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Seismic Analysis of Vertical Geometric Irregular Diagrid Structures with Different Diagonal Angles

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Abstract - *In present world due to increase in vertically irregular structures, it becomes difficult for a structural engineer to choose most efficient structural system. Lately Diagrid is considered as efficient structural system in resisting both lateral loads and gravity loads. This paper presents a brief study about diagrids on a vertically irregular structure. For this particular study a building with base dimension 36 m × 36 m and 168 m height is considered. Each storey height is 3.5 m. Diagrid with two uniform angle throughout the height is provided as lateral load resisting system. Response spectrum analysis is done using ETABS 2018. Seismic performance of vertical geometric irregular building provided with diagrids is studied by using diagrid angles. The results in terms of maximum storey displacement, maximum storey drift, time period and base shear are compared.*

***Key Words*: Diagrid, Uniform angle, Etabs**

1. INTRODUCTION

Diagrid have emerged as a new design trend for tall buildings. The major difference between conventional exterior braced frame structures and diagrid structures is that diagrid structures removes all the vertical columns. The diagrid system is feasible because the diagonal members in diagrid structures can carry both gravity loads as well as lateral forces through their triangulated configuration. Compared with normal conventional framed tubular structures without diagonals, diagrid building transfers load by axial action and reduces shear deformation, while the conventional framed tubular structures transfer shear by the bending of the vertical columns.

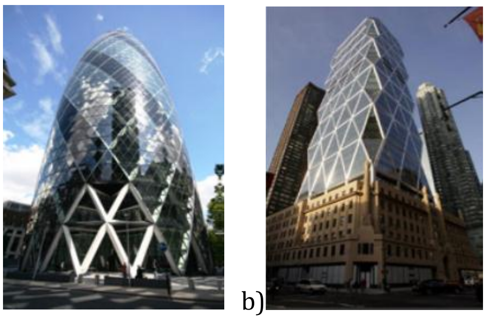

a) b)

Fig-1: Diagrid structures (a) Swiss Re in London (b)Hearst Tower in New York

2. OBJECTIVES

a) To understand the effect of vertical irregularity on seismic response of steel diagrid structure.
b) To compare maximum base shear, time period, storey displacement, inter storey drift to predict the behavior of structures under earthquake loading.
c) To analyze the diagrid structure for two different diagonal angles in zone iii and zone v.

3. SCOPE OF PRESENT STUDY

The present study consists of modelling and analysis of steel diagrid structure with different diagrid angle having vertical irregularity in terms models having different lateral length ratio (A> 0.125L) each subjected to earthquake load.
As per code IS: 893 (Part 1): 2016

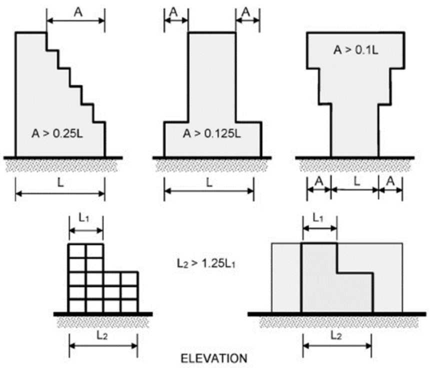


Fig -2: Vertical geometric irregularity

Present study carried out considering four models namely,

1. Model-1: 100% of total height (H) having regular plan of 36mx36m as shown in Figure 3
2. Model-2: 75% of total height (H) having regular plan of 36mx36m as shown in Figure 3 and remaining portion having plan dimension 12mx 12m as shown in Figure 3
3. Model-3: 50% of total height (H) having regular plan of 36mx36m as shown in Figure 3 and remaining portion having plan dimension 12mx 12m as shown in Figure 3
4. Model-4: 25% of total height (H) having regular plan of 36mx36m as shown in Figure 3 and

