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AN ANALYTIC STUDY ON THE BEHAVIOR OF TYPES OF GRID SLAB SUBJECTED TO SEISMIC LOADING

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Abstract - *Grid slabs are a very popular structural configuration deployed for the construction of hotels porch, airport terminals, larger banquet hall, car parks. In this project work, an attempt is made to study the behaviour of the different types of grid slabs i.e. Diagonal grid slab, Square grid slab and Rectangular grid slab. These are studied and analyzed under Zone-II and Zone-IV. A G+9 storey with different types of grid slab structures is considered for this study and the models are analyzed with Gravity(DL+LL) and Lateral (earthquake) loads. These models modelled in E-tabs 2016 software and analysis is carried out using a Response Spectrum method as per Indian standard. The comparison is made on the three models for two different zones, for storey displacement, storey drift and storey stiffness, it was observed that the rectangular grid slab is more effective for both seismic zones compared to the other two grid slab.*

Key Words: Diagonal grid slab, Rectangular grid slab, Square grid slab, Response spectrum method, E-tabs2016

1. INTRODUCTION

Shelter is the most important need from the earliest civilizations. Different types of structures are designed for a better life. Researches on the comfort of the structure adopting the grid slab, safety with the grid slabs, aestheticism and the economy are carried out. The need for the construction of high-rise building in the urban area to accommodate due to exponential population growth is increasing in recent days

The grid slab is considered as a planar structure made up of two or more continuous members which may either intersect or cross each other. The grid slabs are used to cover the large areas without the obstruction of the vertical members and are adopted by most of the structures located all over the world. The gravity loads (like dead loads, live loads, etc..) applied to the structure are in the direction of the gravity or in the direction which is normal to the plane of the grid. The structure is known as a grid-slab as it is the inclusion of horizontal members which intersect each other continuously. The grid slab systems are widely used in the large spanned support buildings, bridges and overhead tank grids in addition to their good aesthetic appearance provide more benefits than various roofing systems.

Grid slab is most popularly used as the structural layout which is constructed in the hotel's porch, entrances of the airports' terminals, larger banquet hall, Convention or public Centre and car parking spaces. The void space under the grid slab is used for architectural lighting. Without using lots of additional features, the grid slab gives more stability and makes a grid-slab a perfect choice for large free areas. Grid slab is crack-resistant and most of the sagging is reduced. The grid-slab can hold the larger gravity loads like the floor loads as compared to normal concrete slabs. Introducing an opening in the grid slabs will reduce the strength of the grid slab.

Grid slabs are the composition of the closely spaced interconnected beams in both directions with the monolithic slab at the top of the interconnected beams. The figure shows a typical grid-slab which is shown fig(1). It may be termed as a thick slab on the top of grids. The volume of concrete in the tension zone and the compression zone is reduced. The beam here behaves as the T beam because they are cast as monolithic.

1.1 Types of grid Slab

Grid slab are classified based on the intersection of grids

1. Orthogrid

The term ortho means at the right angles. As referred to in the term, ortho grid-slabs are the slabs in which the grids of the beams may intersect perpendicular to each other. Orthogrids may have the layout of a square and rectangular grid.

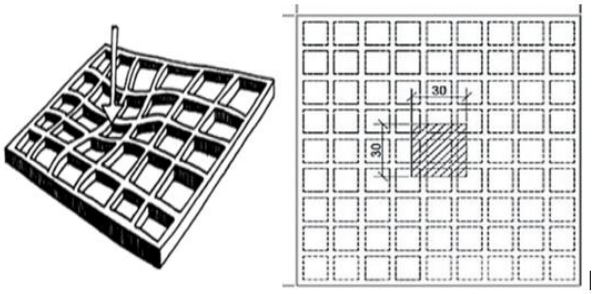


Fig-1: Orthogrid

2. Diagonalgrid

The beams in the diagonal grid slabs are cut across the diagonals for architectural perspective. The figure below shows the diagonal grid-slabs.

