International Journal of Scientific Research in Civil Engineering
© 2022 | IJSRCE | Volume 6 | Issue 3 | ISSN : 2456-6667

Analysis of Diagrid Structure Resist Lateral Forces with Soft Soil Conditions

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Article Info
May-June-2022

Publication Issue :
Volume 6, Issue 3

Page Number : 08-26

Article History
Accepted : 01 May 2022
Published : 13 May 2022

ABSTRACT

As India is a developing nation, there is a drastic development taking place in infrastructure and modern living standards, India is number two in population in the world therefore to settle this population there is a high demand of high rise structure, But in India earthquake prone areas where lateral forces are very high there is a requirement of introducing structures with resisting members which can eliminate the failure of the structure due to sudden forces generated by earthquake, thus, the primary target of this study is to decide the effect of seismic forces (Dynamic Analysis) on the high rise structures. Considering Steel diagrid and hybrid diagrid frame at the outer periphery of structure to resist lateral forces, considering seismic zone V with soft type of soil conditions. Comparative study have been made on an unsymmetrical building of G+11 floors considering seismic zone as per I.S. 1893 part 1 2016. For analysis and modeling purpose STAAD.Pro programming is utilized and study is done on the premise of maximum storey displacement, axial forces, shear forces, maximum bending and displacement and most importantly cost analysis of both the structure as per S.O.R. 2017. In this study we adopt 13 loading combination in each case as per Indian Standards and dimensions of column (450 mm x450 mm), beam (400 mm x300 mm) and diagrid (ISMB 100) in all the cases.

Keywords: Hybrid Diagrid, Staad.Pro, Diagrid, Highrise Structure, Structural Analysis, Unsymmetrical Frame, Dynamic Analysis, Conventional Frame.

I. INTRODUCTION

Hybrid Diagrid structure

The word Hybrid Diagrid is a mixing of the words askew and framework and alludes to a basic framework that is single thickness in nature and grains its auxiliary trustworthiness using triangulation. Hybrid Diagrid frameworks can be planar, crystalline or go up against various ebbs and flows. Hybrid Diagrid structures frequently utilize crystalline structures or bend to expand their solidness. This separates a Hybrid Diagrid from any of the three dimensional triangulated frameworks, for example, space outlines, space brackets or geodesic structures, in spite of the fact that it will be appeared a portion of the improvements of Hybrid Diagrid structures have been gotten from the subtleties of these three dimensional frameworks.

Objectives:

The objectives of the study are as follows:
1. To determine the effect of seismic forces (Response spectrum) on a High rise irregular school building.
2. To study the effect of lateral load resisting members i.e. Diagrids and Hybrid diagrid comparing with conventional frame on a live project.
3. To determine the variation in forces due to diagrid as well as Hybrid diagrid structure under seismic zone V considering Finite Element method (F.E.M).

II. LITERATURE REVIEW

Rohit Kumar Singh and Vivek Garg (2014) The author here analyzed a regular five storey RCC building with plan size 15 m × 15 m located in seismic zone V is considered for analysis. STAAD.Pro software was used for modelling and analysis of structural members. All structural members were designed as per IS 456:2000 and load combinations of seismic forces were considered as per IS 1893(Part 1): 2002. Comparison of analysis results in terms of storey drift, node to node displacement, bending moment, shear forces, area of reinforcement, and also the economical aspect is 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. This causes economical design of diagrid structure compared to conventional structure. Drift in diagrid building is approx. half to that obtained in conventional building. In this study, steel reinforcement used in diagrid structure was found to be 33% less compared to conventional building.

Here the author observed that due to diagonal columns in periphery of the structures, the diagrid structure was found more effective in lateral load resistance. Due to this property of diagrid structure, interior column was used of smaller size for gravity load resistance and only small quantity of lateral load was considered for the same. While in case of conventional frame building, both gravity and lateral load was resisted by exterior as well as interior column.

The author concluded points as under:

• Structural performance: Diagrid building shows less lateral displacement and drift in comparison to conventional building.
• Material saving property: Although volume of concrete used in both building was approx. same, but diagrid proved more economical in terms of steel used. Diagrid building saves about 33% steel without affecting the structural efficiency.
• Better resistance to lateral loads: Due to diagonal columns on its periphery, diagrid shows better resistance to lateral loads and due to this, inner columns get relaxed and carry only gravity loads. While in conventional building both inner and outer column are designed for both gravity and lateral loads.
• Aesthetic look: In comparison to conventional building, diagrid buildings are more aesthetic in look and it becomes important for high rise buildings.

Rajib Kumar Biswas and Arman Chowdhury (2013) Here the author was concerned about column axial load and to review our structure with special features like shear walls & diagonal bracing where they modelled a 15 storied flat plate garments building using software package “STAAD Pro” for earthquake zone II in Bangladesh .

The author recommended Shear Wall to be implemented in flat plate Structure as Flat plate was good in perspective of gravity load but flat plate building couldnt stand strongly against wind, seismic or other lateral forces. As a result, more than any other structural component, the lateral force-resisting structure had significant impact on space planning. So it was essential for a structure to have lateral resistance. To do the initial schematic design in right way it was important to consider lateral forces from the very start and to integrate lateral force –resisting structure.