remaining portion having plan dimension 12mx 12m as shown in Figure 3

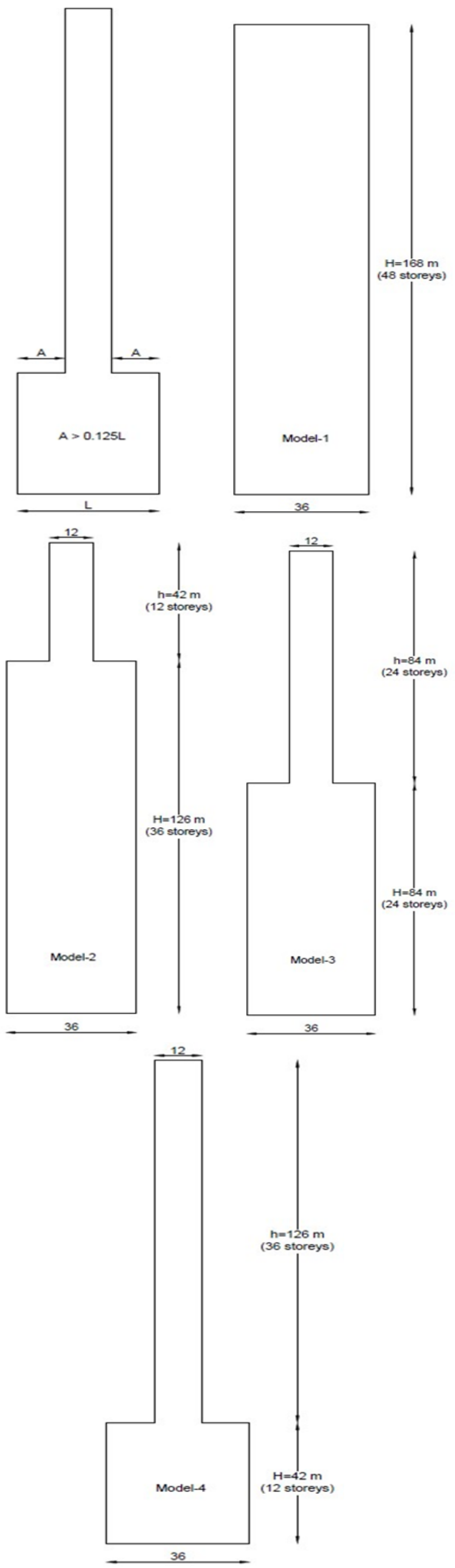


Fig-3: Elevation view of models

3.1 BUILDING DESCRIPTION

Plan dimension- 36x36 m
Number of storeys- 48
Storey height (meters)- 3.5 m
Total height of the structure- 168 m
Plan type - Square building
Type of the structure- Diagrid steel structure
Diagrid angles- 49.4° (D2) and 66.8° (D4)
Type of analysis- Dynamic Analysis with the structure subjected to earthquake load.

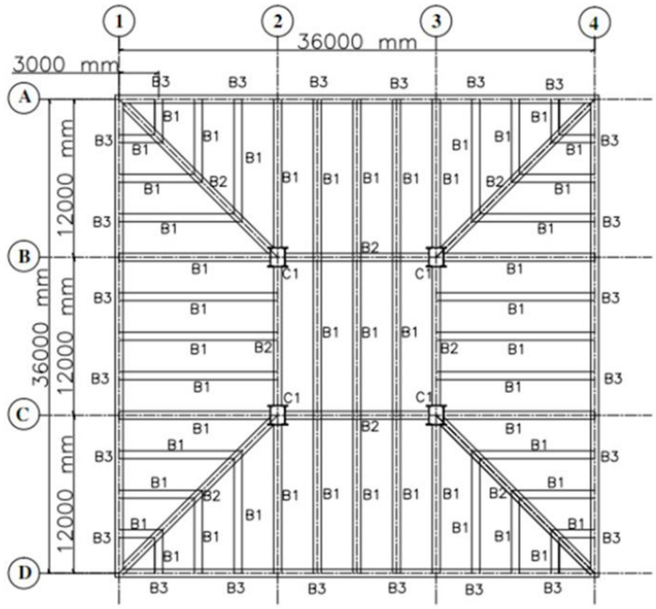


Fig -4: Building plan view

3.2 PARAMETERS CONSIDERED

DESIGN VARIABLES

The design variables are considered from journals for the analysis for the above-mentioned plan description.