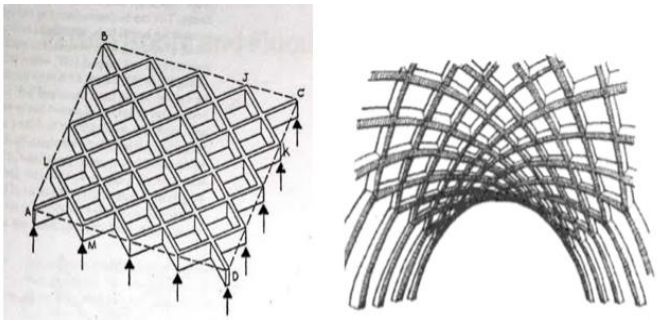


Fig-2: Diagonalgrid

1.2 Features of Grid Slab

1. They have used a flat surface.
2. No beam excavation is required.
3. They are above the ground.
4. Cardboard Slab panel are used.
5. Trench mesh or individual bars can have used.
6. The spacing of beams is usually 0.75mm to 1.5m sometimes even up to 2 m spacing should be provided.
7. The Depth of the beam kept around 1/25th to 1/20th of the grid-slab span based on the intensity.
8. The Width of the grid-slab beam should not be lesser than 1/3rd to 1/4th of depth.
9. The width of the panel should be at least 1/4th the depth of the rib or 65mm, whichever has the greater value.
10. The depth of the slab of the grid slab can have a slightly lesser depth.
11. The minimum depth of grid-slab required is equal to the sum of two times of the cover plus the diameter of the bar.
12. There is minimum concrete volume.
13. They used 30%less concrete and 20% less steel by the stiffened raft.

1.3 Advantages of Grid Slab

Grid slab can be used as both celling and floor slab.

1 Grid-slab can be used as both ceiling without the use of additional ceiling works for aesthetic perfections.

2 A grid Slab is used as the substitute for the obstruction-free space that is needed.

3 Most of the industrial buildings adapt to the grid-slabs as the metal and the timber grids are used in most of the temporary structures

4 Grid-slabs are used in the spaces where the structures need more stability

5 Used for special structures.

2. OBJECTIVES

The following are the objective of the present study

1. To analyses and study the structural behavior of various kinds of grid-slabs considered for the structure subjected to seismic loading.

3. Methodology

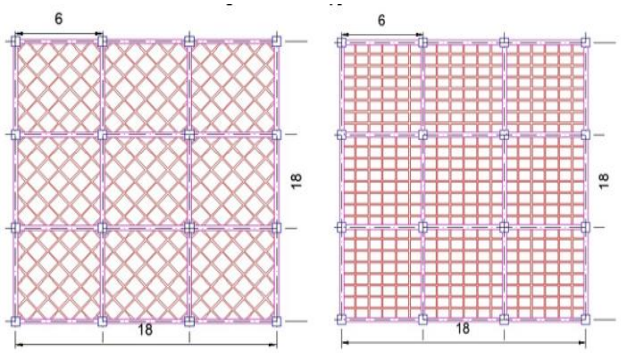
1. A study of literature on RCC framed multi-storey residential structure of G+9 of storey.
2. Preparation of frames layout on considering particular building dimensions and column spacing.
3. Modelling the prepared layout into ETABS software on assigning material specification and gravity loads.
4. Assigning the lateral seismic loads under seismic Zone II & IV separately.
5. Analysis of prepared model and understand the structural behaviour of model in both zones separately.
6. Comparative study on following parameters in consideration with both zones:
7. Storey-displacement, Storey-drift and Storey-stiffness .