III. METHODOLOGY

This examination demonstrates a comprehensive report on High-ascent structure rise G+11 building outline with three distinctive basic frameworks to be specific, customary shear wall framework, diagrid framework and hybrid diagrid framework considering seismic zone V with soft soil type Under the seismic impact according to IS 1893 (section I) - 2016 Dynamic investigation. A correlation of investigation results as far as hub removals, forces on columns support reaction, beam forces bolster responses and storey displacement has been completed. Push-over examination of the structure has been executed.

The building is considered to be located in seismic zone V and intended for residential use. The building is founded on medium strength soil through isolated footing under the columns. Response reduction factor for the special moment resisting frame has taken as 5.0 (assuming ductile detailing). The floor finish on the floors is taken to be 1.0 kN/m2.

The live load on floor is taken as 3.0 kN/m2and that on the roof to be 1.5 kN/m2. In seismic weight calculations, 25 % of the floor live loads are considered in the analysis.

This investigation endeavors in the accompanying procedures:

Step-1 Building Geometry of symmetric shape [53.13 x 46.72m] a G+11 Storey of 3 dimensional frame selection stated

Modelling

The building is viewed as situated in seismic zone II and expected for private use. The building is established on medium quality soil through isolated footing under the columns. Reaction decrease factor for the uncommon moment opposing edge has taken as 5.0 (accepting flexible enumerating). The floor complete on the floors is taken to be 1.0 kN/m2. The live load on the floor is taken as 3.0 kN/m2and that on the rooftop to be 1.5 kN/m2. In seismic weight counts, 25 % of the floor live loads are considered in the investigation.

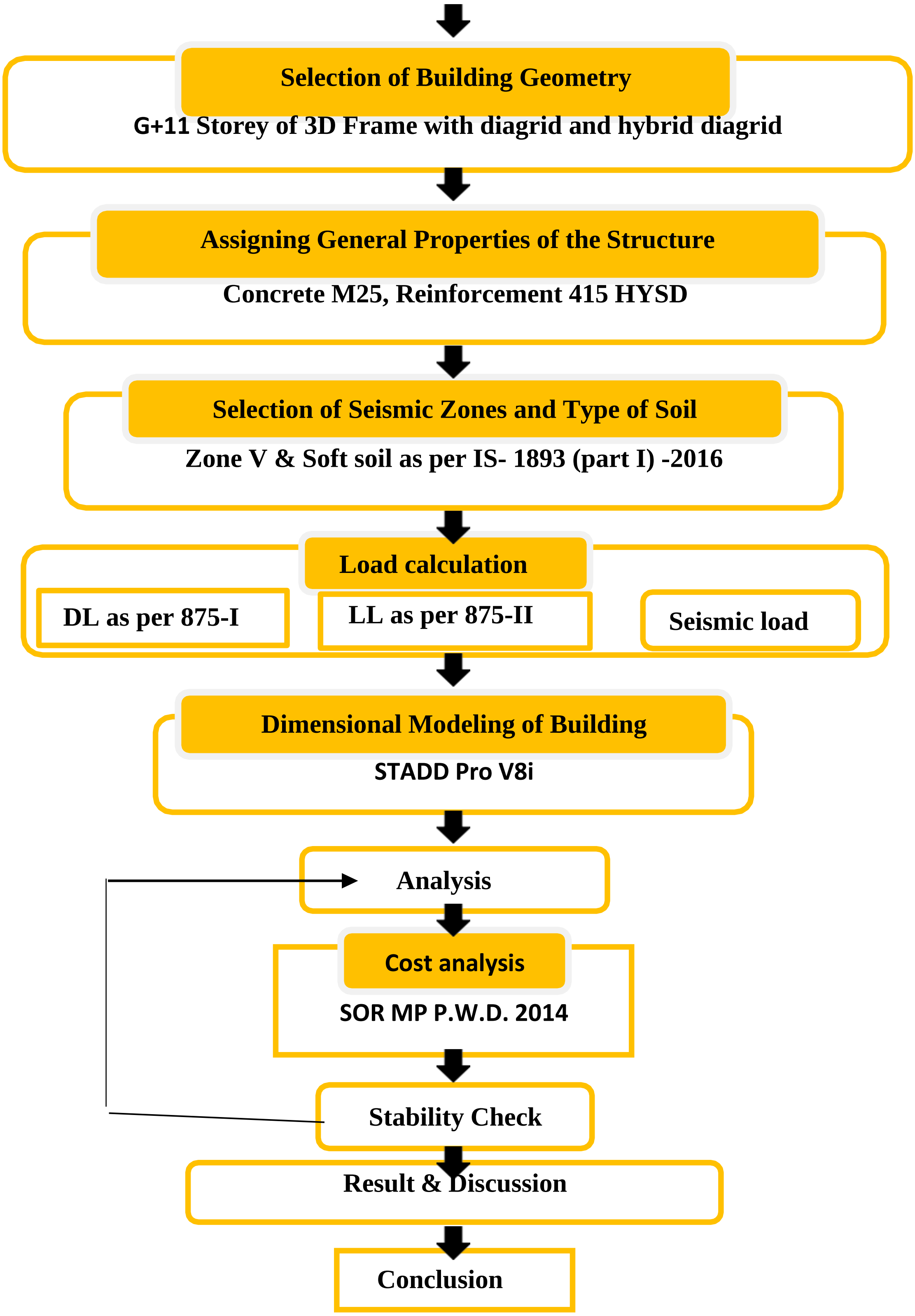
Table 3.1: Details of Structure

Type of structure	(G+11)
Plan dimensions	53.13 m × 43.72 m
Total height of building	15.5 m
Height of each storey	3.2m
Depth of foundation	2.5m

