Comparative Analysis Of Diagrid Building With Conventional Building Against Seismic Activity By E-TABS Software

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ABSTRACT

The Diagrid are perimeter structural configurations characterized by a narrow grid of diagonal members which are involved both in gravity and in lateral load resistance. Now a days a renewed interest in and a widespread application of Diagrid is registered with reference to large span and high rise buildings, particularly when they are characterizedby complex geometries and curved shapes, sometimes by completely free forms.

Diagonal members in Diagrid structures act both as inclined columns and as bracing elements, and carry gravity loads as well as lateral forces, Due to their triangulated configuration, mainly internal axial forces arise in the members, thus minimizing shear racking effects.

The static and dynamic analysis is done with the help of computer software E- TAB Nonlinear 9.7.2 for two different models.

Model1. - Simple frame *Model2. - Diagrid Frame*

Result of this analysis indicated, Model-1 has very large displacement thanModel-2. Model 2 is More Stiff than Model 1.The story drift are checked according to ***clause no. 7.11.1 IS 1893(Part-I):2002,Page No.27*** *in table no. 4.5, and it is found that drifts for Model 2 are more safe.*

Keyword: - *Behavior Analysis, Comparative Analysis, Conventional Building, Diagrid building, Seimic resistence*

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1. INTRODUCTION

Amongst the natural hazards, earthquakes and wind force have the Potential for causing the greatest damage, since Earthquake and wind forces are random in nature and unpredictable. The engineering tools need to be sharpened for analyzing the structures under the action of these forces. Earthquake loads as well as wind forces are to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be controlled. This Study focuses on analysis of multistory RC Framed building subjecting them, to monotonically increasing lateral forces with an invariant height wise distribution, until the preset performance level (target Displacement) is reached.

The scope of present study aims at evaluation of Diagrid Building using response spectrum analysis and designing the elements of the frame the performance based seismic engineering technique known as static Analysis procedure has been effectively used to re-analyze the Diagrid Building. The Static and response spectrum analysis is carried out using E-TAB Software, a product of Computers and Structures International. For present analysis two types of models, are discussed and comparison of seismic performance is carried out. The result of the analysis is compared in terms of Story drift, story displacement, story shear, as per IS 1893 (Part1) 2002, clause no 7.11.1.

The Diagrid systems are the evolution of braced tube structures, since the perimeter configuration still holds for preserving the maximum bending resistance and rigidity, while, with respect to the braced tube, the mega-diagonal members are diffusely spread over the façade, giving rise to closely spaced diagonal elements and allowing for the complete elimination of the conventional vertical columns. Therefore the diagonal members in Diagrid structures act both as inclined columns and as bracing elements, and carry gravity loads as well as lateral forces; due to their triangulated configuration, mainly internal axial forces arise in the members, thus minimizing shear racking effects.

Diagrid structure is modeled as a beam, and subdivided longitudinally into modules according to this repetitive diagonal pattern. Each Diagrid module is defined by a single level of diagonals that extend over 'n' stories.

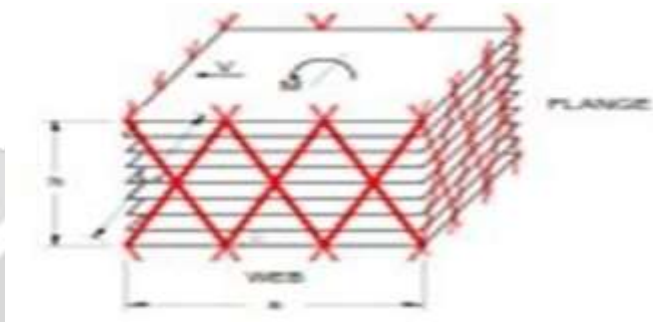


Fig -1 Typical Story Diagrid

1.1) Structural Action Of A Diagrid Module:

1.1.1) Effect Of Gravity Loading:

The Diagrid module under gravity loads G is subjected to a downward vertical force, NG,mod, causes the two diagonals being both in compression and the horizontal chord in tension.

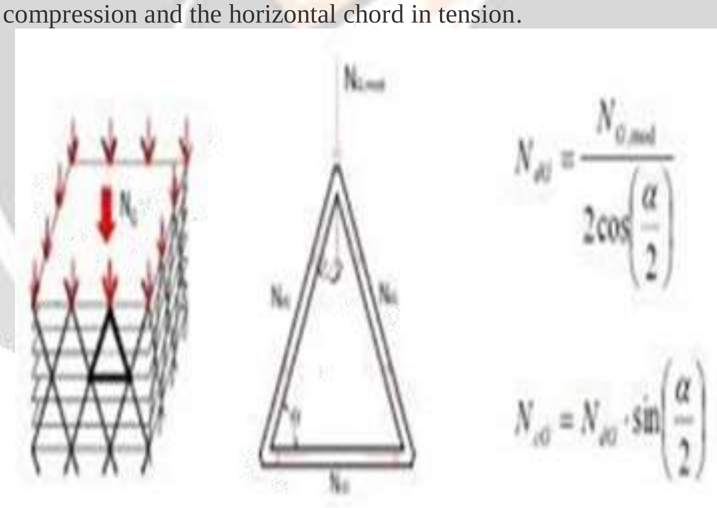


Fig -2 Effect of Gravity Loading

1.1.2) Loading Effect Of Lateral:

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.

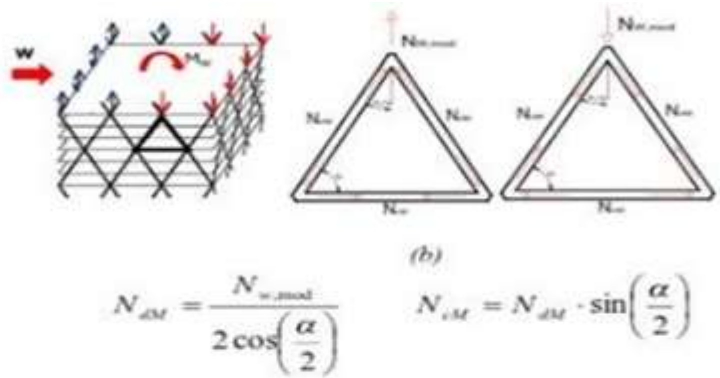


Fig -3 Effect of Lateral Loading

1.1.3) Effect Of Shear Loading:
The global shear VW causes a horizontal force in the apex joint of the Diagrid modules, Vw,mod, which intensity depends on the position of the module with respect to the direction of wind load, i.e. the shear force VW is mainly absorbed by the modules located on the web façades, i.e. parallel to the load direction.

