Optimum design of concrete diagrid building and its comparison with conventional frame building

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Abstract – *Multistorey building requirements are increasing day by day.There are different new technology develops regarding construction technique,material,typeof system,analysis and design. Diagrid buildings are best in terms of structural stability and architectural looks. For diagrid building steel,concrete,timber is used. Mostly steel and concrete diagrid buildings are constructed.Structural design of multistorey buildings is analyzed and designed by lateral loads due to wind load and earthquake load. Lateral load resistance of the structure is important factor in tall building.It should be provided in building as external or internal system.In diagrid building inclined columns are provided at exterior of the building.Lateral load is resisted by this inclined members.*

In this paper, a twenty storey RCC building with plan size 15 m × 15 m located in seismic zone V is considered for analysis. ETABS software is used for modelling and analysis 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(Part 1): 2002. Comparison of analysis results in terms of diagrid angle, storey drift, node to node displacement, shear forces are presented. In diagrid structure, the major portion of lateral load is taken by external diagonal members which in turn release the lateral load in inner columns. It also concludes optimum diagrid angle for economical design.

***Keywords*-Diagrid building, Conventional building, Storey displacement, Storey drift, Diagrid angle**

I. INRODUCTION

The development of population and limited space for construction have effected the residential development of city. In tall structure lateral load resistance provision is important factor.Lateral load resistance in tall structure is provided by different structural system like shear wall,rigid frame,outrigger sysrtem,tubular system,wall frame.In recent year diagrid system is used in tall structure as exterior system.

Diagrid is formed by intersection of inclined column as diagonal and beams as horizontal components. There are some examples of diagrid structure are the Swiss Re in London, Hearst Tower in New York, Cyclone Tower in Asan (Korea), Capital Gate Tower in Abu Dhabi and Jinling Tower in China as shown in Fig 1. The new headquarter for Central China Television in Beijing is the examples of utilization of diagrid structural system to support the challenging shape.

Diagrid system reduces large number of structural elements at exterior of the building.It facilitate for less obstruction to the outside view. This type of structure also avoid corner column and interior columns as total lateral load is resisted by exterior inclined column there is no need to provide more interior column.It provides large interior space which is important in architectural manner.

The diagonal members in diagrid building forms triangulated pattern.This triangulated pattern can carry gravity loads as well as lateral loads.Diagrid structures reduces shear deformation because they carry lateral shear by axial action of diagonal members. Diagrid structures do not need high shear rigidity cores because lateral shear can be carried by the diagonal members located on the exterior of the structure.

In this paper, a comparative study of 20-storey simple frame building and with same configuration, a diagrid structural system building is presented here. A floor plan of 15m x 15m size is considered. ETABS 15 software is used for modelling and analysis of structural members. The analysis is carried out for 20-storey building with floor height 3m. Here, 4 models are made for different angle 45˚, 63˚, 71˚, 75˚ and 1 model is for conventional building where only vertical column are provided which is similar as angle 90˚. Comparison of analysis results in terms of different diagrid angle, top storey displacement, inter storey drift, shear force, axial load is presented here.

Fig. 1. Diagrid buildings (a) Swiss Re in London (b) Hearst Tower in New York (c) Cyclone Tower in Asan (Korea) (d) Capital Gate Tower in Abu Dhabi and (e) Jinling Tower in china.(ref-paresh.v.patel dec.2013)

II. METHODOLOGY

In this paper comparison of diagrid and conventional building under seismic load is observed. Here G+ 20 storey is taken and same live load,dead load and slab load is applied in both the buildings for its behavior and comparison.

The framed buildings are subjected to vibrations because of earthquake. Seismic analysis is essential for these building frames. The fixed base system is analyzed for both building frames in seismic zone V by using ETABS software. The results of both the building is studied.

III. BUILDING CONFIGURATION

The G+20-storey building is having 15m x 15m plan dimension and 63m total height of building. The storey height is 3m. The typical elevation shown in figure 2. There are two models for comparative study, one is for simple frame building and another is for diagrid structure. The building data is kept same for both models.