Bay width in longitudinal direction	54.13 m
Bay width in transverse direction	43.72 m
Size of beams	230 mm X 400 mm
Size of columns	450 mm X 450 mm
Thickness of slab	125 mm
Diagrid section	I.S.M.B 100
Seismic zone	V
Soil condition	Soft (type III)
Response reduction factor	5
Importance factor	1.5
Floor finishes	1 kN/m^2
Live load at roof level	1.5 kN/m^2
Live load at all floors	3 kN/m^2
Grade of Concrete	M25
Grade of Steel	Fe 415
Density of Concrete	25 kN/m^3
Density of brick masonry	20 kN/m^3
Design philosophy	Limit state method conforming to IS 456-2000

Flow chart:

FLOW CHART DIAGRAM



Structural modelling of both cases:

a.) Structure modelling with Hybrid Diagrid

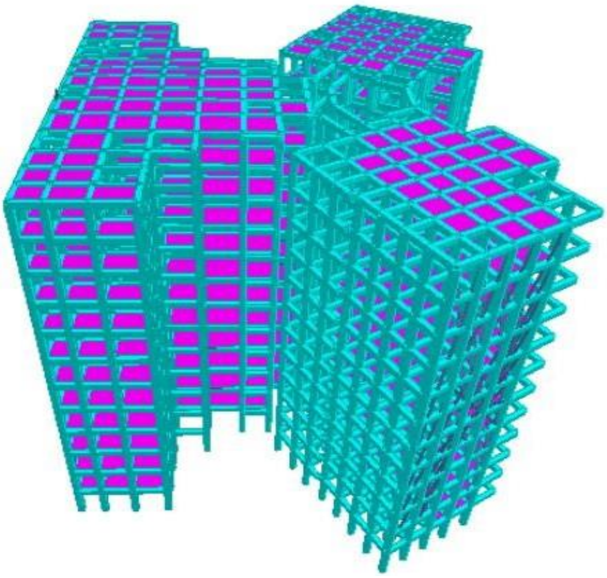
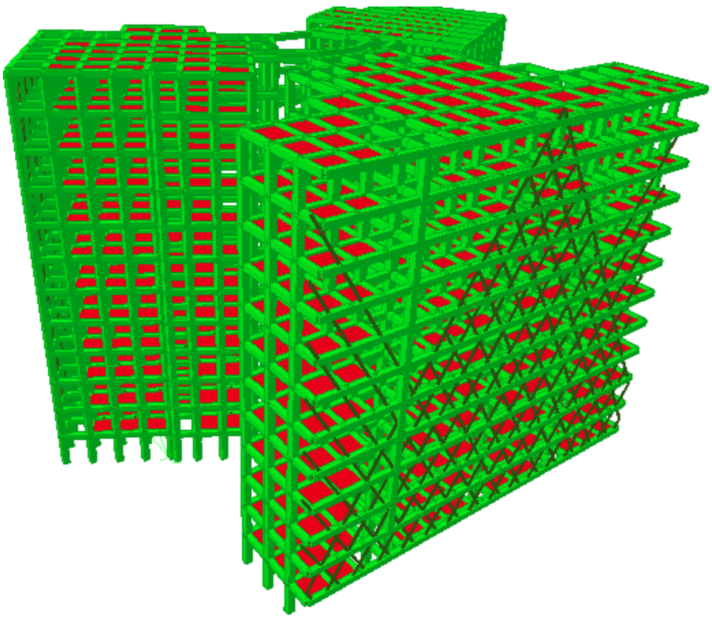


Fig 4.1: Hybrid diagrid structure



Loading conditions

Following loading is adopted for analysis: -

a). **Dead Loads**:
As per IS: 875 (part-1)-1987.

Table 4.1: Details of dead load

Brick masonry wall load				
Loading type	Calculation	Load	Unit	
For floor height3m	0.23m x (3.2-0.5)m x 18 kN/m^2	10.35	kN/m^2	As per wall height
Parapet wall	0.23m x (1.0)m x18 kN/m^2	4.6	kN/m^2	Assume parapet wall height 1 m
Floor Load				
Slab load	0.15m x 25kN/m^2	3.75	kN/m^2	Adopting Slab Thickness 150 mm
Floor Finishing	(16 x 16) = 256m^2	0.9	kN/m^2	Assume
Total Floor Load		**4.65 kN/m^2**		

b). **Live Loads**:

As per IS: 875 (part-2) 1987. Live Load on each floor = 3.00KN/m^2

Live Load considered for seismic calculation as per I.S. code 1893-part-1 = 0.75 KN/m^{2}c).

Earth Quake Loads:

All frames are analyzed for (V) earthquake zone. The seismic load calculation is as per IS: 1893(part-1)-2016.

Table 4.2: Seismic force parameters for proposed issue

S No.	Parameter	Value	Remarks
1	Zone Intensity	0.36	**Table 2 (1893-part-1 2002)**
2	Damping ratio	0.5	**Table-3 (1893-part-1 2002)**
3	Importance factor	1.5	**School building Table6 (1893-part-1 2002)**
4	Response Reduction Factor	5	**Ductile detailing (S.M.R.F.) Table-7 1893-part-1 2002**
5	Soil site factor	Soft	**Adopt**

Calculation for Sa/g

The infill walls in upper floors may contain large openings, although the solid walls are considered inload calculations. Therefore, fundamental time period T is obtained by using the following formula:

$Ta = 0.075\ h^{0.75}$ [IS 1893 (Part 1):2002, Clause 7.6.1]

$= 0.075 \times (15)^{0.75} = 0.571$ sec.