Table -1: Design variables

Elements	Label	Dimensions	Material	Grade
Interior Columns	C1	1650x1650 mm (Fig -5)	Steel	Fe250
Beams	B1,B2,B3	B1 and B3 = ISMB 550 B2= ISWB 600 with top and bottom plate of 220mm×50 mm	Steel	Fe250

Diagonal member	-	450mm pipe sections with 25mm thickness (from 25th to 48th storey) 525mm Pipe sections with 25mm thickness (from 1st to 24th storey)	Steel	Fe250
Slab	-	150 mm thick slab	Composite	M25 Fe250

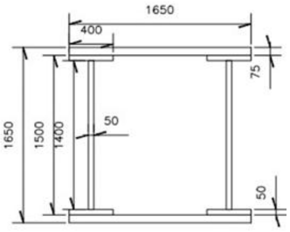


Fig -5: Interior column

LOADS CONSIDERED

1. Dead load (flooring) = 2 kN/m^2
2. Imposed load = 2.5 kN/m^2

SEISMIC PARAMETERS

Seismic parameters as considered as per IS:1893(Part 1): 2016

1. Zone - III and V
2. Zone factor - 0.16 and 0.36
3. Soil type - Medium
4. Importance factor - 1.2
5. Response reduction factor - 5
6. Scale factor - 1177.2

3.3 STRUCTURAL MODEL

The 48 storey tall building having 168 m of total height with storey height of 3.5 m. Typical floor plan of sizes 36mx36m and 12mx12m are used as shown in Figure 6 and Figure 7. The slab thickness is taken as 150mm. In this diagrid structures pair of braces is located on the periphery of the building. The angle of inclination is kept 49.4^o(D2) and 66.8^o(D4) throughout the height. The inclined diagonal grids are provided at 6m spacing along the perimeter. The above-mentioned plan dimensions and parameters are used in modelling of each model i.e., Model-1, Model-2, Model-3, Model-4 (Fig -3).