Size of inner beam is taken as 230 x 450 mm for both buildings. For conventional model size of outer beam is taken as 300x600 and for diagrid outer beam is taken as 230x500. The size of column in conventional frame building is taken as 450 x 450 mm for perimeter column and 750 x 750 mm for inner column. In case of diagrid 300 x 300 mm for outer diagrid pattern column and 700 x 700 mm for inner column.

Diagrid is taken for different angles. Four models are made for angle 45˚, 63˚, 71˚ and 75˚ and also one simple frame building having vertical columns. The design dead load and live load on terrace level are 5.6kN/m2 and 1.5kN/m2 respectively and for typical floor slab is 4.6kN/m2 and 2kN/m2. The design earthquake load is computed based on the zone factor 0.36, soil type II, Importance factor 1, Response Reduction 5 as per IS-1893-2002. The design wind load is taken as Wind speed 50 m/s, Terrain category 2, Structure class B, Risk Coefficient 1, and Topography factor 1. Modelling, analysis and design of diagrid structure are carried out using ETABS15 software. The end condition for diagrid is assumed as hinged. The support conditions are assumed as fixed. The design of member is carried out on the basis of IS-456-2000.

A. Steps for comparison

A comparison of results in terms of displacements, drift and optimum diagrid angle for different diagrid pattern has been made. Following steps are adopted in this study –

Step-1 Selection of building geometry and Seismic zone:The response of both the models is studied for Zone V of Seismic zones of India as per IS code 1893 (Part 1): 2002 for which zone factor (Z) is 0.36. G+20 storey building is taken. Each storey is of 3m height. Depth of foundation is taken as 1.5 m.

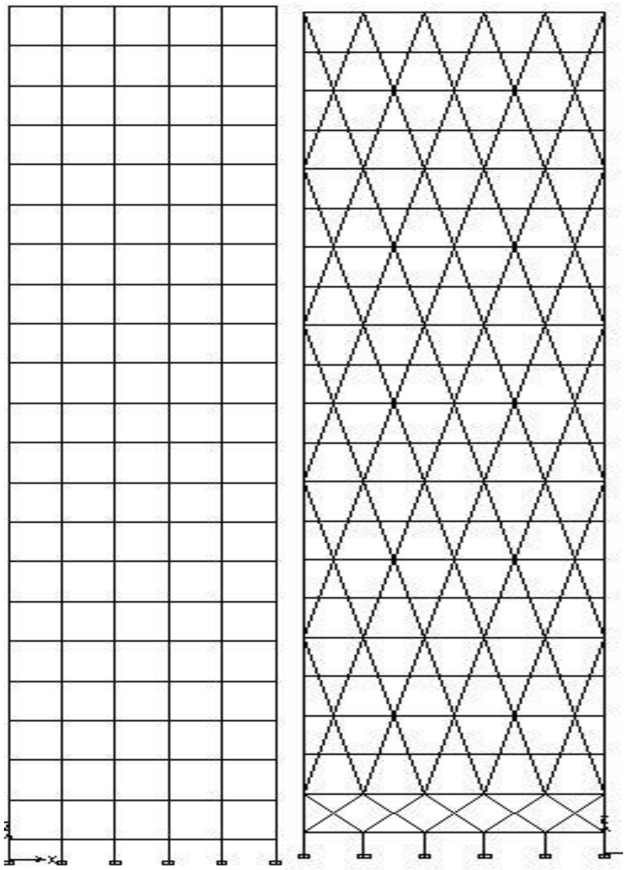
Step-2 Formation of load combination: Six primary load case and thirteen load combination is considered for analysis and design.

Step-3 Modelling of building frames using ETABS software.

Step-4 Analysis of both the building frames is done under seismic zone V ,load combinations and live load taken.

Step-5 Comparative study of results in terms of Storey displacement, shear force, drift and optimum angle.