Zone factor, Z = 0.36 for Zone V IS: 1893 (Part 1):2016, Table 2Importance

factor, I = 1.5 (building)

Medium soil site and 5% dampingSa/g

= 1.36/0.571 = 2.381

IV. RESULTS & DISCUSSION

Introduction

Comparative analysis of both the cases have been done here in terms of forces, axial force, displacement and weight of sections to determine the best suited and stable frame. In order to emphasize the differences, loading is considered same.

Parameters on which study done are-

1. Shear force in KN.
2. Axial Force in KN.
3. Bending Moment in KN-m
4. Maximum deflection due to seismic loadings.
5. Reaction at Supports.

The results of analysis of considered structure have been represented in the form of tables and figures. Inferences have been drawn based on the results so obtained.

This chapter presents the results of comparative study prepared on a High rise building frame where Seismic load is assigned as per I.S. specifications to compute which type of frame will be better in all aspects. For modelling, analysis and optimized designing of allthe cases analysis tool staad.pro v8i. with fixed support is considered.

F.E.M. Analysis Result

Table 5.1 Conventional Structure results

F.E.M. Analysis output for Conventional Structure						
Output Case	**GlobalFX**	**GlobalFY**	**GlobalFZ**	**GlobalMX**	**GlobalMY**	**GlobalMZ**
Unit	KN	KN	KN	KN	KN-m	KN-m
NODAL	122.	26.56	8.7607	-15.123	2.45	44.45
NODAL	119.02	27.09	0.033	-17.54	2.87	38.09
NODAL	115.56	28.09	-1.5491	28.65	3.29	26.61
NODAL	112.10	24.98	-9.561	54.357	3.71	24.56
NODAL	108.48	21.87	-339.06	25.7	4.13	22.51
NODAL	105.01	18.76	2.082	-12.54	4.55	20.46

NODAL	101.2	15.65	-0.011	18.34	4.97	18.41
NODAL	97.4	12.54	1742.26	13.2	5.39	16.36
NODAL	94.62	10.45	-34.765	-26.87	5.81	14.31
NODAL	91.13	9.45	-279	-20.98	6.23	12.26
NODAL	87.64	8.45	0.00178	43.33	6.65	10.21
NODAL	84.15	7.45	-59621	-44.32	7.07	8.16

Table 5.2 Diagrid frame results

F.E.M. Analysis Output for Diagrid frame						
Output Case	**GlobalFX**	**GlobalFY**	**GlobalFZ**	**GlobalMX**	**GlobalMY**	**GlobalMZ**
Unit	**KN**	**KN**	**KN**	**KN**	**KN-m**	**KN-m**
NODAL	20.04	21.54	9.07	-15.123	3.2006	22.32
NODAL	19.05	25.06	-4.54	-17.54	3.56	21.09
NODAL	118.75	22.05	1.65	28.65	3.9194	19.86
NODAL	102.354	19.04	9.765	54.357	4.2788	18.63
NODAL	85.958	16.03	-7.87	25.7	4.6382	17.4
NODAL	69.562	13.02	2.082	-12.54	4.9976	16.17
NODAL	53.166	10.01	-0.011	18.34	5.357	14.94
NODAL	66.43	13.54	10.09	13.2	5.7164	18.09
NODAL	63.23	17.07	-21.07	-26.87	6.0758	41.56
NODAL	75.65	20.6	-2.08	-20.98	6.4352	40.87
NODAL	88.095	14.55	0.56	43.33	6.7946	38.66
NODAL	90.66	18.76	-5.76	-44.32	7.154	3.23

Table 5.3 Hyrbid Diagrid frame results

F.E.M. Analysis Output for Hybrid Diagrid frame						
Output Case	**GlobalFX**	**GlobalFY**	**GlobalFZ**	**GlobalMX**	**GlobalMY**	**GlobalMZ**
Unit	**KN**	**KN**	**KN**	**KN**	**KN-m**	**KN-m**
NODAL	16.04	18.54	8.07	-15.123	3.2006	22.32
NODAL	14.05	24.06	-3.54	-17.54	3.56	21.09
NODAL	112.75	22.05	0.65	28.65	3.9194	19.86
NODAL	91.354	18.04	8.765	54.357	4.2788	18.63
NODAL	79.958	15.03	-6.87	25.7	4.6382	17.4
NODAL	54.562	12.02	1.082	-12.54	4.9976	16.17
NODAL	41.166	09.01	-0.008	18.34	5.357	14.94
NODAL	59.43	12.54	11.09	13.2	5.7164	18.09
NODAL	52.23	16.07	-20.07	-26.87	6.0758	41.56
NODAL	67.65	19.6	-2.08	-20.98	6.4352	40.87
NODAL	88.095	13.55	0.56	43.33	6.7946	38.66
NODAL	92.66	17.76	-5.76	-44.32	7.154	3.23

Mode period in second:

Table: 5.4 Mode period in sec for Conventional structure

Mode shape	time period in sec.
mode1	1.725
mode2	1.725
mode3	1.594
mode4	0.559

mode5	0.558
mode6	0.517
mode7	0.317
mode8	0.317
mode9	0.295
mode10	0.213
mode11	0.213
mode12	0.198