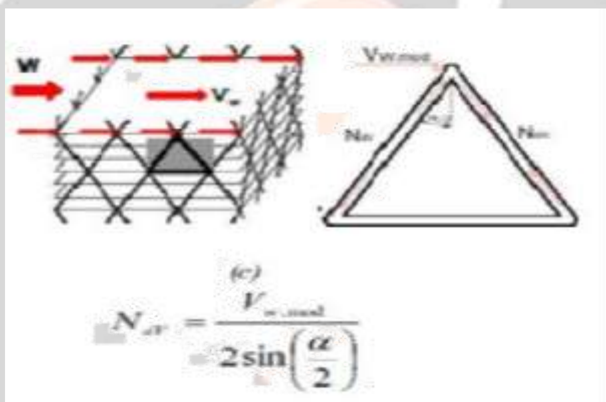


Fig -4 Effect of Shear Loading

2) METHOD OF ANALYSIS
The method of analysis is broadly categorized into Static method known as Seismiccoefficient Method and Dynamic method.

2.1) Seismic Coefficient Method:

The method is based of static approach normally referred to as pseudo static appro1ach employing 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

VB = Ah x W

Where Ah = Design horizontal spectrum value using fundamental natural period in the considered direction of vibration.

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

Z= Zone Factor
I= Important Factor
R =Response Reduction Factor
Sa/g = Average acceleration response coefficient for approximate, naturalperiod 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 theheight of the building is given by:

$$\mathrm{Qi} = VBX\frac{Wihi^2}{\sum_{j=1}^{n} Wihj^2}$$

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

2.2) 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 energyand maximum strain energy.

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

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 :

Emax = ½ m (w Sd)2 = ½ m Spv

Emax = ½ k Sd2 = ½ m (w sd)2 = ½ m S2pv

3) STRUCTURAL MODELING

Earthquake and wind analysis is an art to simulate, the behavior of a structure subjected to an earthquake ground motion, based on a mathematical model of the structure. The correct analysis will depend upon the proper modeling of the behavior of materials, elements and connections of structure. Therefore, it is important to select an appropriate and simple model to match the purpose of the analysis. Because of the difficulties in modeling, verification and numerical calculation, mostly one dimensional or two dimensional models are commonly used. However, for the proposed work, three-dimensional model is selected. A three dimensional model has independent displacements at each node and can simulate any type ofbehavior. Three-dimensional model of a frame considered for analysis.

3.1) Models Considered For Analysis

Non-linear static and Response spec analysis is performed with the help of computer software E-TAB Non-linear version 9.7.2. The Residential G+20 building is considered for analysis. The building is model in following two different categories which are as follows.

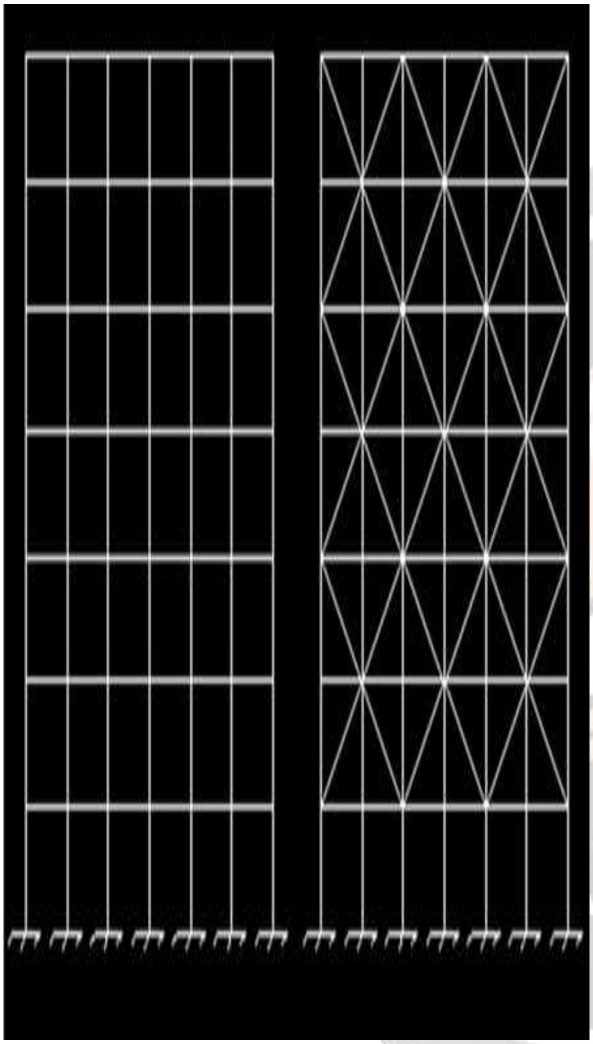


Fig -3.1(a) Typical Layout (MODEL 1 and 2)

