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Comparative Seismic Analysis of Diagrid Structure of Varying Diagonal Angles with X Braced Frame Structure and Conventional RC Structure Using ETABs Software

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***Abstract* - Diagrid structural system have emerged as one of the most innovative and adaptable approaches to structuring buildings in this millennium. Variations of the diagrid system have evolved to the point of making its use non-exclusive to the tall building. Diagrid construction is also to be found in a range of innovative mid-rise steel projects. The structural and architectural design of diagrid buildings falls cleanly between the typical education or experience of the architect and engineer. In this present study, G +23 the building with different frame of structures such as Diagrid frame with different diagonal angles, X braced frame with different position and Conventional RC frame is compared and analysed against the seismic lateral load in seismic zone v using ETABs software. The results are tabulated and graphs are plotted for base shear, storey drift and maximum lateral storey displacement, weight of structure. The seismic analysis is done according to IS 1893:2016 part 1 by using dynamic analysis method.**

Keywords: Diagrid, geometry, twisted, stability, periphery, module, braced.

I. INTRODUCTION

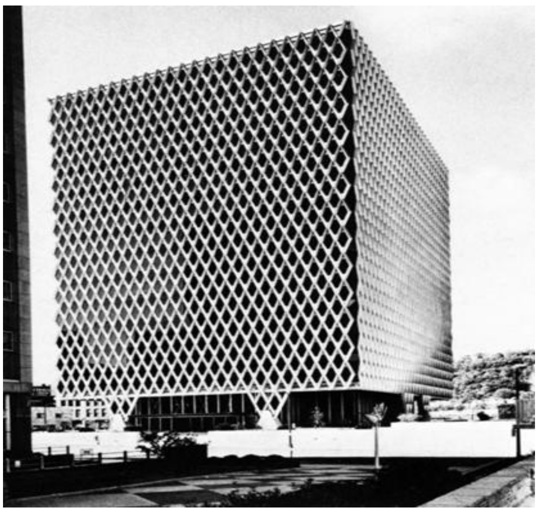
As in the modern world we are seeing giant structures which will mesmerize anybody, high rise buildings are also one of them. Around the world we can see a rapid growth of multistory buildings construction in its full swing. In diagrid structure system diagonal member are used to connect the beam and diaphragm and lateral loads and gravity loads are transferred by these members. Diagrid system has become very popular in the complex structures such as curved shape. With the use of diagrid conventional vertical column are not in use and diagonal elements use is rapidly increasing. However different parameters involved in diagrid system needs to figure out to give the structure better optimization, such as optimal angle of diagonal member. A diagrid system in any high rise building can be analysed for many things such as for different angle of diagonal elements or a comparative study between conventional frame structure buildings by moment resisting frame building, shear wall position in building at different places to study the structure.

II. METHODOLOGY

Diagrid is a particular form of space truss. It consists of perimeter grid made up of a series of triangulated truss system. Diagrid is formed by intersecting the diagonal and horizontal components. Diagrid is a particular form of space truss. It consists of perimeter grid made up of a series of triangulated truss system. Diagrid is formed by intersecting the diagonal and horizontal components. 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.

1. IBM Building, Pittsburgh

The first diagrid supported building stands along the development timeline, the IBM building, now called the United Steel workers Building, and was completed in 1963 in Pittsburgh.



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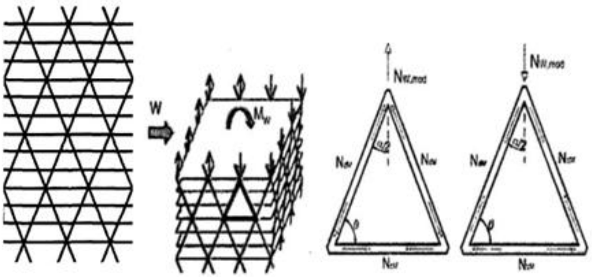
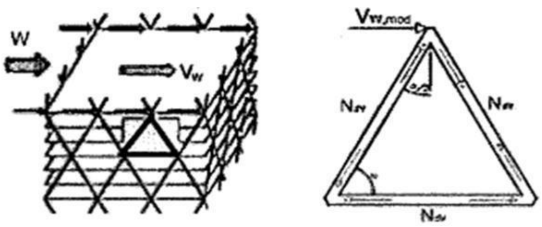
2. Hearst Tower, New York

This building is 46 Storey towers of total 597 ft height. This Hearst is one of the most environmentally friendly high rises building ever constructed. This adoption of diagrid structure causes it advantage of 20% less steel than conventional moment frame structure.80% of building steel contains recycled material.