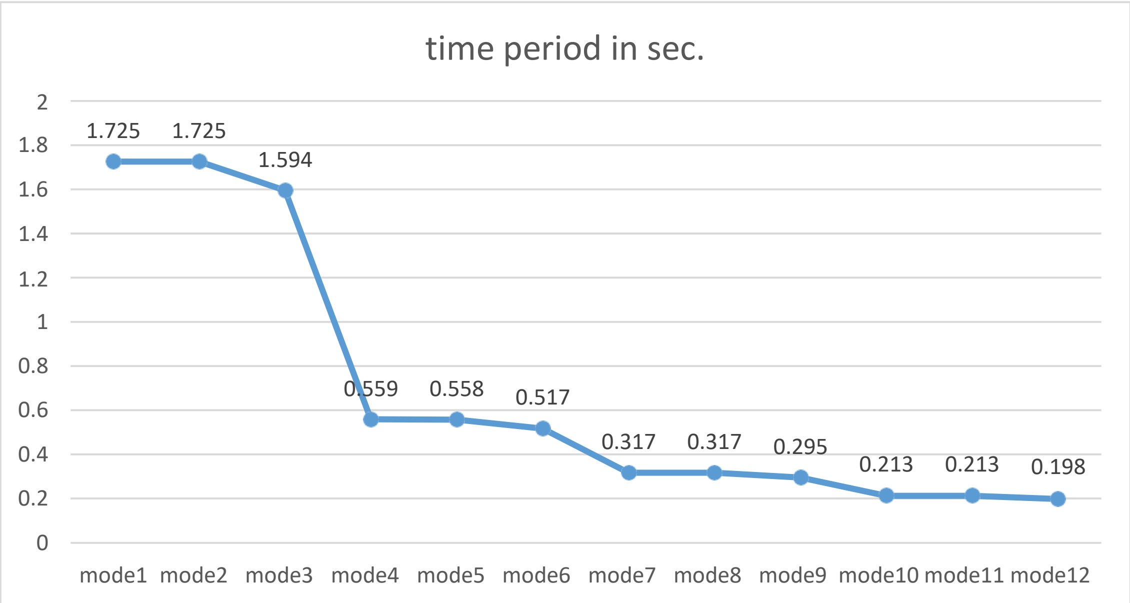


Fig 5.1 Mode period in sec. for Conventional Structure

Table 5.5 Mode period in sec. for Diagrid structure

Mode shape	time period in sec.
mode1	0.988
mode2	0.895
mode3	0.659
mode4	0.236
mode5	0.213
mode6	0.15

mode7	0.11
mode8	0.101
mode9	0.075
mode10	0.071
mode11	0.07
mode12	0.068

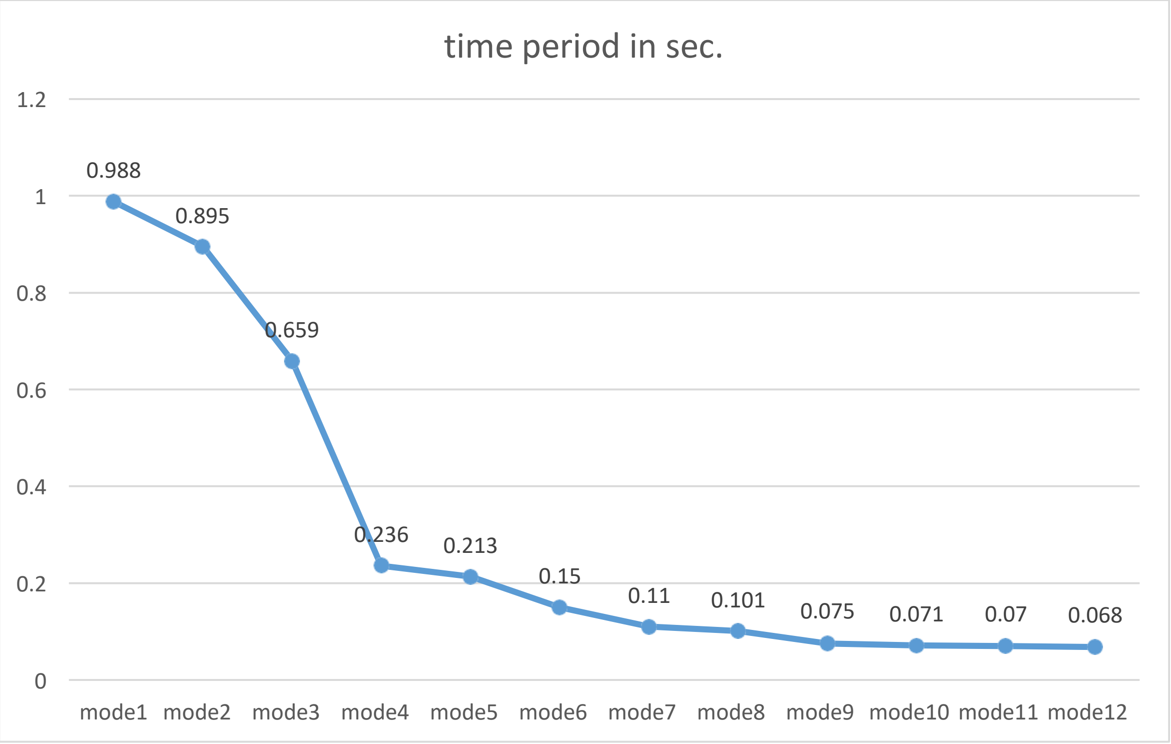


Fig 5.2 mode period in sec for diagrid frame

Storey displacement mm:

Table 5.6: Maximum displacement in mm

S.NO.	Storey displacement (mm)		
	Conventional Structure	Diagrid Structure	Hybrid Diagrid Structure
G+11	32.54	20.615	18.978
G+10	29.14	18.593	17.467

G+9	27.94	16.212	15.94
G+8	24.14	14.4365	13.347
G+7	21.34	12.354	11.232
G+6	18.54	10.307	9.839
G+5	15.74	8.118	7.142
G+4	12.94	6.142	5.527
G+3	10.14	4.772	3.307
G+2	7.34	2.527	1.976
G+1	4.54	0.839	0.519
BASE	0	0	0

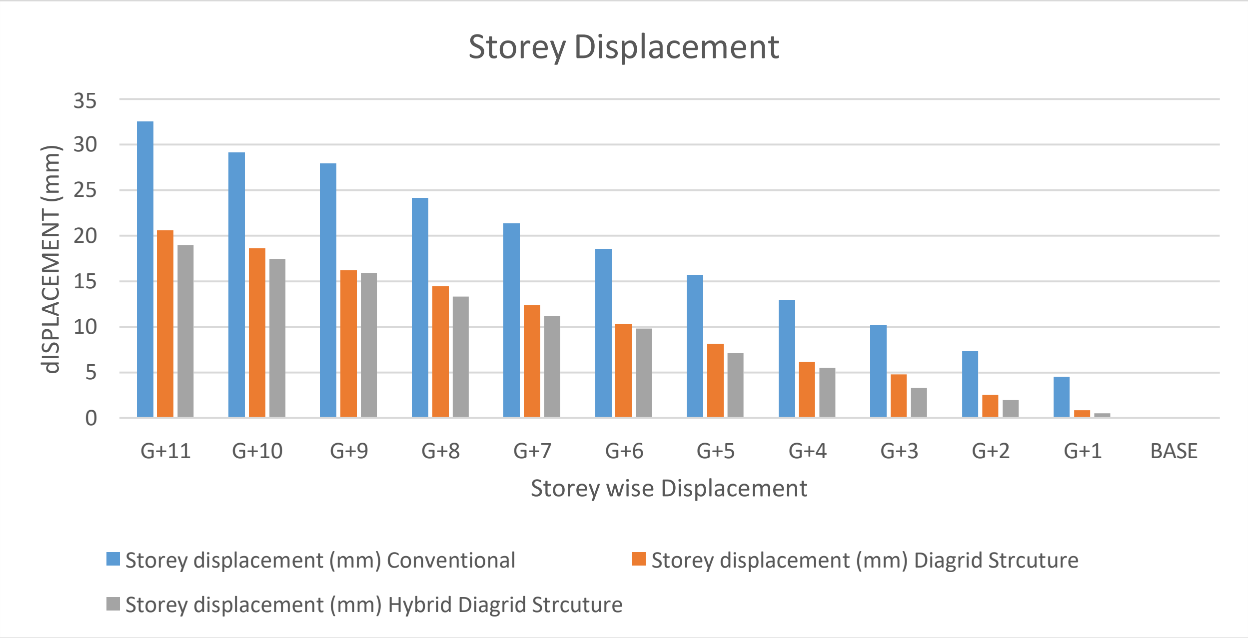


Fig 5.3: Maximum displacement in mm

Maximum Bending moment:

Table 5.7: Maximum bending moment kN-m

Bending Moment KN-m		
CONVENTIONAL STRUCTURE	DIAGRID STRUCTURE	Hybrid Diagrid Structure
882.372	365.843	298.743