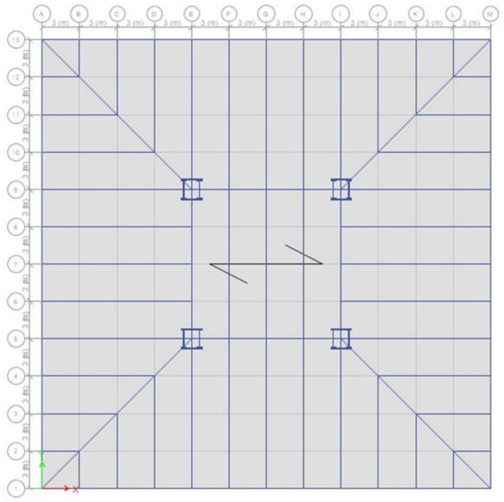


Fig -6: Plan view 36x36 m

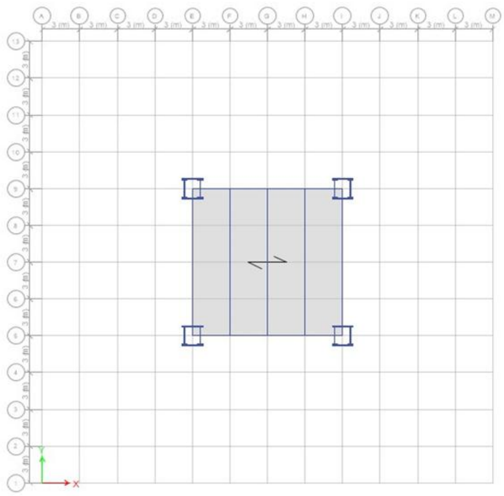


Fig -7: Plan view 12x12 m


Fig -8: Elevation view of Model-1 with diagrid angle D2

Fig -9: Elevation view of Model-2 with diagrid angle D2

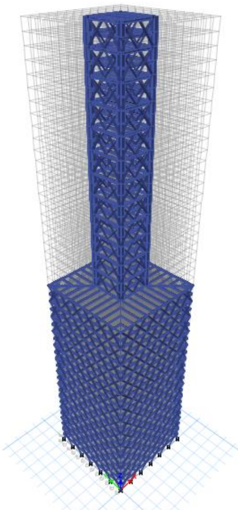


Fig -10: Elevation view of Model-3 with diagrid angle D2

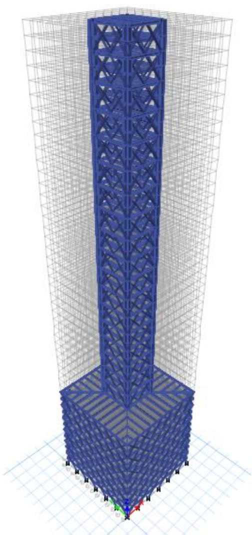


Fig -11: Elevation view of Model-4 with diagrid angle D2

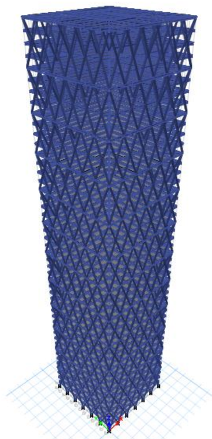


Fig -12: Elevation view of Model-1 with diagrid angle D4

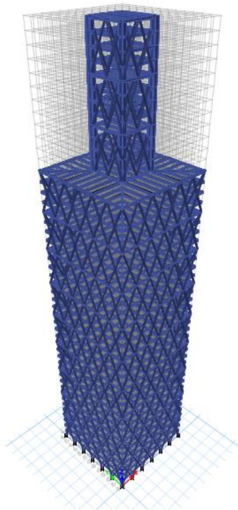


Fig -13: Elevation view of Model-2 with diagrid angle D4

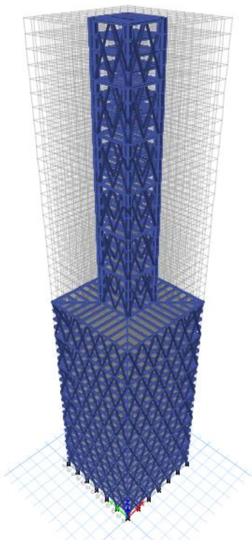


Fig -14: Elevation view of Model-3 with diagrid angle D4

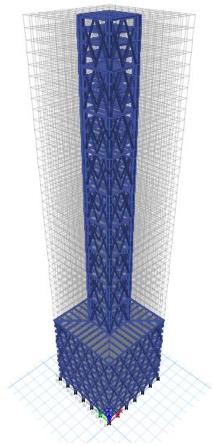
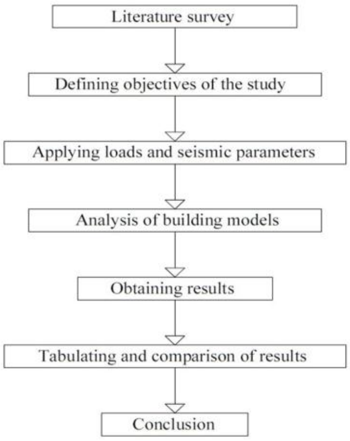