B. Structural model



(i) (ii)

Fig- 2: (i) Elevation of simple frame structure, (ii) Elevation of diagrid structure

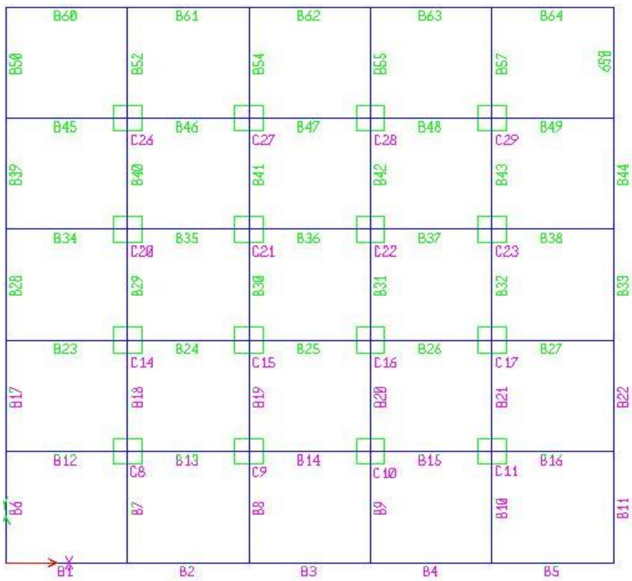


Fig- 3: Plan of building showing the selected beam and column numbering

IV. ANALYSIS RESULTS

Table-1: Comparison of Shear force in ground floor beams for both diagrid and conventional structure

	Shear force(KN) in structure	
Beam no.	**Conventional building**	**Diagrid building(angle 63°)**
B1	17.06	10.4
B2	21.56	17.32
B3	21.56	18.00
B4	21.56	18.11
B5	21.56	18.67
B6	17.06	15.54
B7	26.91	17.44
B8	32.71	24.25
B9	32.76	24.39
B10	32.11	23.97
B11	21.56	17.88
B12	21.63	22.04
B13	18.95	15.15
B14	16.99	14.91
B15	15.17	14.49
B16	11.39	13.95
B17	17.06	16.45
B18	14.48	18.95
B19	14.81	18.99
B20	14.81	18.99
B21	14.35	19.99
B22	17.06	16.65

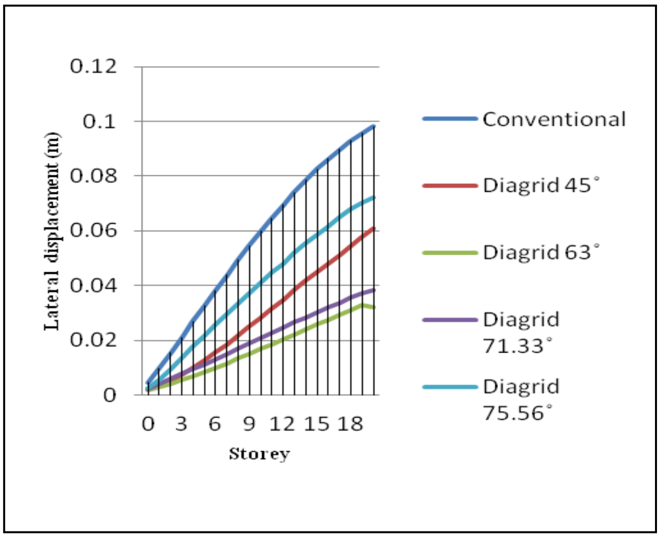


Fig-4: Lateral displacement at each floor with respect to ground

Table-2: Comparison of Axial force in column C8 for both diagrid and conventional structure

Storey	Axial force(KN) for column C8	
	Conventional building	Diagrid building(angle63°)
20	29.65	30.60
19	63.28	38.69
18	97.39	76.15
17	132.65	86.37
16	168.90	124.26
15	206.02	136.49
14	243.83	175.36
13	282.09	188.97
12	320.59	228.17
11	359.05	242.65
10	397.20	281.30
9	434.74	296.19
8	471.37	333.54
7	506.73	348.51
6	540.49	383.11
5	571.95	397.87
4	598.44	436.52
3	632.09	457.07
2	661.72	487.68
1	686.52	505.12
Gr.	705.46	534.90