3.1. Modelling

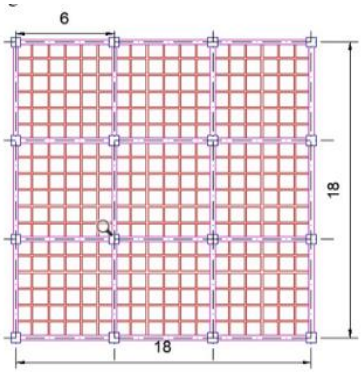
The commercial R C structures are modelled by using E-tabs software. The current project deals with the G+9 multi-storied R C Frame Structure located in zone II and zone IV as per Indian Standard codes is considered for the analysis. The designed frames structures are studied for Gravity and seismic loads for the response spectrum method. The structure is compared for maximum Storey Displacement, maximum Storey Drift and maximum Storey Stiffness. The below-shown models were considered for the analysis

1. Model -1: Diagonal grid slab

2. Model -2; Rectangular grid slab
3. Model -3: Square grid Slab



Model-1 Model-2



Model-3

Fig-3: Different Types of Grid Slab

3.2. **Methodology**

The activity of analysis and design of structure performance on CSI E-Tabs in accordance with IS456:2000, IS1893:2002, IS875:1987(Part1, Part2, Part3) is shown through the flow chart.

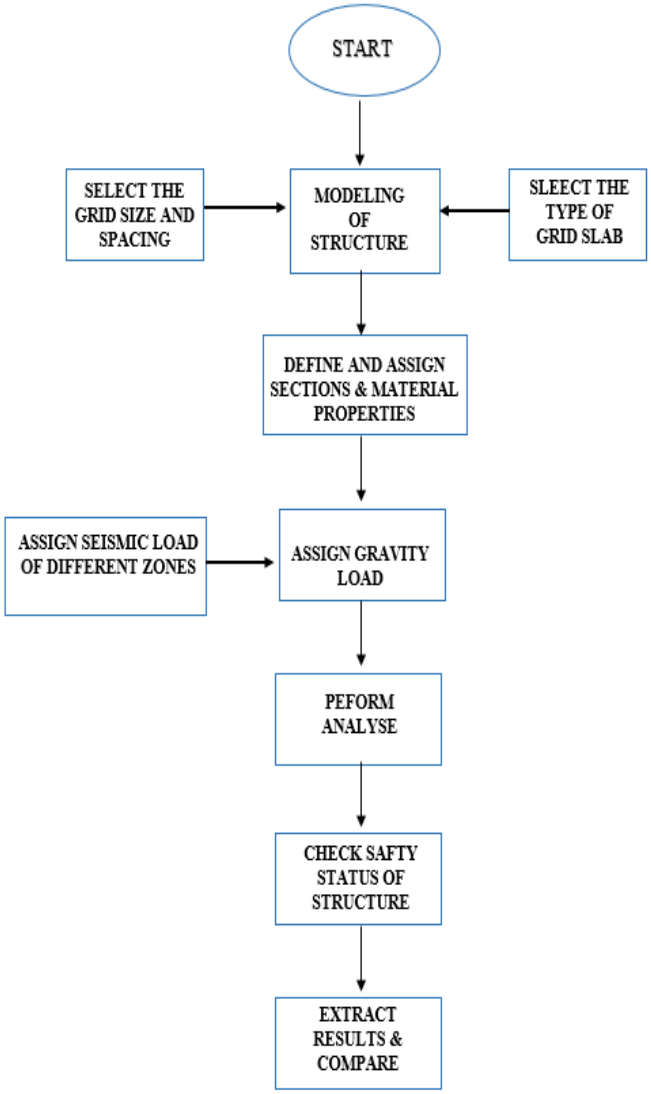


Fig-4: Flowchart

3.3. **Description of Structure**

Table-1: Material Properties

Sl , No	MATERIAL SPECIFICATION	
1	Grade of Concrete, M-30	Fck= 30 N/mm^2
2	Grade of Steel, Fe-500	Fy= 500 N/mm^2
3	Density of concrete	Y=25KN/m^3

Table-2: Structural detail and sectional properties

Sl , No	SPECIFICATIONS	DIFFERENT TYPES OF GRID SLAB		
		DIAGONAL GRID SLAB	RECTANGULAR GRID SLAB	SQUARE GRID SLAB
1	Plan	18mX18	18mX18m	18mX18