Fig -15: Elevation view of Model-4 with diagrid angle D4

4. METHODOLOGY



5. RESULTS AND DISCUSSIONS

RESULTS IN ZONE III AND ZONE V

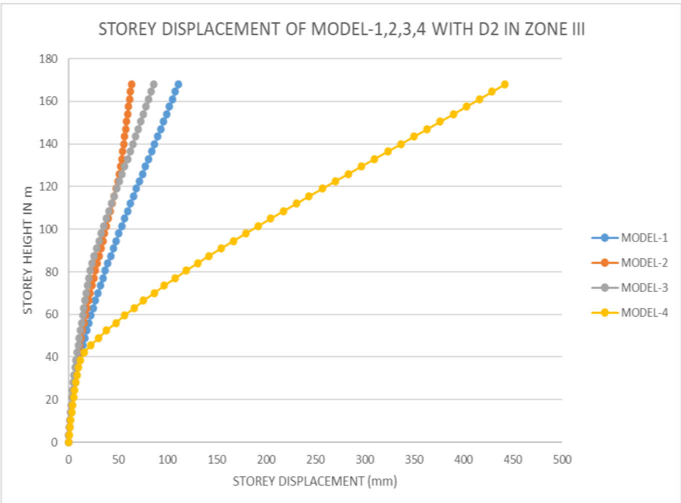


Chart -1: Storey displacement of model-1,2,3,4 with D2 in zone III

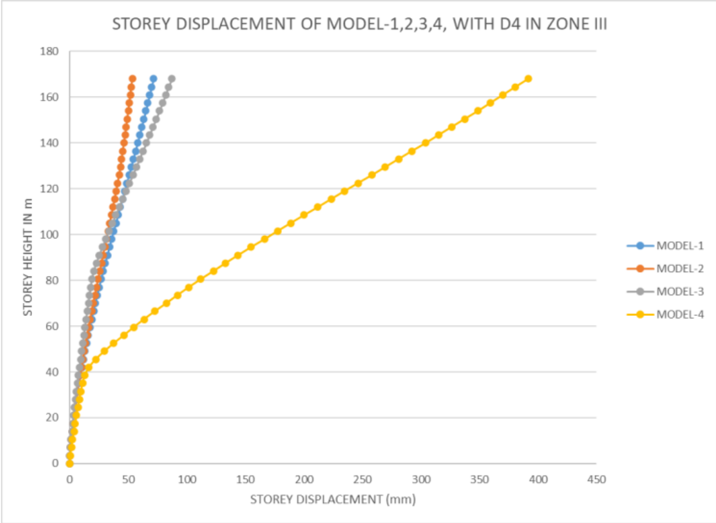


Chart -2: Storey displacement of model-1,2,3,4 with D4 in zone III

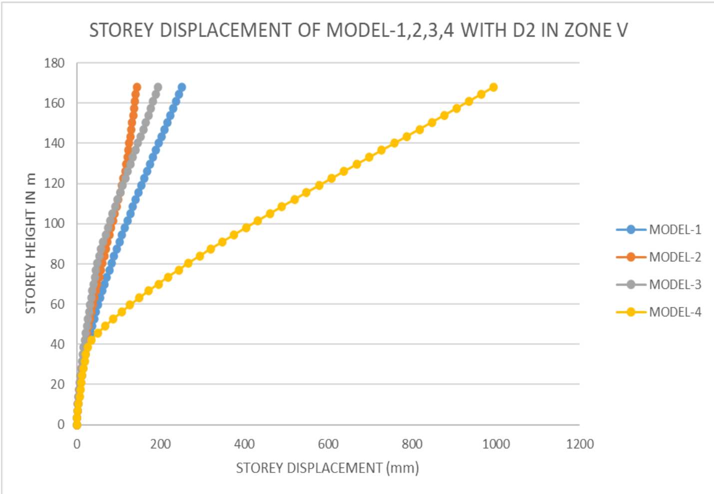


Chart -3: Storey displacement of model-1,2,3,4 with D2 in zone V

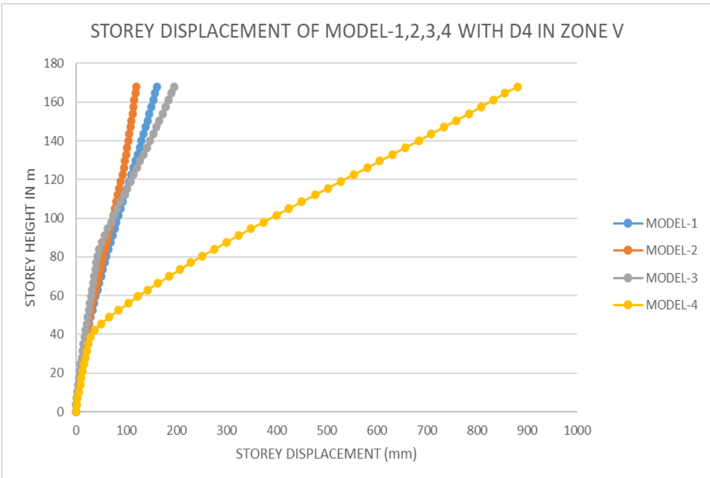


Chart -4: Storey displacement of model-1,2,3,4 with D4 in zone V

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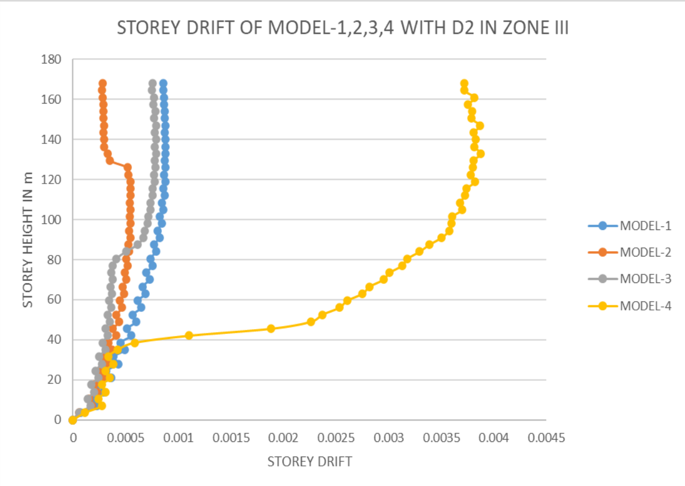