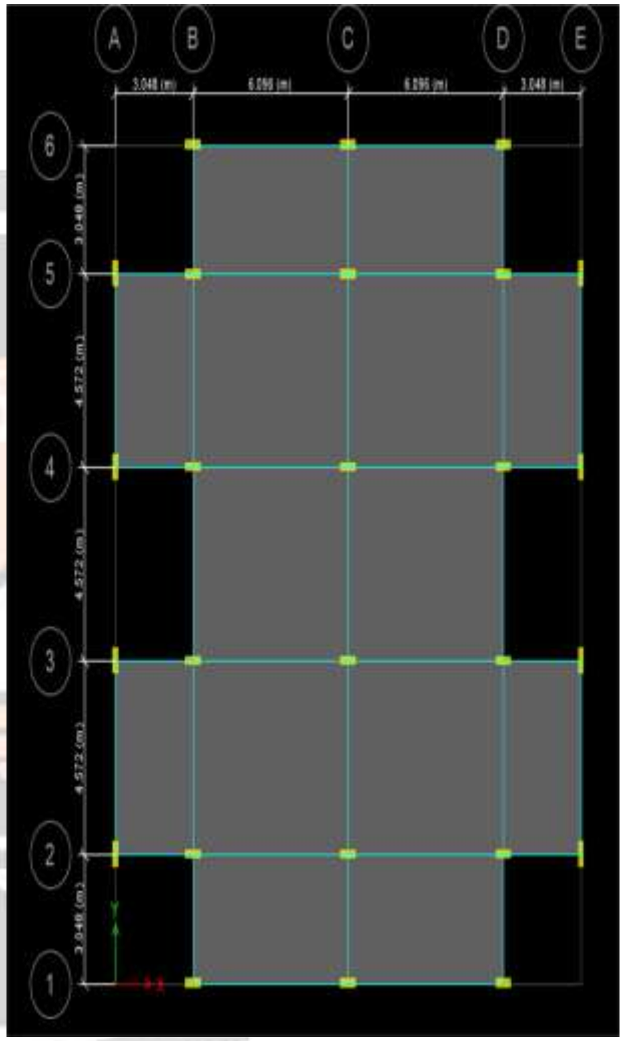


Fig -3.1(b) Plan Of Frame

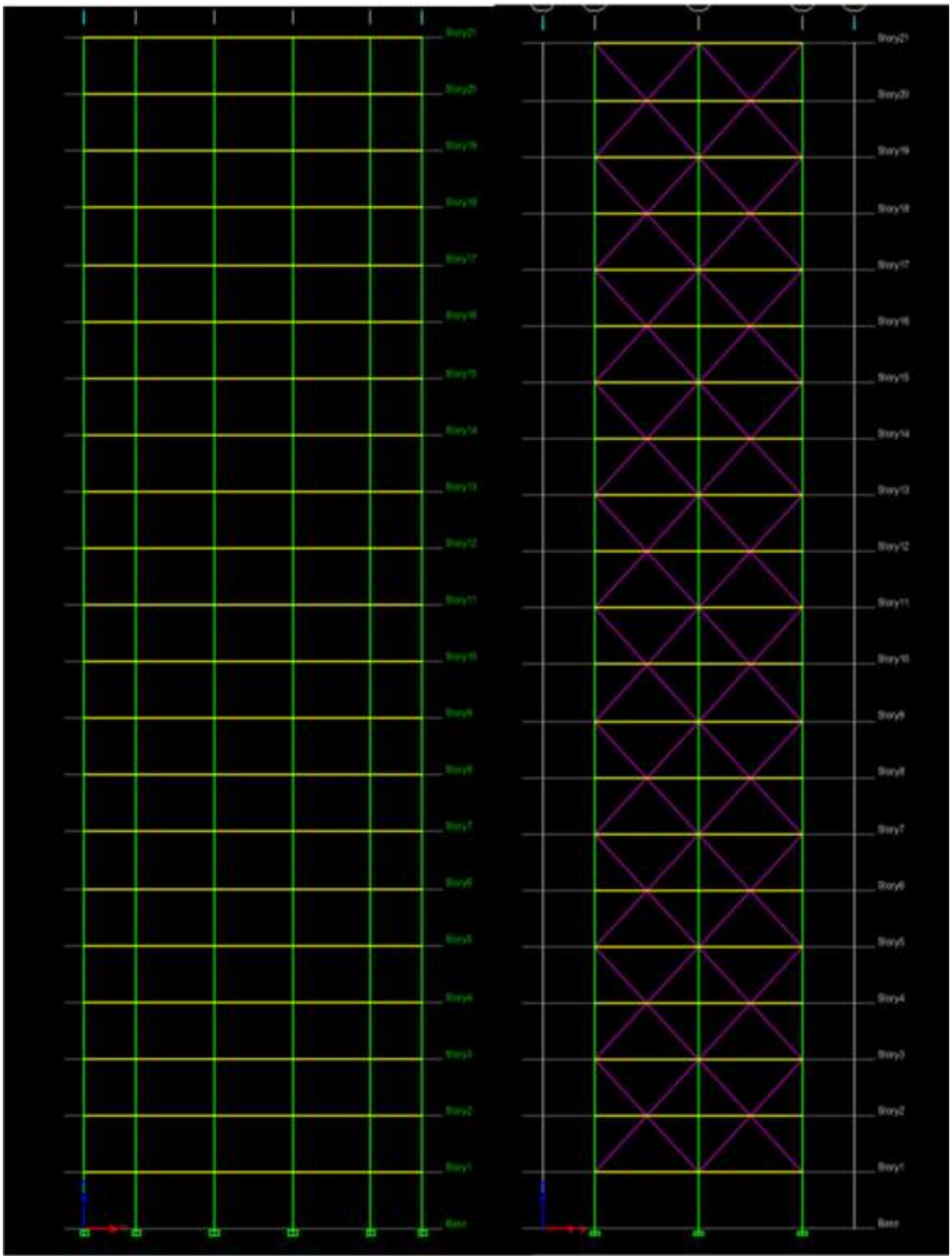


Fig -3.1(c) Elevation Of Frames

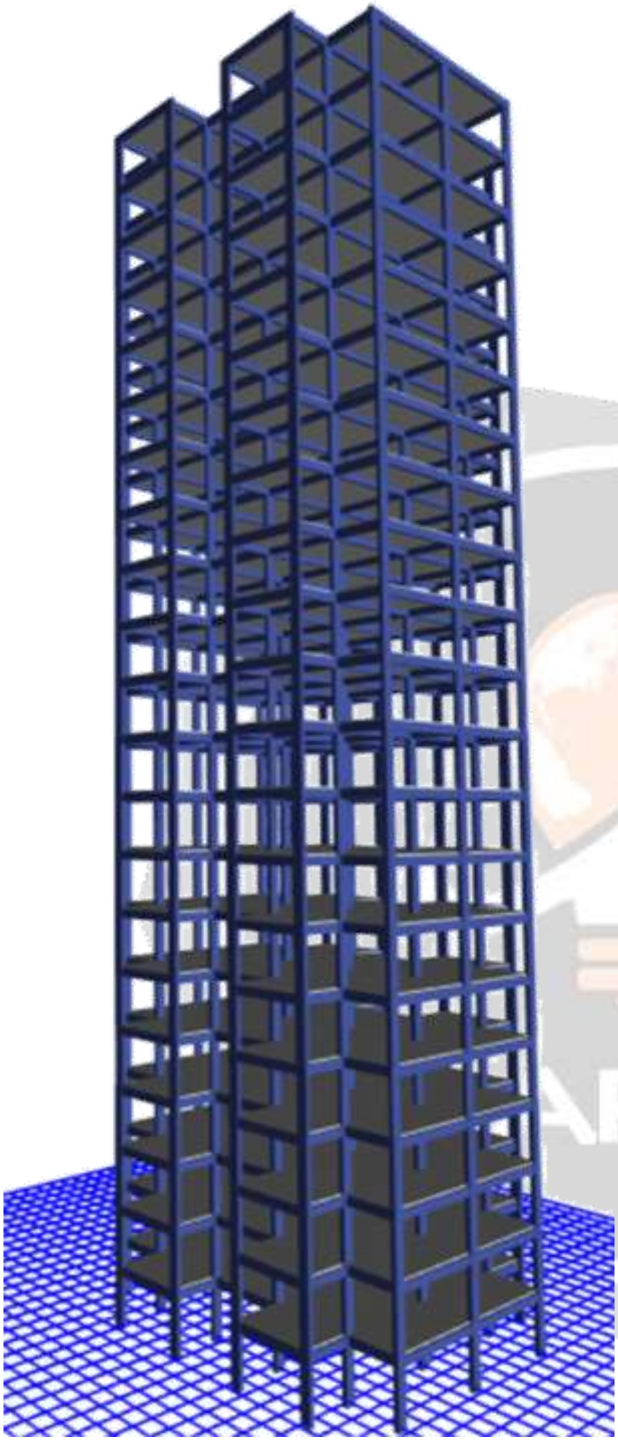


Fig -3.1(d) 3D View Of Conventional Building

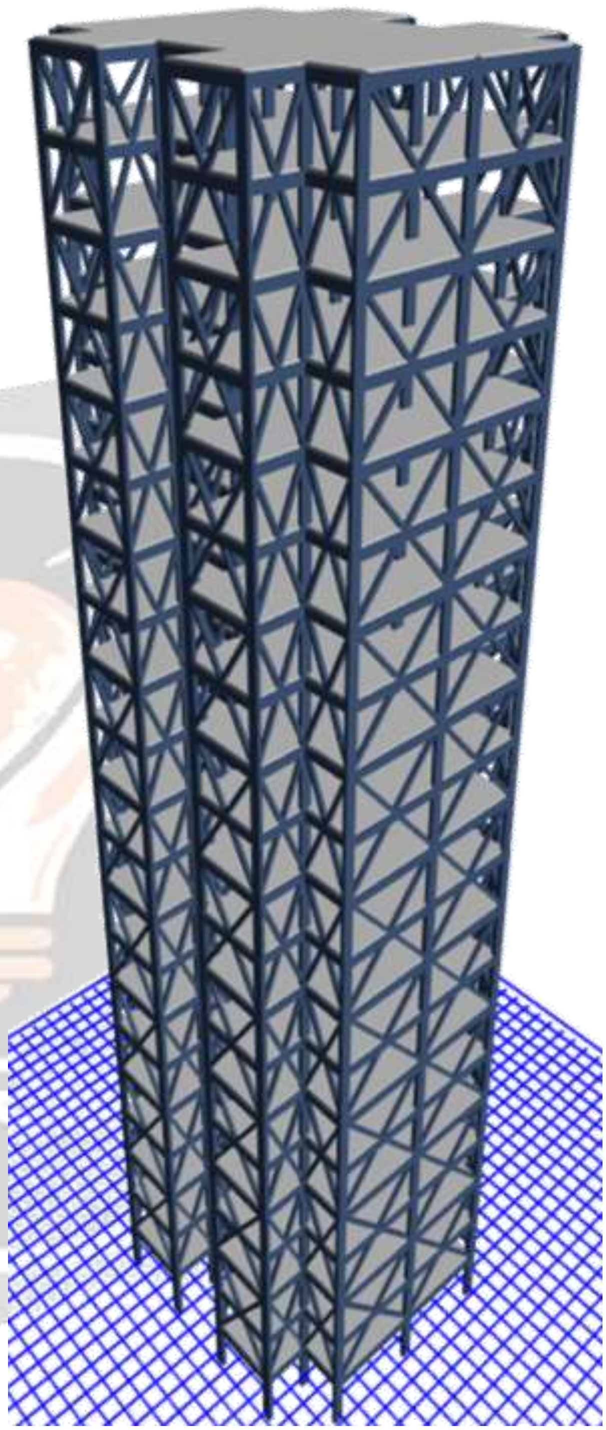


Fig -3.1(e) 3D View Of Diagrid Frame Building

4) DATA USED FOR PERFORMANCE ANALYSIS

Given data and various parameters those are considered in the performance analysis processis listed below.

- R.C.C. Residential building (G+20) twenty story
- Relative Story height is 3.048 m.
- Providing isolated Trapezoidal footing.
- The area is under Seismic Zone III.
- Medium type of Soil.

4.1) Materials :

I. Concrete :

Concrete with following properties is considered for study,

- Characteristic compressive strength (fck) = M40, M30,
- Poisson's Ratio = 0.2
- Density = 25 kN/m3.
- Modulus of Elasticity (Ec) = 5000 x √fck … (MPa) .(IS 456-2000, cl.6.2.3.1., Pg-16)
- For M20 – 22360.67977 (for all slab, beams an Columns of Roof)
- For M30 – 27386127.88 (For all slab, beams and Columns from storey 11th to 21)
- For M40 - 31622776.60 (For columns up to 10^{th} storey)

II. Steel :

Steel with following properties is considered for study,

- Yield strength (0.2% Proof Stress) (IS 456-2000, clause no 5.6.3, Pg-15)for Fe 500 grade steel = 500 MPa
- Modulus of Elasticity (Es) = 2x10^5 MPa. (IS 456-2000, clause no 5.6.3, Pg-15)

4.2) Loads Applied:

- Dead Load Intensities = 1 kN/m2
- Live Load Intensities = 3 kN/m2
- Floor Finish = 1 kN/m2
- Earthquake load on slab as per IS 1893 (Part I) – 2000
- Wind force as per Is 875 part 3
- Load Combinations

4.3) Frame Sections Used For Structure :

- Column = GL to 10 Story 300X600 mm (M40)
- Column = 11 story to 21 Story 230X600 mm (M30)
- Beam = 230X450 mm
- Diagonal column = 230X230 mm
- Slab = 125 mm Thickness.