Structural action of Diagrid model



Under horizontal load W, the overturning moment MW causes vertical forces in the apex joint of The Diagrid modules, NW mod, with direction and intensity of this force depending on the position of the Diagrid module, with upward / downward direction and maximum intensity in modules located on the Windward / leeward façades, respectively, and gradually decreasing values in modules located on the Web sides.



Seismic Coefficient Method

The method is based of static approach normally referred to as pseudo static appro1achemploying use of seismic coefficients. The assumption involved in the methods is Major contribution made to base shear is by fundamental mode of the building. The total building mass is considered as against the model mass used in dynamic analysis. In this method the total design lateral force or seismic is determined by equation Seismic base

From IS 1893-2016, clause no.7.5.3 the design of base shear

$$Vb = Ah\ W$$

Where, Vb = Seismic weight of building, Ah = horizontal seismic coefficient

$$Ah = \frac{z}{2}\ X\ \frac{I}{R}\ X\ \frac{Sa}{g}$$

Z= Zone Factor
I= Important Factor
R =Response Reduction Factor
Sa/g = Average acceleration response coefficient for approximate, natural period of vibration Ta, to be determined as detailed.
W =Seismic weight of Building, the lateral distribution of the base shear to different floor levels along the height of the building is given by

$$Qi = Vb\ X\ WiHi \,/ \sum_{j=1}^{n} (\mathrm{WiHj}^2)$$

Where,

Qi = Design lateral force at floor I,
Wi = Seismic weight of floor I,
Hi = height of floor measured from the base,
N = Number of levels at which masses are located

Dynamic Analysis Method

Dynamic analysis is carried out by the Time history method or Response spectrum Method. Response spectrum of any earthquake ground motion is a plot of peak (or maximum) values of response quantities (viz, displacement, velocity and acceleration) as a function of the natural vibration period or frequency and damping ratio of single degree of freedom system (SDOF). The maximum stiffness force to which to the structure is subjected during ground motion depends on maximum displacement response. The maximum displacement is called as spectral displacement Sd of the structure corresponds to a condition of zero kinetic energy and maximum strain energy.

The maximum strain energy given to SDOF system can written as,

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Maximum Strain energy = Emax = ½ kSd2

The maximum velocity response is approximated by multiplying the spectral displacement

Sd by circular frequency w

The maximum kinetic energy is given by:

$$E_{max} = ½ m (w Sd)^2 = ½ m Spv$$

$$E_{max} = ½ k Sd^2 = ½ m (w Sd)^2 = ½ m S^2pv$$

These models compared and analysed in terms of maximum lateral displacement, Storey drift, Storey shear by response spectrum method in seismic zone V using the same data plan. The plan selected is square in shape. It is not a plan of any existing or proposed building. Analysis and design are carried out using ETABS Software 2019.Concrete of M35 and Steel of Fe 345 is considered.

Table 1: Geometric parameters of the adopted structural plan

S. No.	Specification	Data/Values
1	Number of Storey	G+23
2	Plan Size	24 m X 24 m
3	Storey Height	3m
4	Number of Bays along X axis	6
5	Number of Bays along Y axis	6
6	Length of each Bay	3m
7	Slab Thickness	0.150m
8	Column Size	0.8m X 0.8m
9	Beam Size for (Conventional & X braced system) Beam size for (Diagrid)	0.23 m X 0.5 m ISMB 500
10	Diagrid (Hollow steel pipe)	450 mm Dia.&20 mm Thick
11	Ring Beam	W 10 x 100
12	Bracing	ISA 200 x 200 x 20

Table 2: Loading parameters

Sr No.	Specification	Data/Values	Reference
1	Floor live load	4 KN/m2	As per IS 875(Part 2):1987
2	Roof live load	2 KN/m2	
3	Floor Finish Load	1 KN/m2	As per IS 875 (Part 1):1987
4	Internal wall load	7.04 KN/m	
4	Seismic Zone Factor	0.36 (Zone V)	As per IS 1893(Part 1):2016
5	Soil Type Factor	II (Medium Soil)	
6	Response Reduction Factor	5 (S.M.R.F.)	
7	Importance Factor	1 (Ordinary Building)	
8	Dead Load	Calculated by ETABS itself	As per IS 875(Part1):2016

Table 3: Load Combination as per IS 456:2000

Load Case No.	Load Case Details
1	1.5(DL+FF)
2	1.5(DL+LL+FF)
3	1.5(DL+FF+EQX)
4	1.5(DL+FF-EQX)
5	1.5(DL+FF+EQY)
6	1.5(DL+FF-EQY)
7	0.9DL+0.9FF+1.5EQX
8	0.9DL+0.9FF-1.5EQX
9	0.9DL+0.9FF+1.5EQY
10	0.9DL+0.9FF-1.5EQY
11	1.2(DL+LL+FF+EQX)
12	1.2(DL+LL+FF-EQX)
12	1.2(DL+LL+FF+EQY)
14	1.2(DL+LL+FF-EQY)