Chart -5: Storey drift of model-1,2,3,4 with D2 in zone III

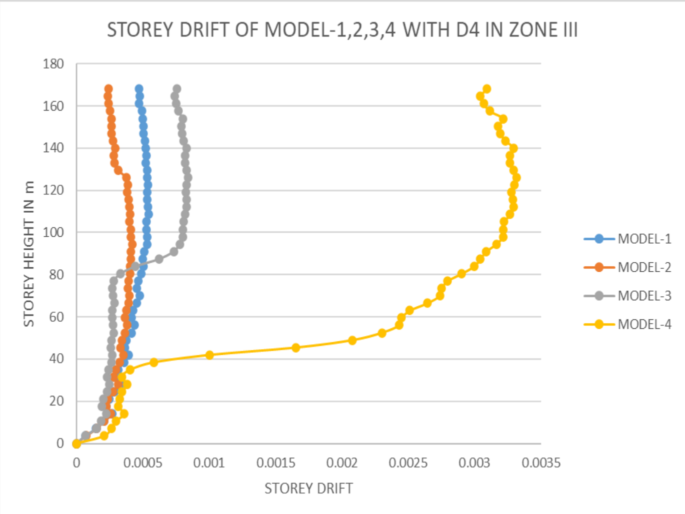

Chart -6: Storey drift of model-1,2,3,4 with D4 in zone III

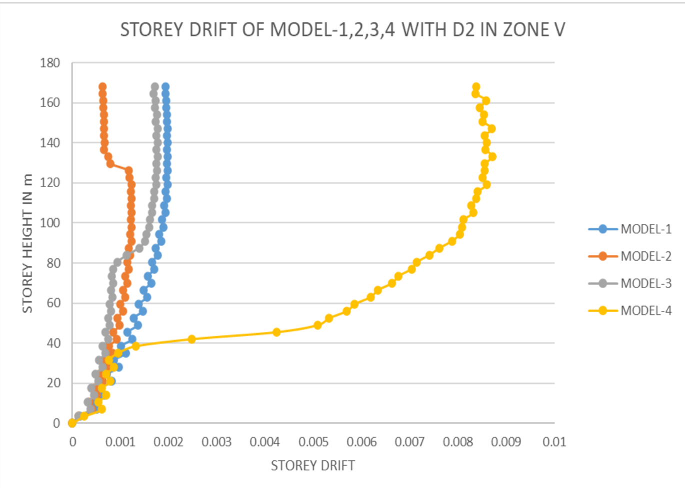

Chart -7: Storey drift of model-1,2,3,4 with D2 in zone V

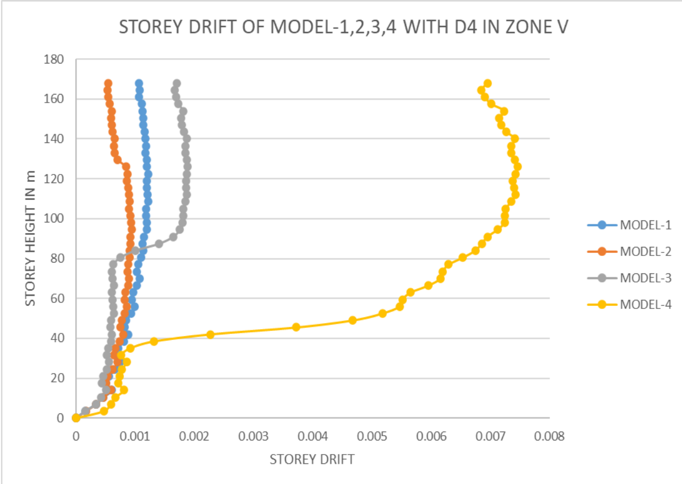

Chart -8: Storey drift of model-1,2,3,4 with D4 in zone V

Diagrid angle	Models	Results			
		Max displacement(mm)	Max drift	Base shear (kN)	Time period (Sec)
D2	Model-1	111.15	0.00085	3411.89	5.172
	Model-2	63.65	0.00028	3231.76	3.349
	Model-3	86.34	0.00075	3401.04	2.352
	Model-4	442.08	0.00372	7666.33	0.672
D4	Model-1	71.77	0.00047	3375.32	4.269
	Model-2	53.58	0.00024	3666.82	2.918
	Model-3	87.30	0.00075	3415.47	2.312
	Model-4	391.57	0.00309	6373.66	0.796

Fig -16: Comparison of maximum storey displacement, storey drift, base shear, time period for both diagrid angle (D2 and D4) in Zone III

Diagrid angle	Models	Results			
		Max displacement(mm)	Max drift	Base shear (kN)	Time period (Sec)
D2	Model-1	250.10	0.00193	7676.76	5.172
	Model-2	143.21	0.00063	7271.47	3.349
	Model-3	194.28	0.00170	7652.36	2.352
	Model-4	994.68	0.00837	17249.24	0.672
D4	Model-1	161.49	0.00106	7594.48	4.269
	Model-2	120.56	0.00054	8250.36	2.918
	Model-3	196.43	0.00170	7684.82	2.312
	Model-4	881.04	0.00695	14340.74	0.796

Fig -17: Comparison of maximum storey displacement, storey drift, base shear, time period for both diagrid angle (D2 and D4) in Zone V

In this paper the analysis for earthquake load for two diagonal angles D2(49.4°) and D4(66.8°) with model-1, model-2, model-3, model-4 is compared and tabulate above. The above table compares max storey displacement, max storey drift, base shear and time period with all the models for two diagonal angles under zone iii and zone v.

From the above table, the values of base shear, time period, max storey displacement and max storey drift increases as the vertical irregularity of the structure increases. The value of time period is less with respect to two diagonal angles for model-1, model-2, model-3 in zone iii and zone v. It is also observed that the value is more with increase in slope in model-4 in both the zones. Max storey displacement of model-1, model-2, model-4 is