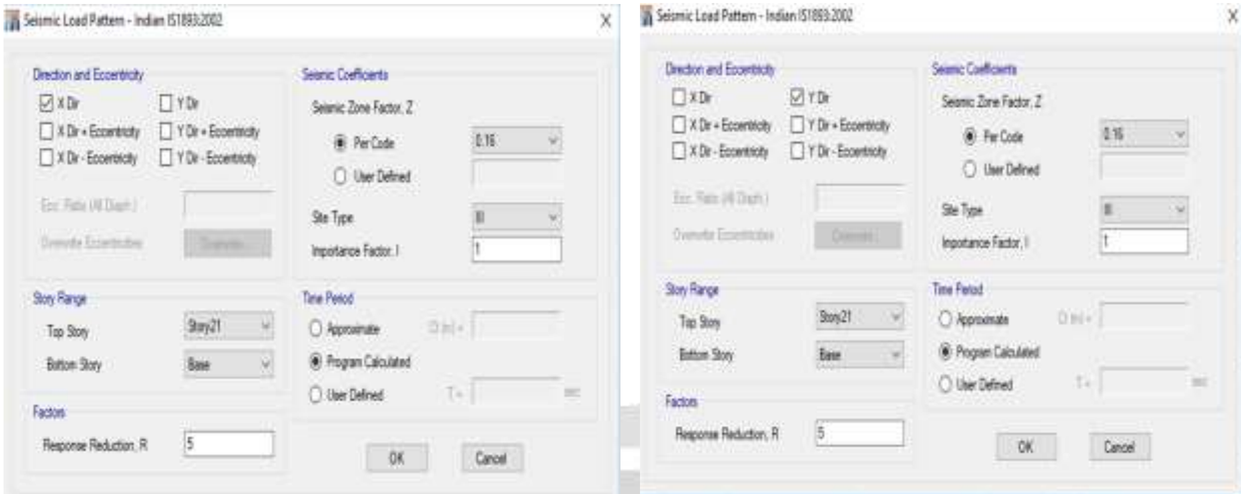


Fig. 4(a) Seismic Loading In X and Y Direction

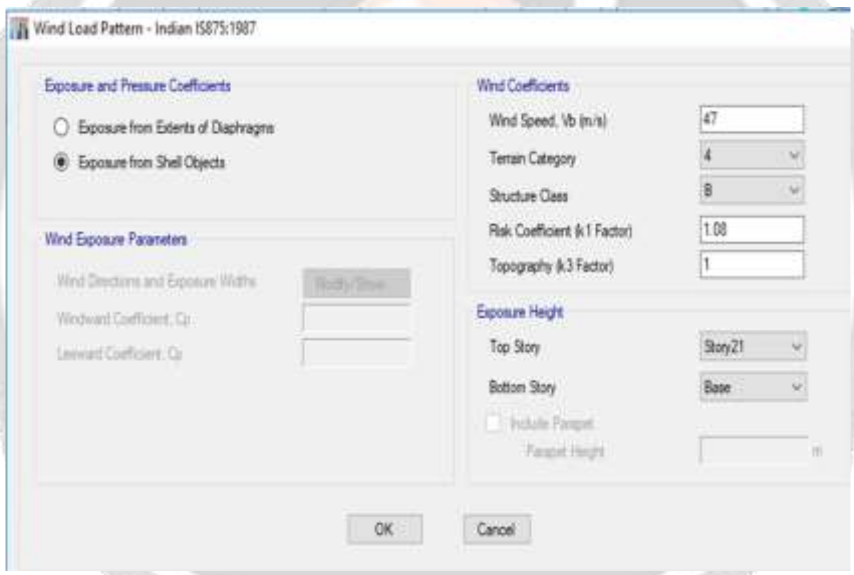


Fig. 4(b) Wind Loading

5) ANALYTICAL PERFORMANCE

Analysis of Twenty one story (21) R.C. Building is carried out using various models. The project is mainly focused on the behavior of Reinforced concrete frame, the results obtained from the analysis are critically reviewed and discussed in details.

5.1) Results Obtain From E-TAB Software (All Cases)

Table -1 Story Displacement For Conventional Building (All Cases)

No Of Story	EARTH QUICK-X	EARTH QUICK-Y	WIND X	WIND Y
story 21	49.3	61.1	50.6	60.5
story 20	48.5	59.9	50	59.7
story 19	47.3	58.3	49.2	58.6
story 18	45.9	56.3	48.1	57.2
story 17	44.1	54	46.8	55.5
story 16	42.1	51.3	45.2	53.4
story 15	39.8	48.3	43.4	51
story 14	37.4	45	41.3	48.3
story 13	34.8	41.5	39	45.3
story 12	32.1	37.9	36.5	42
story 11	29.2	34.1	33.7	38.5
story 10	26.3	30.3	30.8	34.8
story 9	23.5	27.1	27.9	31.6
story 8	20.7	23.9	24.9	28.3
story 7	17.8	20.7	21.8	24.8
story 6	14.9	17.5	18.5	21.3
story 5	12	14.2	15.2	17.6
story 4	9	10.4	11.5	13.2
story 3	6.2	7.2	8.1	9.3
story 2	3.5	4.2	4.7	5.5
story 1	1.2	1.5	1.6	2

