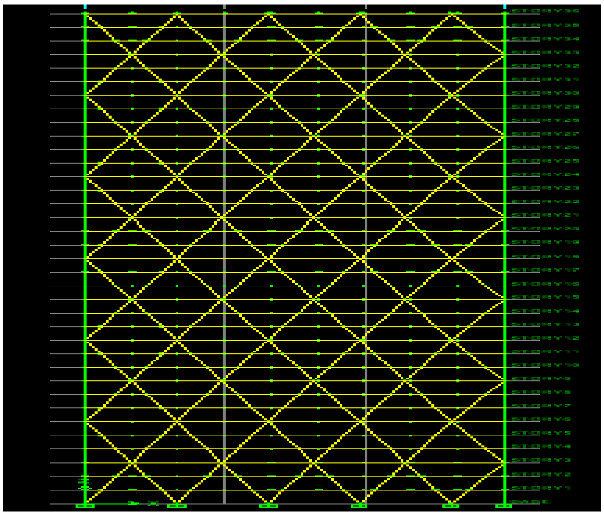

Fig -4: Elevation of Diagrid structure

3. RESULTS

3.1 DISPLACEMENTS OF STOREYS

a. DLLLEQX COMBO FOR BOTH STRUCTURES

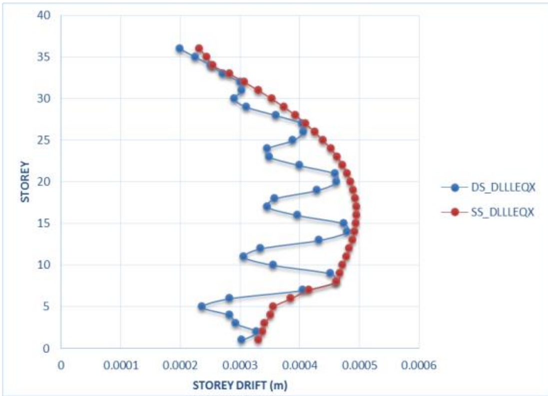

Fig -5: Storey Vs storey displacement drift

b. DLLLWLX COMBO FOR BOTH STRUCTURES

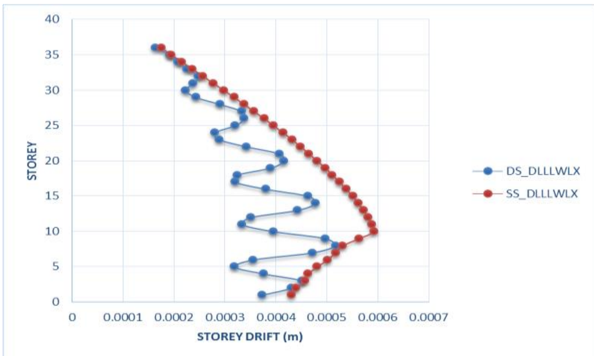

Fig -6: Storey Vs storey displacement drift

3.2 SHEAR FORCES OF STOREYS

a. DLLLEQX COMBO FOR BOTH STRUCTURES

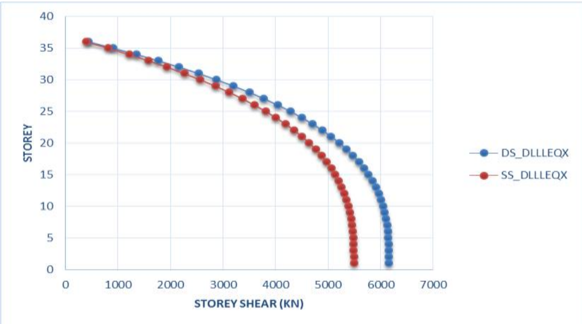

Fig -7: Storey Vs Storey shear

b. DLLLWLX COMBO FOR BOTH STRUCTURES

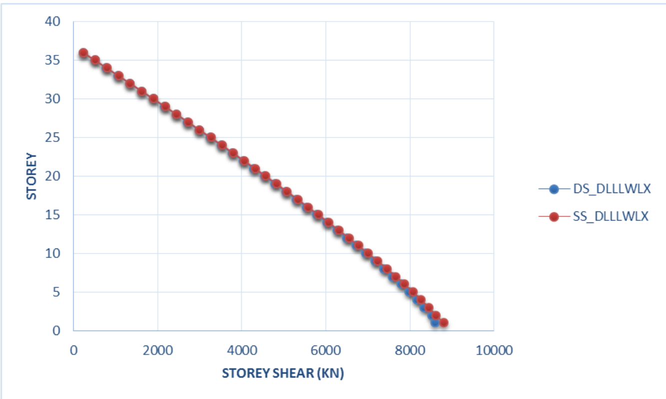

Fig -8: Storey Vs Storey shear

3.3 MODE AND TIME PERIOD

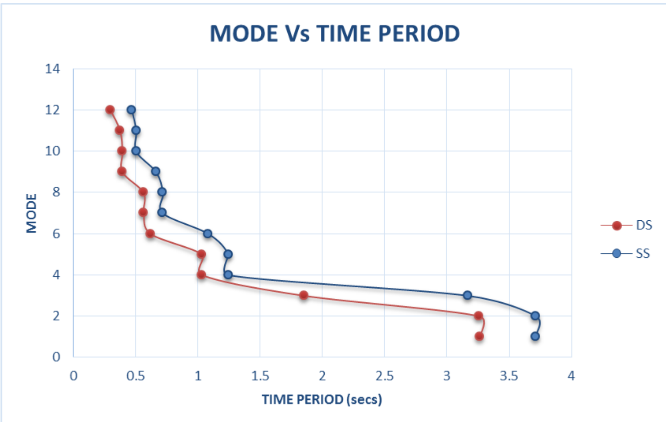

Fig -9: Mode Vs Time period for different modes

4. CONCLUSION

1. From the graphs of storey vs storey displacement we can conclude that for all the load combinations the top story displacement in case of diagrid structure is less than conventional structure. This is because the diagrid structures are stiffer and hence they displace less as compared to conventional ones.

2. For all the earthquake load combinations we can see from the graph plotted for storey vs storey shear that the storey shear in case of diagrid structure is more as compared to simple R.C.C. structure.

3. For all the load combinations we can see from the graph plotted for storey vs storey drift that the storey drift in case of diagrid structure is lesser as compared to simple R.C.C. structure.