more with angle D2 when compared to D4 respectively in zone iii and zone v. For the angle D4 the value of max storey displacement is slightly more in model-4 when compared with angle D2 for the same model. So, it can conclude angle D4 performs better in resisting storey displacement with model-1, model-2 and model-4. From the above table, the model-1, model-2, model-4 with angle D4 have lesser value in terms of max storey drift compared to angle D2 in both the zones (iii and v). For model-3 the angles D2 and D4 performs equally in terms of storey drift under zone iii and zone v.

In diagrid structure base shear also plays important role in deciding the optimal angle that can be used. From the values above it is found that the values of base shear for model-1 and model-4 with angle D4 performs better in resisting base shear than angle D2 in both zone iii and zone v. Based on values of model-3 for both diagonal angles D2 and D4 it is observed both the angles perform closely in resisting base shear and storey displacement under zone iii and zone v.

6. CONCLUSIONS

1) From the study it is observed that as irregularity increases the values of base shear, time period, storey displacement and storey drift increases gradually. For this present study irregularity is directly proportional to base shear, time period, displacement and drift.
2) This study examined the influence of the diagonal angle on the behavior of diagrid type structure. It was found that, angle D4(66.8°) performed well than D2(49.4°) in terms of storey displacement, storey drift, base shear and time period as the irregularity increased.
3) According to this study, the diagonal angles D4(66.8°) and D2(49.4°) have performed closely in resisting lateral loads for model-3 (50% irregularity). So, it can be said both diagonal angles D2(66.8°) and D4(49.4°) can be adopted for model-3 (50% irregularity).
4) From the results obtained it is observed that storey drift are within the permissible limit as per IS: 1893 (Part 1): 2016.
5) According to the results obtained the values of base shear, time period, storey displacement and storey drift gets increased by 55.55% from zone III to zone V.

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