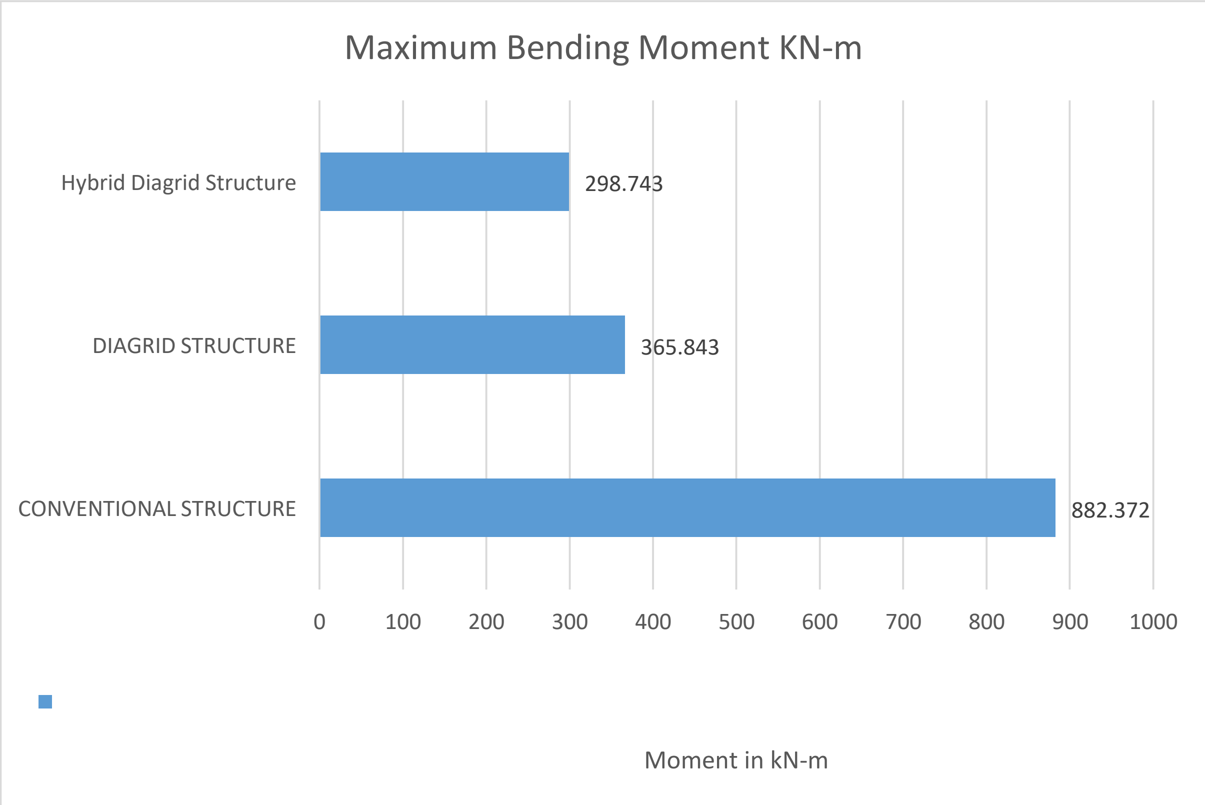


Fig 5.4: Maximum bending moment kN-m

Inferences:

As shown in fig 5.4 above, minimum moment is observed in Hybrid diagrid system which conclude that in this comparative study hybrid diagrid structure is comparatively more stable and economical than other two cases.

Maximum Shear force kN:

Table 5.8: Max. Shear Force kN

Shear Force KN		
CONVENTIONAL STRUCTURE	DIAGRID STRUCTURE	Hybrid Diagrid Structure
378.890	742.278	856.743

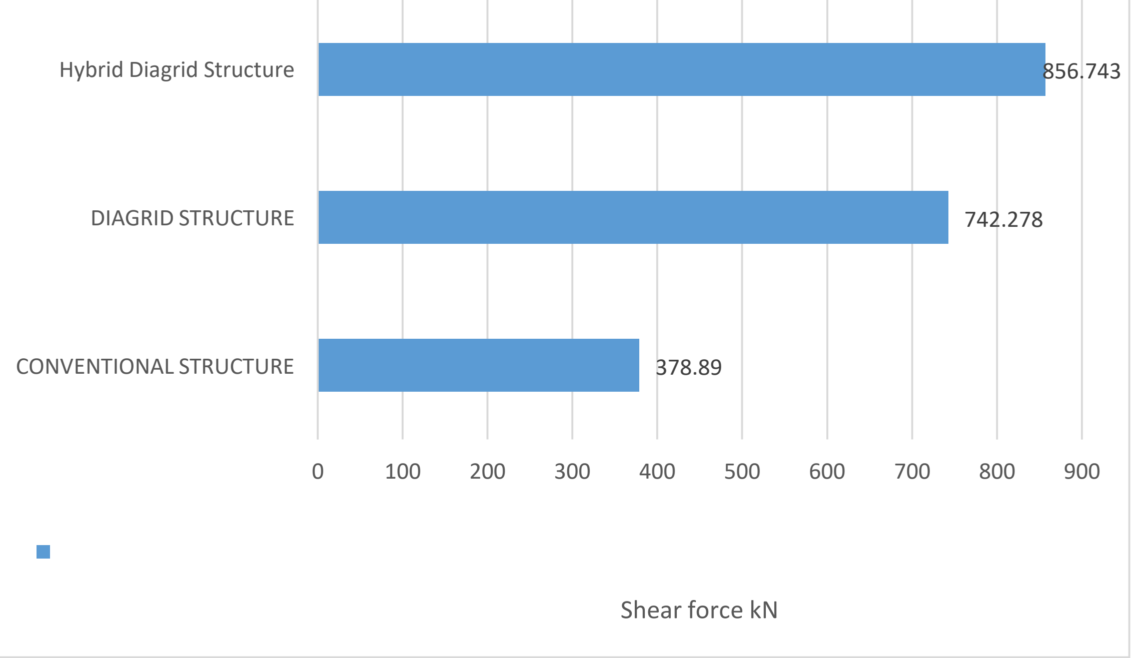


Fig 5.5: Max. Shear Force kN

Inferences:

As shown in above fig 5.5 it is observed that unbalance forces at the joint are maximum in hybrid diagridshape due to distributive members availability is more in that case.

5.2.6. Maximum Axial force kN:

Table 5.7: Max. Axial Force kN

Axial Force KN-m		
CONVENTIONAL STRUCTURE	DIAGRID STRUCTURE	Hybrid Diagrid Structure
5590.372	5789.646	5932.743