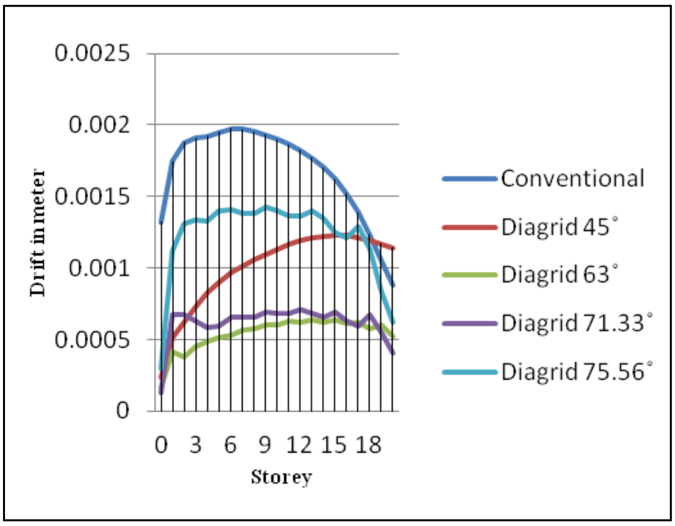


Fig- 5: Maximum drift of floor w.r.t. adjacent floor

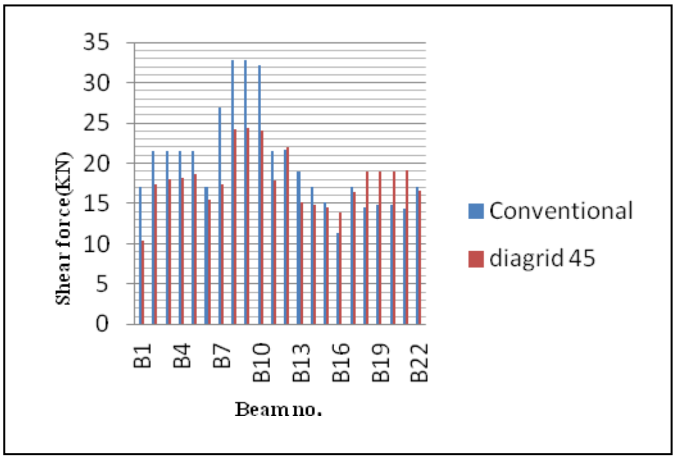


Fig-6: Comparison of shear force in ground floor beams

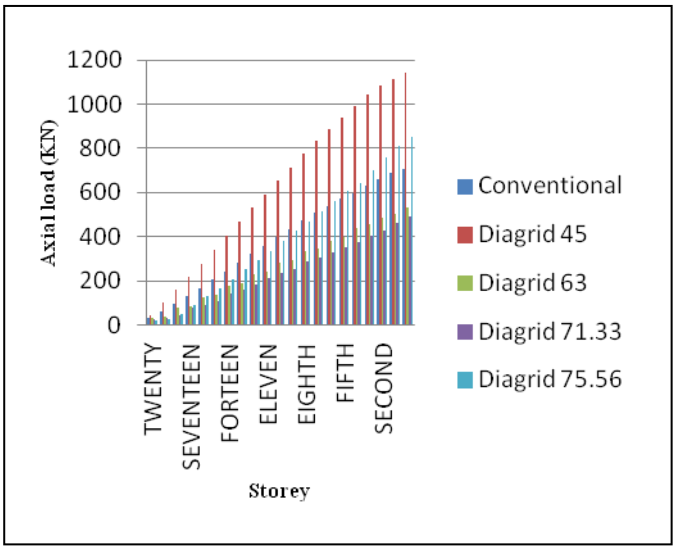


Fig- 7: Comparison of axial force in column C8 for both buildings

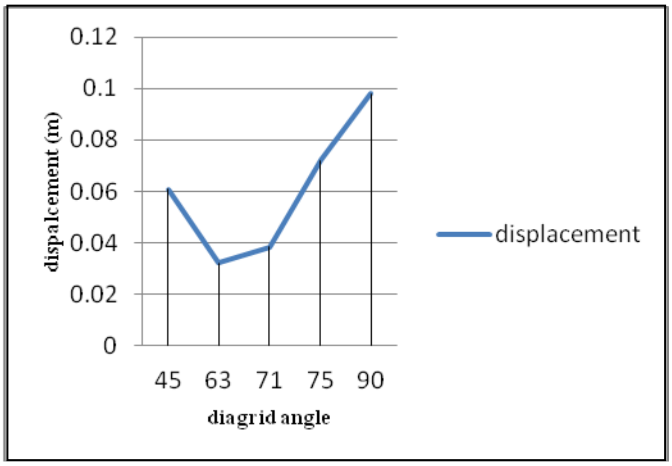


Fig- 8: Comparison of displacement for different diagrid angle at 20th floor

The analysis results in terms of Displacement, Interstorey Drift, Shear force in beams, axial force in columns for different diagrid angles like 45˚, 63˚, 71˚, 75˚ are presented in this section. The shear force in beam for different floors are compared between conventional and diagrid building. From shear force diagram, in figure6 the corner beams in case of diagrid is having slightly higher value as compared to conventional building. But for interior beams, the value in diagrid is less as compared to conventional building.

Interior Column Analysis: The analysis of the interior column is carried out at each floor in terms of axial force, bending moment in y and z direction. The plan of the selected location for analysis is shown in fig.3. The behavior of the rest of interior column is shown by symmetry. The selected location of the column to be analyzed.
From graph in fig.7 it is cleared that axial force is increases from conventional to angle 45˚but after increasing diagrid angle axial force decreases as compared to conventional. This depends on number of floors. . This is due to internal column in diagrid structure carry only gravity load and seismic force is resist by external diagonal column while in conventional both internal and external column resist gravity and seismic load.

Lateral displacement means the total displacement of the floor with respect to ground.

Lateral displacement is decreases in diagrid structure for different angle. It is cleared from graph shown in figure4, that displacement in conventional is maximum as compared to diagrid structure. It is caused due to lateral forces (wind or seismic) acting on building.