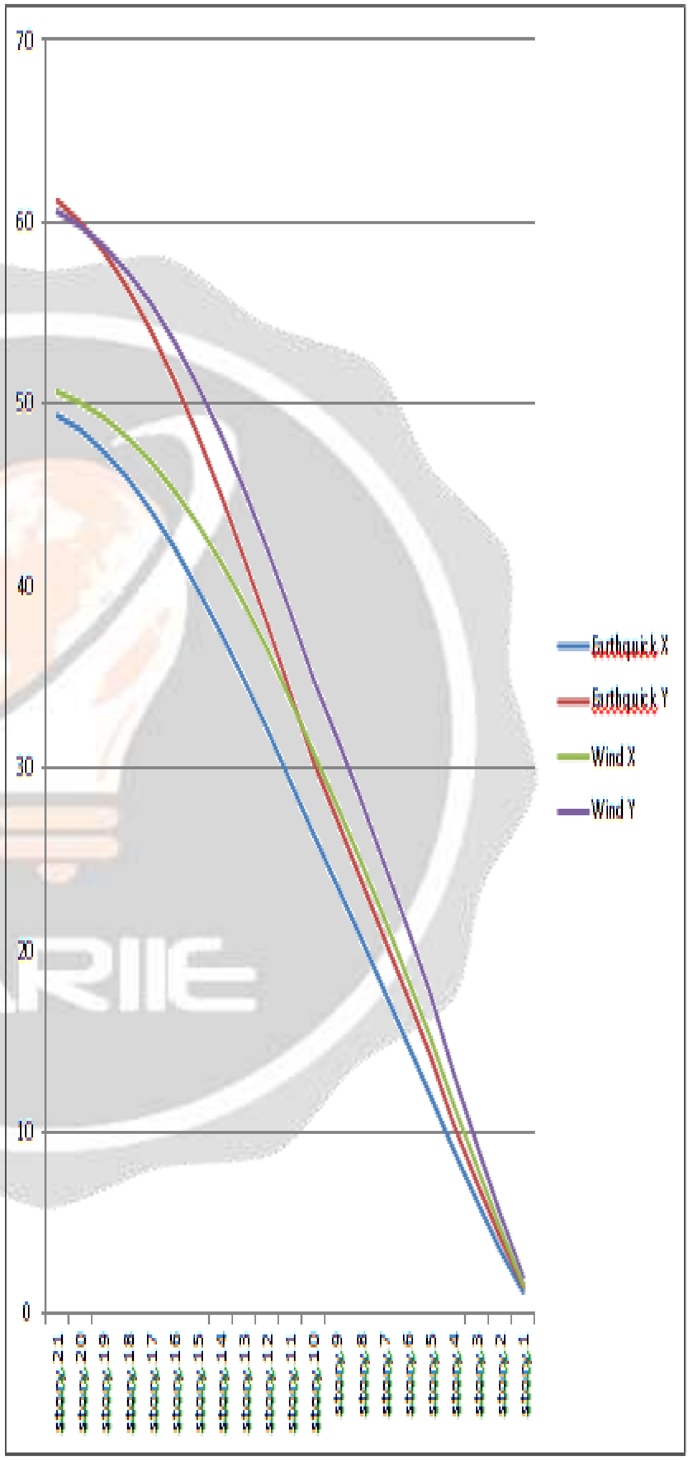


Chart -1 Story Displacement For Conventional Building

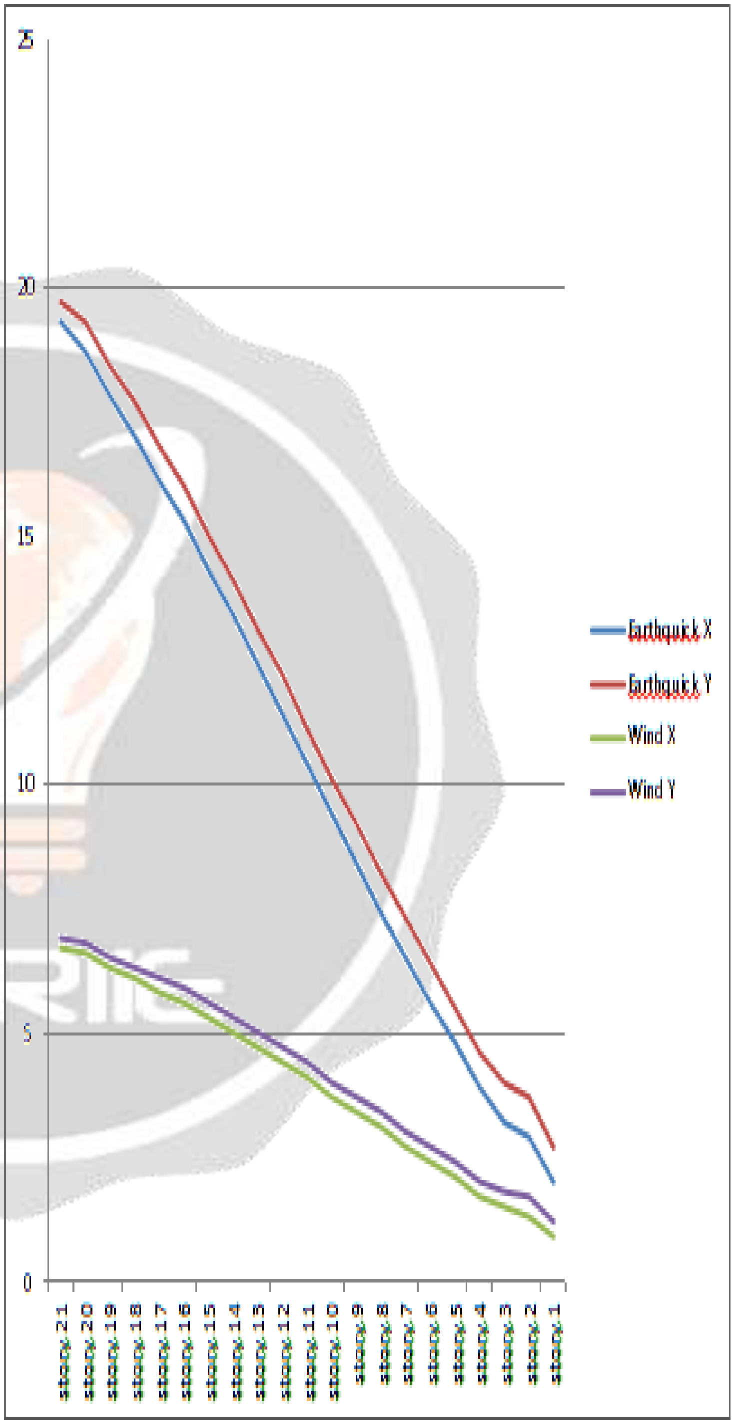
Table -2 Story Displacement For Diagrid Building

(All Cases)