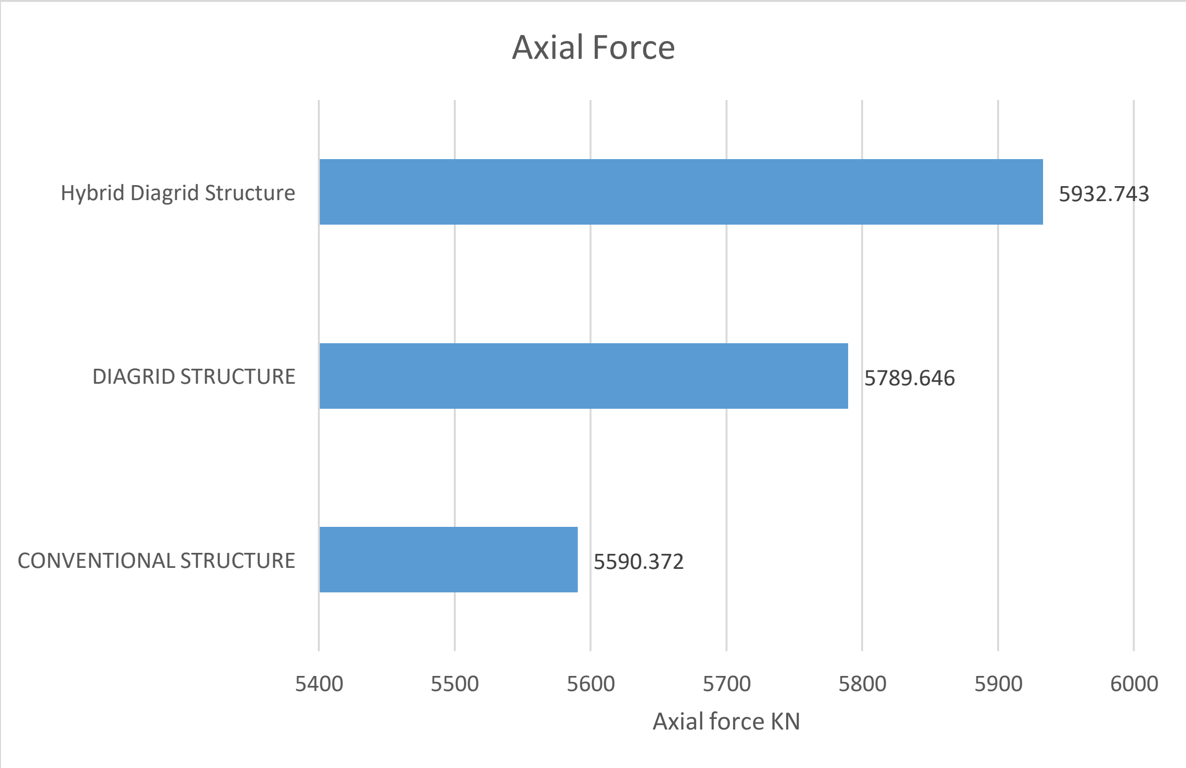


Fig 5.6: Max. Axial Force kN

Inferences:

As shown in figure 5.6 above it is observed that distribution of vertical forces in most precise in HybridDiagrid case whereas second best is Diagrid and third best is Conventional in our study.

Cost Analysis:

Table 5.8: Cost Analysis

Type	**concrete (cu.m)**	**Rebar (kg)**	**S.O.R. rate concrete**	**S.O.R. rate rebar**	**total concrete**	**total rebar**
Conventional Structure	352.75	2215.05	4500	56	1584000	124043

Diagrid Structure	302.98	2096.45	4500	56	1390009	117401
Hybrid Diagrid Structure	295.69	1998.32	4500	56	1330605	111906

Inferences:

As shown in Cost analysis as per S.O.R It is observed that in terms of cost hybrid diagrid structure is most economical as it observed most resistivity in resisting forces, moment and due to which it is stablein less dimensional sections.

V. CONCLUSION AND FUTURE SCOPE

CONCLUSION

From the present study it is concluded that both infill and diagrid structures are resisting lateral forces, but in comparison of both it is observed that diagrid structure is more stable, suitable and economical as compared to Infill structure.

Here are the following conclusion carried out are as follows:

- Max. Bending Moment (kN-m): The comparison determined less moment in a hybrid diagrid structure more economical than diagrid structure and conventional structure.
- Shear Force: This parameter went vice-verse as Conventional Structure presented less bending moment in comparison to Hybrid Diagrid Structure and Diagrid Structure due to its stiff structure resulting in less unbalanced forces.
- Axial Force: these vertical forces are maximum in approximately all the three cases.
- Displacement: Storey relocation is happening because of seismic sidelong powers and in the above section, it is unmistakably seen that Hybrid Diagrid structure is similarly additionally opposing and stable as far as storey savvy removal. As it is fit for opposing sidelong powers all the more precisely.
- Cost comparison: The material amounts for structures in all cases demonstrates that the Hybrid Diagrid structure is nearly demonstrating more prudent than different conditions.

Around 15% lesser concrete and 25% lesser steel are required for this situation contrast with others.

Conclusion Summary

In this relative examination, it is inferred that Hybrid Diagrid Structure at outside shows similarly more steadiness than different cases regarding opposing powers and moments. Likewise,as far as cost-adequacy Hybrid diagrid framework is most reasonable for parallel load opposing though Diagrid structure is second best while the exposed casing case demonstrates the most noticeably awful outcome. In this manner, it tends to legitimize
that diagrid outline is generally more steady than the exposed edge.

Future scope

1) In this study mid rise structure is considered whereas in future tall structure can be consider.
2) Effect of rigid diaphragm can be consider In future.
3) Wind analysis can be taken in future.

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Cite this article as :

Akash Sharma, Prof. Surendra Ahirwar, "Analysis of Diagrid Structure Resist Lateral Forces with Soft Soil Conditions", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 6 Issue 3, pp. 08-26, May-June 2022.

URL : https://ijsrce.com/IJSRCE226281