	Dimension	m		m
2	Length of Grid in X- direction	6m	6m	6m
3	Length of Grid in Y- direction	6m	6m	6m
4	Floor to Floor height	3.5m	3.5m	3.5m
5	No. of Stories	9	9	9
6	Plinth Level	2m	2m	2m
7	Slab Thickness	150mm	150mm	150mm
8	Size of Beam	300 X 600mm	300 X 600mm	300 X 600mm
9	Size of Column	600 X 600mm	600 X 600mm	600 X 600mm
10	Size of Grid	100 X 300mm	100 X 300mm	100 X 300mm
11	Spacing of Grid in X-direction	75mm	75mm	100mm
12	Spacing of Grid in Y-direction	75mm	75mm	75mm
13	Grade of concrete	M30	M30	M30
14	Grade of Steel	Fe-500	Fe-500	Fe-500

Table-3: Gravity Load Condition

GRAVITY LOADS	
Dead Load	Default values taken by E-tabs
Live Load	3 kN/m^2
Floor Finish	1kN/m2
Wall Load	12kN/m^2 (.23X2.9X18)

Table-4: Seismic Load Condition

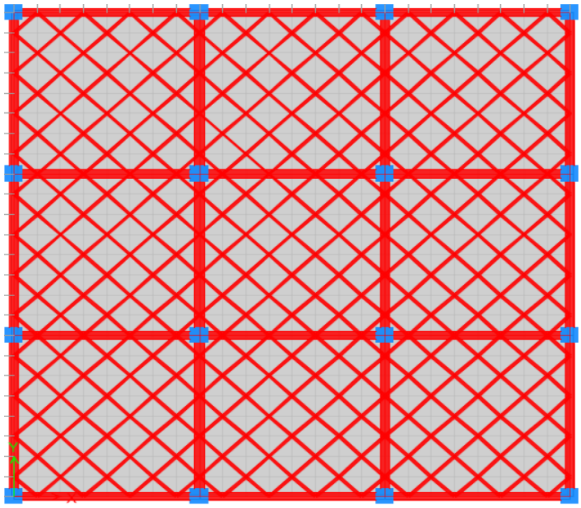
LATERAL LOADS(Seismic Load)		
Earthquake Zone	II	IV
Zone Factor, Z	0.1	0.24
Response Reduction Factor, R	3	3
Importance Factor ,I	1.5	1.5
Soil Type	Type 2 (Medium Soil)	Type 2 (Medium Soil)

Table-5: Wind Load Condition

Wind loads	
Wind Speed, Vb	33 m/s
Terrain Category	3
Structure Class	B
Risk co-effcient,k1	1
Topography,k3	1