III. OBSERVATION AND CONCLUSION

1. Storey Drift

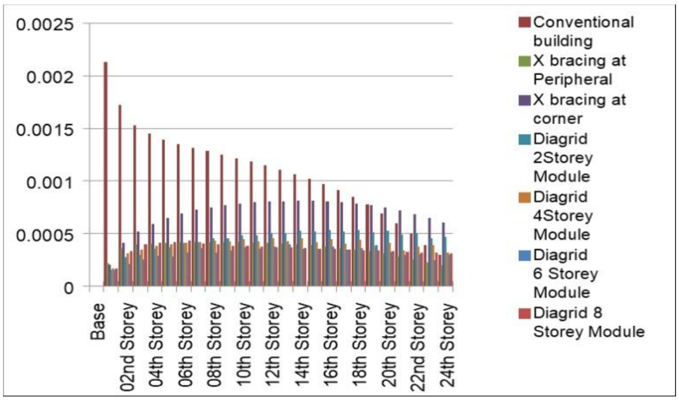

Table 4: Comparative analysis of storey drift

Frame	**Maximum Storey Drift** (unitless)	**% decrease in drift** (As per Conventional frame)
Conventional	0.00213	
X type bracing at periphery	0.000418	80%
X type bracing at corner end	0.000809	62 %
Diagrid (2 storey module) (45 degrees)	0.000534	74%
Diagrid 4 storey module (63.43 degrees)	0.000453	79%
Diagrid 6 storey module (71.56 degrees)	0.000396	81 %

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Diagrid 8 storey module (76.54 degrees)	0.000430	80 %

Storey drift means lateral displacement of floor relative to the floor below and Storey drift ratio is the storey drift divided by the storey height. So here we can see that Storey drift gets reduced as shear wall gets closer to the core. Maximum Storey Drift allowed is 2.5 % of Storey height. So all models have safe Storey drift.

1. Storey Displacement (In mm)

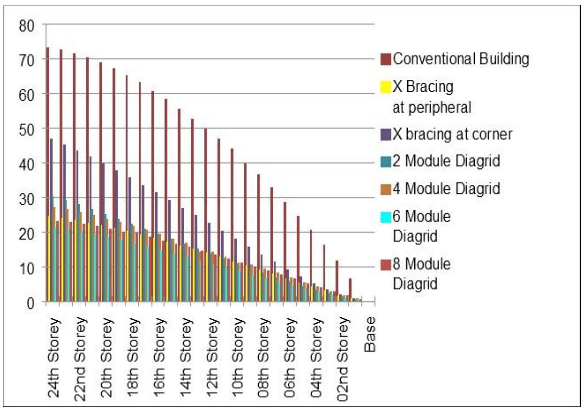

Figure: Storey Displacement Vs Storey

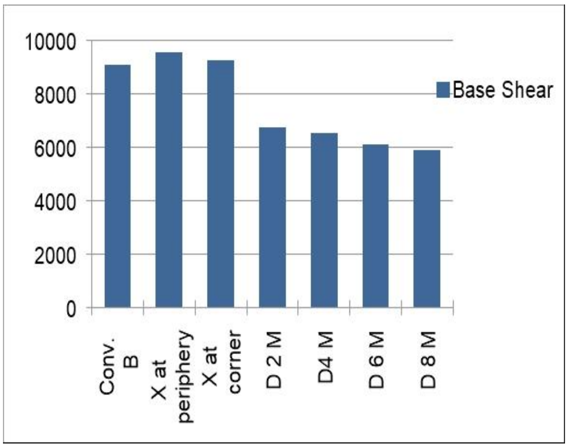

Figure: Base shear Vs All frames

Based on the above analytical study carried out on 7 Structural models, it is evident that buildings with Diagrids and X type bracing resist more effectively than Conventional frame building when subjected to lateral seismic loads. Positioning of X type bracing and angle of Diagrid gives different result are as:

- Diagrid Structure performs optimum against lateral force at an angle 71.56 degrees.
- With the increase in the angle of diagonal, Diagrid structure becomes lighter and Stiffer.
- In some cases, X type bracing at periphery outperforms Diagrid structures but providing bracing over the entire face in elevation is practically not desirable for economic and aesthetic reasons.
- X type bracing at the corner end has Shear stress less than the X type at periphery but still more Shear stress than the conventional building.
- Diagrid structure gives around 60 % reduction in weight of building as compared to conventional Building.

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