Drift means the relative displacement of floor with respect to lower one. It is shown in figure5. From all these graphs it is cleared that optimum results are occurred at 63˚ angle .And hence we can take diagrid angle between 60˚ to 70˚ for getting optimum results.

In fig.8 it shows graph of displacement for different diagrid angle 45˚,63˚, 71˚, 75˚ at 20th floor. In this graph displacement is maximum at 90˚angle, at 45˚ it decreases. As we increased angle after 45˚ to 63˚ again it is reduced. After 63˚ if we increased angle near 71˚ it starts increasing .So we can conclude here that we get optimum results at angle 63˚ for G+20 storey structure. This angle may change for different number of storey. But it varies between 60˚ to 70˚.

CONCLUSION

In this paper, comparative analysis and design of 20-storey diagrid structural system building and simple frame building is done here. A regular floor plan of 15m x 15m size is considered. Different models for different diagrid angle (45, 63, 71, 75 and conventional) are made. ETABS 15 software is used for modelling and analysis of structure. Analysis results like displacement, storey drift, shear force, axial force are presented here.

- Diagrid building results less lateral displacement and drift in comparison to conventional building.
- Axial load on internal column is less in diagrid building as compared to conventional building.
- Shear force of interior beam is less in diagrid as compared to conventional building.
- For 20 storey diagrid structure, the optimal range of diagrid angle is from about 60º to 70º.
- diagrid buildings are more aesthetic in look and it is important for high rise building.
- Diagrid structural system provides more flexibility in planning interior space and facade of the building.
- Torsional rigidity in diagrid structure is less compared to conventional.Torsional factor should be studied carefully in diagrid.
- Diagrid structures are economical as compared to conventional,as less members required at interior and exterior of the structure.

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