3.4. **E-Tabs Models**

Fig-5: Plan, Elevation and 3D view of Diagonal Grid Slab



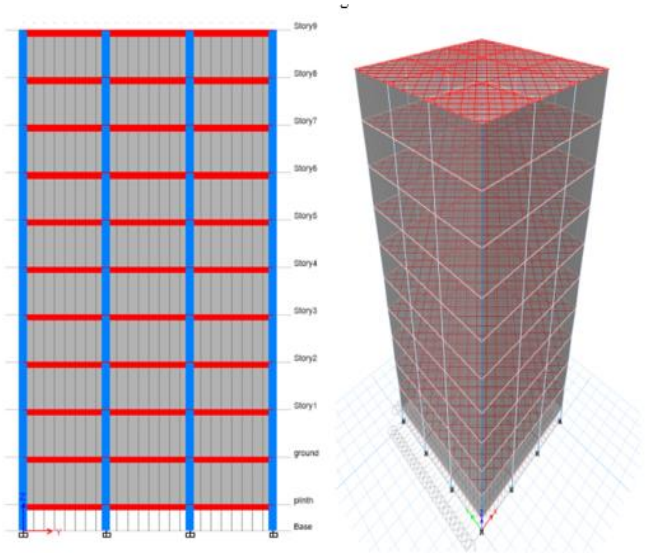


Fig-6: Plan, Elevation and 3D view of Rectangular Grid Slab

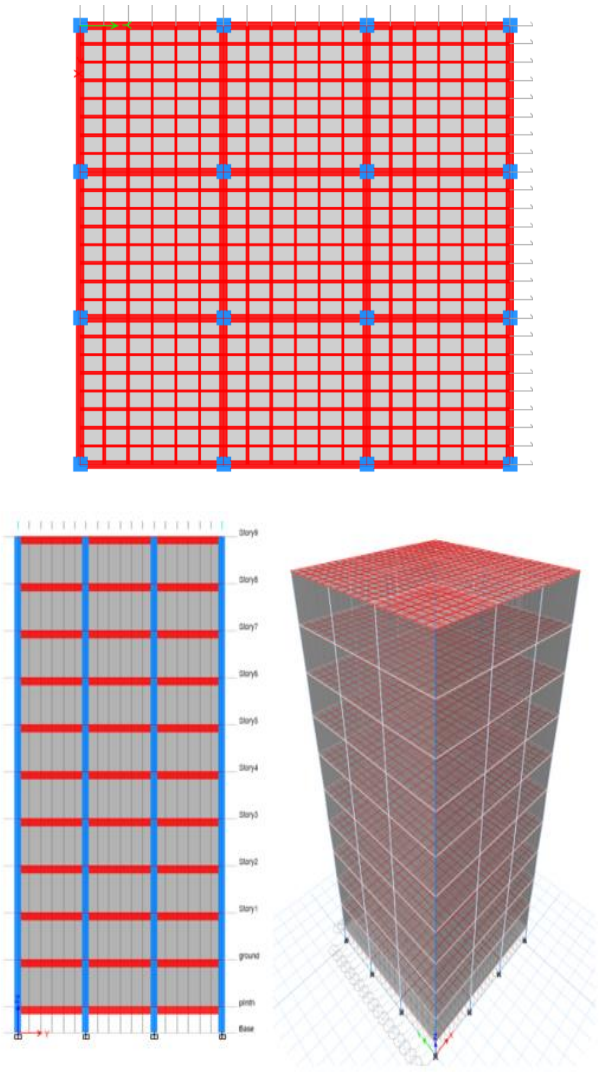
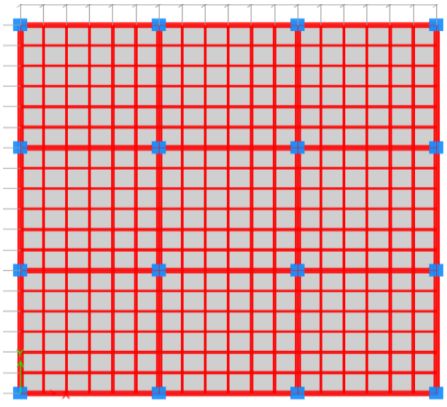
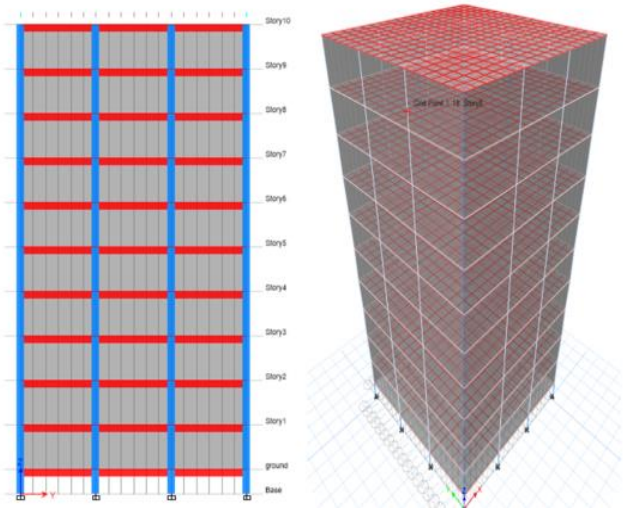


Fig-7: Plan, Elevation and 3D view of Square Grid Slab





4. Results and discussions

4.1. Storey Displacement for Earthquake Zone II

The comparison between Storey displacement of Seismic loading of Diagonal grid slab, Rectangular grid slab and square grid slab for seismic zone II as shown in table 6 below.