NO OF STORYS	EARTH QUICKX	EARTH QUICK Y	WIND X	WIND Y
story 21	19.3	19.7	6.7	6.9
story 20	18.7	19.3	6.6	6.8
story 19	17.8	18.4	6.3	6.5
story 18	17	17.7	6.1	6.3
story 17	16.1	16.8	5.8	6.1
story 16	15.3	16	5.6	5.9
story 15	14.3	15	5.3	5.6
story 14	13.4	14.1	5	5.3
story 13	12.4	13.1	4.7	5
story 12	11.4	12.2	4.4	4.7
story 11	10.4	11.1	4.1	4.4
story 10	9.4	10.1	3.7	4
story 9	8.4	9.2	3.4	3.7
story 8	7.4	8.2	3.1	3.4
story 7	6.5	7.3	2.7	3
story 6	5.6	6.4	2.4	2.7
story 5	4.8	5.5	2.1	2.4
story 4	3.9	4.6	1.7	2
story 3	3.2	4	1.5	1.8
story 2	2.9	3.7	1.3	1.7
story 1	2	2.7	0.9	1.2

Table -3 Story Drift For Conventional Building

Chart -2 Story Displacement For Diagrid Building



NO OF STORYS	EARTH QUICK X	EARTH QUICK Y	WIND X	WIND Y
story 21	0.00028	0.000387	0.000195	0.000262
story 20	0.000381	0.000514	0.000267	0.000351
story 19	0.000483	0.00065	0.00035	0.000459
story 18	0.000576	0.000775	0.000435	0.00057
story 17	0.00066	0.000887	0.000518	0.00068
story 16	0.000733	0.000985	0.0006	0.000787
story 15	0.000798	0.00107	0.000679	0.00089
story 14	0.000852	0.001143	0.000755	0.000988
story 13	0.000898	0.001202	0.000826	0.00108
story 12	0.000935	0.001245	0.000894	0.001163
story 11	0.000958	0.001235	0.000952	0.001198
story 10	0.000924	0.001057	0.000951	0.001063
story 9	0.000934	0.001044	0.000993	0.001085
story 8	0.000942	0.00105	0.001032	0.001125
story 7	0.000946	0.001054	0.001066	0.001163
story 6	0.000947	0.001076	0.001099	0.001222
story 5	0.000992	0.001236	0.00119	0.001451
story 4	0.000917	0.001047	0.001135	0.001268
story 3	0.000872	0.000989	0.001114	0.001238
story 2	0.00076	0.000888	0.001001	0.001148
story 1	0.0004	0.000498	0.000539	0.00066