4. From the graph of mode vs time period we can see that for all the 12 modes the time period of oscillation for diagrid structure is much less as compared conventional structure. This is because as the diagrid structure is stiffer than the conventional structure, its flexibility is less and hence it has lesser time period.

5.

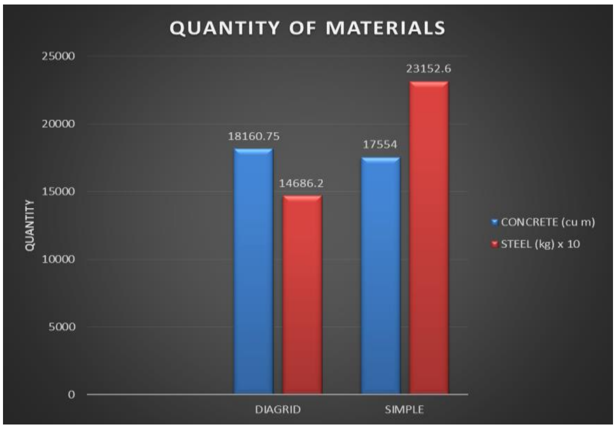

Fig -10 : Material consumption for both structures

6. From the above bar chart we can see that the quantity of steel required in case of diagrid structure is approximately 37 % less than conventional structure of same plan area whereas the concrete requirement is approximately 3.5 % more than conventional structure. Therefore overall diagrid structure is more economical than conventional structure.

7. From the bar chart of reactions for both structures we can see that for all the load

combinations the reaction coming on diagrid structure is less than conventional structure and hence the diagrid structure is much more stable than the conventional structure.

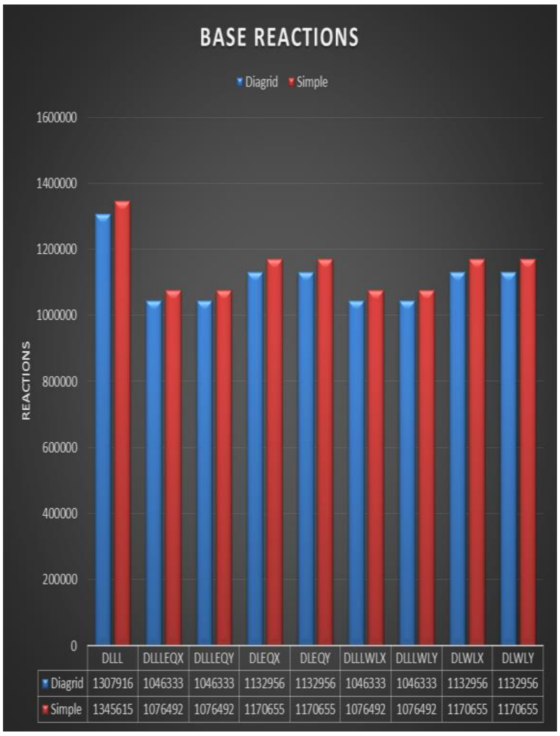

Fig -11 : Base reactions for both structures

8. Diagrid structural system provides more flexibility in planning interior space and façade of the building.

9. Generous amount of day lighting, natural air and improved cross air ventilation can be achieved due to minimum provision of interior columns in the plan of structure and thus the optimum usage of natural resources could be achieved.

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