Story	Diagonal	Rectangular	Square
Base	0	0	0
plinth	0.462	0.4238159	0.429
ground	2.59	2.3202273	2.378
Story1	5.177	4.5204768	4.7
Story2	7.743	6.6667913	6.987
Story3	10.126	8.6578954	9.111
Story4	12.271	10.456912	11.028
Story5	14.157	12.043046	12.715
Story6	15.765	13.395237	14.15
Story7	17.067	14.486107	15.307
Story8	18.031	15.286386	16.156
Story9	18.665	15.794648	16.701

Table-6: Storey Displacement (mm)

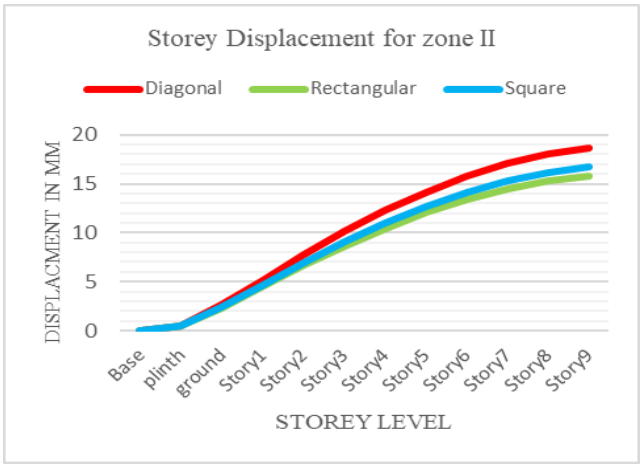


Fig-8: Storey Displacement by Response Spectrum

Figure 8: For Seismic Zone II, the graph is plotted for Storey number in X-direction & displacement in Y-direction. The graph express that the storey displacement of the diagonal slab is 1.1% to 1.2% greater than the square and rectangular grid slab.

4.2. Storey Displacement for Earthquake Zone IV:

The comparison between Storey displacement of Seismic loading of Diagonal grid slab, Rectangular grid slab and square grid slab for seismic zone IV as shown in table 7 below.

Story	Diagonal	Rectangular	Square
Base	0	0	0
plinth	1.109	1.017	1.029
ground	6.216	5.569	5.707
Story1	12.426	10.849	11.28
Story2	18.583	16	16.769
Story3	24.301	20.779	21.867
Story4	29.45	25.097	26.468
Story5	33.977	28.903	30.516
Story6	37.837	32.149	33.961
Story7	40.961	34.767	36.737
Story8	43.276	36.687	38.774
Story9	44.795	37.907	40.081

Table-7: Storey Displacement (mm)

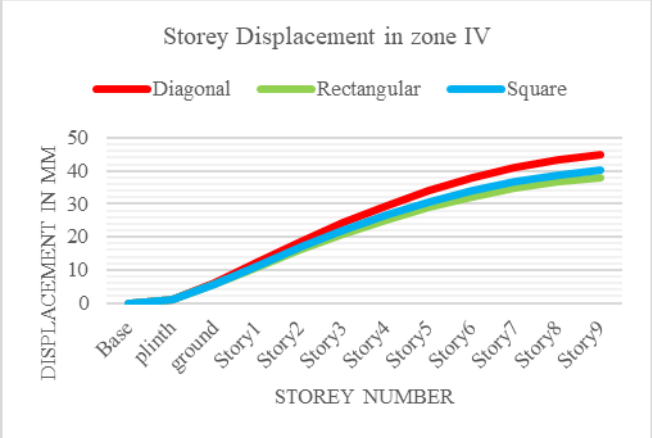


Figure 9: For Seismic Zone IV, the graph is plotted for Storey number in X-direction & displacement in Y-direction. The graph express that the storey displacement of the diagonal slab is 1.1% to 1.2% greater than the square and rectangular grid slab.