Table -4 Story Drift For Diagrid Building

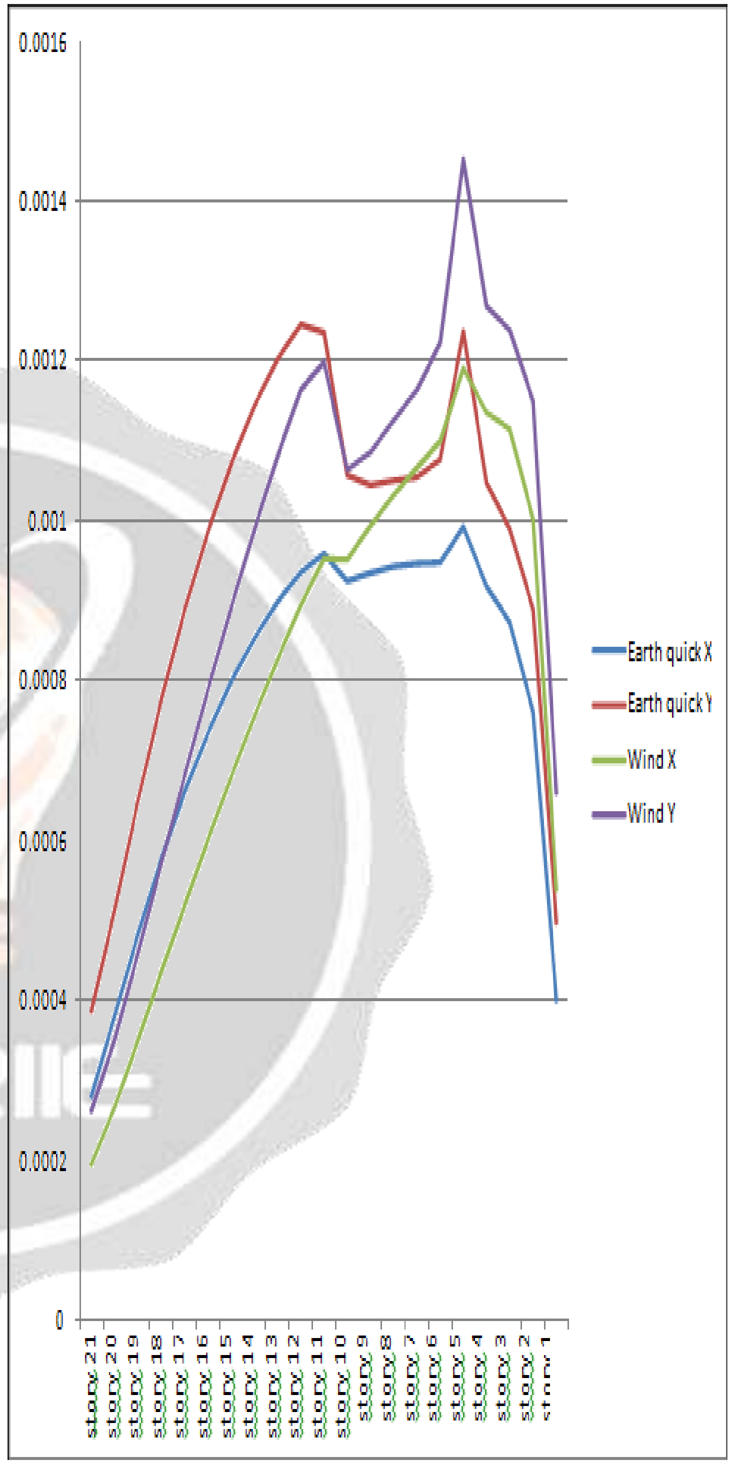


Chart -3 Story Drift For Conventional Building

NO OF STORYS	EARTH QUICK -X	EARTH QUICK- Y	WIND X	WIND Y
Story 21	0.000222	0.000161	0.000066	0.000049
Story 20	0.000298	0.000298	0.000085	0.000083
Story 19	0.000256	0.000221	0.000073	0.000061
Story 18	0.000305	0.000305	0.00009	0.000089
Story 17	0.000282	0.000257	0.000081	0.000071
Story 16	0.000327	0.000326	0.0001	0.000099
Story 15	0.000307	0.000288	0.000092	0.000082
Story 14	0.000338	0.000338	0.000108	0.000107
Story 13	0.000321	0.000305	0.0001	0.00009
Story 12	0.00034	0.000342	0.000115	0.000114
Story 11	0.000327	0.000327	0.000107	0.000103
Story 10	0.000328	0.00032	0.000116	0.000113
Story 9	0.000318	0.000312	0.00011	0.000105
Story 8	0.000313	0.000314	0.000115	0.000114
Story 7	0.000299	0.000297	0.000108	0.000104
Story 6	0.000294	0.000296	0.000113	0.000113
Story 5	0.000293	0.00031	0.000112	0.000116
Story 4	0.000225	0.000213	0.000091	0.000087
Story 3	0.000118	0.000093	0.000039	0.000027
Story 2	0.000329	0.000359	0.00015	0.000164
Story 1	0.000663	0.000877	0.00031	0.000408

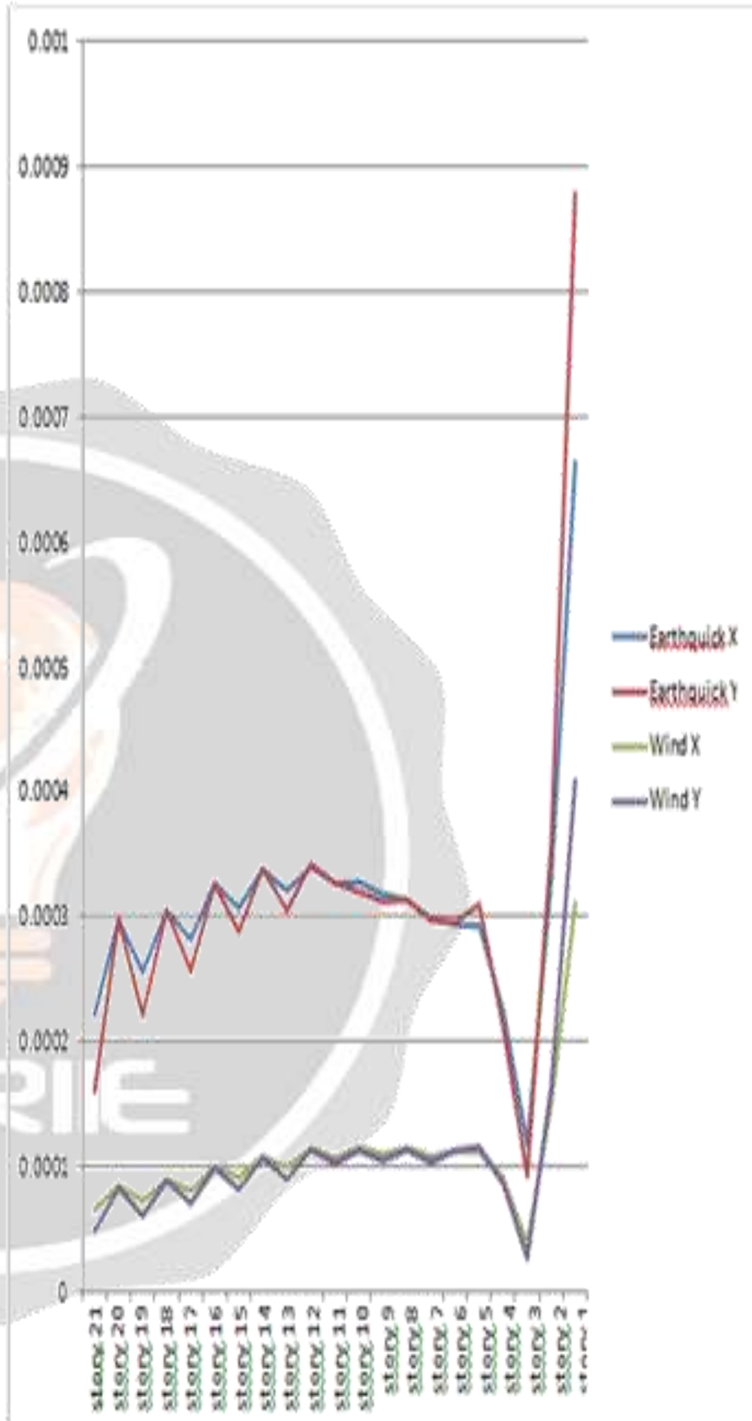


Chart -4 Story Drift For Diagrid Building

6. CONCLUSIONS

An analytical model for Simple Frame and Diagrid Frame is proposed in this dissertation. The conclusion based on, the results of Story Drift and Displacement with Static and Dynamic Analysis of Model 1 and Model 2, as described in the previous chapters, are presented herewith.

- The Story Drift result is obtained using E-Tab Software satisfied the clause 7.11.1 (IS1893-2000) shall not excel 0.004 times the story height
- Model 1 and Module 2 has 0.00119 and 0.00031 m story drift which shows thatModel 2 is safe than Model 1. in wind x direction.
- . Model 1 and Module 2 has 0.001451 and 0.000408 m story drift which shows thatModel 2 is safe than Model 1. in wind y direction.
- Model 1 and Module 2 has 0.000992 and 0.000663 m story drift which shows thatModel 2 is safe than Model 1. in earth quick x direction.
- Model 1 and Module 2 has 0.001245 and 0.000877 m story drift which shows thatModel 2 is safe than Model 1. in earth quick y direction.
- Model 1 and Module 2 has 50.6 mm and 6.7 mm story displacement shows that Model 2 is more safe than Model 1 in wind x direction.
- Model 1 and Module 2 has 60.5 mm and 6.9 mm story displacement shows that Model 2 is more safe than Model 1 in wind y direction.
- Model 1 and Module 2 has 49.3 mm and 19.3 mm story displacement shows that Model 2 is more safe than Model 1 in earth quick x direction.
- Model 1 and Module 2 has 61.1 mm and 19.7 mm story displacement shows that Model 2 is more safe than Model 1 in earth quick y direction.
- Model 2 is More stiff than Model 1.
- The use of Diagrids results in roughly 1/5th reduction in steel as compared to Bracedframe structures.

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