4.3. Storey Drift for Earthquake Zone II:

The comparison between Storey drift of earthquake loading of Diagonal grid slab, Rectangular grid slab and square grid slab for seismic zone II as shown in table 8 below.

Story	Diagonal	Rectangular	Square
Base	0	0	0
plinth	0.000231	0.000212	0.000214
ground	0.000608	0.000542	0.000557
Story1	0.000741	0.00063	0.000665
Story2	0.00074	0.000619	0.000659
Story3	0.0007	0.000582	0.000622
Story4	0.000649	0.000538	0.000575
Story5	0.000594	0.000489	0.000523
Story6	0.000529	0.000432	0.000462
Story7	0.000448	0.000361	0.000387
Story8	0.000345	0.000273	0.000294
Story9	0.00023	0.000174	0.000191

Table-8: Storey Drift

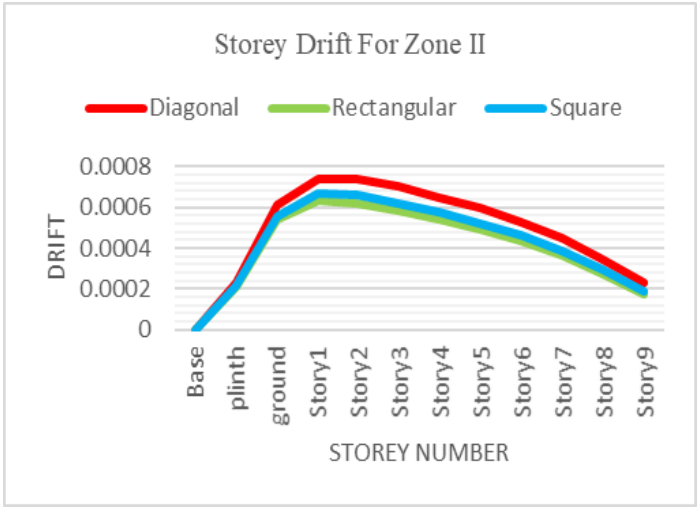


Fig-10: Storey Drift by Response Spectrum

Figure 10: For Seismic Zone II, the graph is plotted for Storey number in X-direction & storey drift in Y-direction. The graph express that the storey drift of the diagonal slab is 1.2% to 1.3% greater than the square and rectangular grid slab.

4.4. Storey Drift for Earthquake Zone IV:

The comparison between Storey drift of earthquake loading of Diagonal grid slab, Rectangular grid slab and square grid slab for seismic zone IV as shown in table 9 below.

Story	Diagonal	Rectangular	Square
Base	0	0	0
plinth	0.000555	0.000509	0.000514
ground	0.001459	0.0013	0.001337
Story1	0.001778	0.001511	0.001595
Story2	0.001777	0.001484	0.001582
Story3	0.00168	0.001397	0.001492
Story4	0.001558	0.001292	0.00138
Story5	0.001425	0.001174	0.001255
Story6	0.001271	0.001036	0.001109

Story7	0.001075	0.000866	0.000928
Story8	0.000828	0.000654	0.000705
Story9	0.000553	0.000419	0.000458

Table-9: Storey Drift

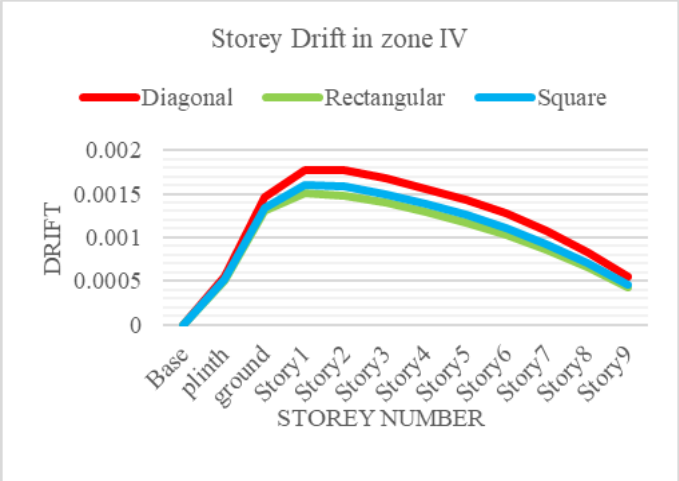


Fig-11: Storey Drift by Response Spectrum

Figure 11: For Seismic Zone II, the graph is plotted for Storey number in X-direction & storey drift in Y-direction. The graph express that the storey drift of the diagonal slab is 1.2% to 1.3% greater than the square and rectangular grid slab.

4.5. Storey Stiffness for Earthquake Zone II and IV:

The comparison between Storey Stiffness of earthquake loading of Diagonal grid slab, Rectangular grid slab and square grid slab for seismic zone II and IV as shown in table 10 below.

Story	Diagonal	Rectangular	Square
Base	0	0	0
plinth	1038735.1	1380643.1	1192846.52
ground	224931.95	309385.11	261538.969
Story1	175865.29	256475.98	209661.913
Story2	163637.87	244845.35	197616.904
Story3	159696.37	240658.09	193663.77
Story4	158363.98	238271.16	191957.031
Story5	158581.35	236910.97	191511.173
Story6	159403.7	235831.33	191518.961
Story7	159787.58	234023.91	191012.46
Story8	157038.5	228246.97	187052.112
Story9	128457.77	189835.97	154110.105

Table-10: Storey Stiffness

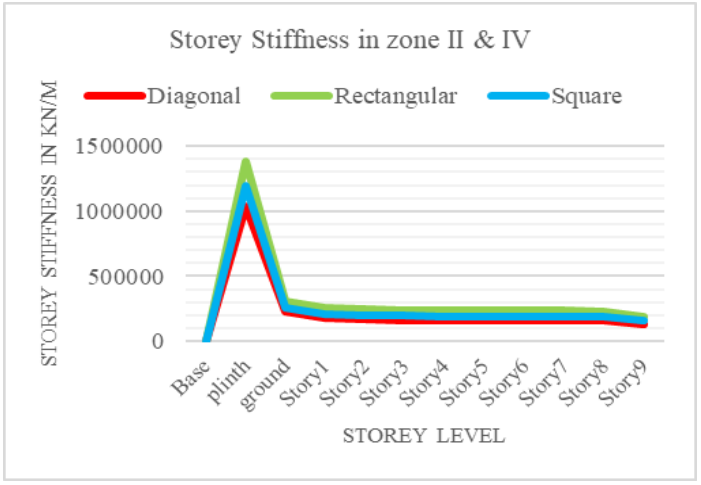


Fig-12: Storey Stiffness by Response Spectrum

Figure 12: For Seismic Zone II & IV, the graph is plotted for Storey number in X-direction & storey Stiffness in Y-direction. The graph express that the storey Stiffness of the Rectangular slab is 1.2% to 1.3% greater than the square and diagonal grid slab.

5. CONCLUSIONS

The behaviour of G+9 multi-Storey building with different types of grid slab (Square, Rectangular and Diagonal) with two different seismic zones is studied by comparing various parameters such as Storey displacement, Storey drift and Storey stiffness.

Based on the above results obtained it can be concluded that the rectangular grid slab is more effective for both seismic zones compared to square and diagonal grid slab. The storey displacement and storey drift found in rectangular grid slab is comparatively lower than that of square and diagonal grid slab for seismic zone II and zone IV because the relationship between storey displacement and storey stiffness is inversely proportional to each other. Hence the stiffness of the rectangular grid slab is higher than the Square and Diagonal grid slab.

The diagonal grid slab shows more storey displacement and storey drift compared to that of rectangular and square grid slab. Hence the stiffness of the diagonal grid slab is less. So the diagonal grid slab sways more compared to the other two grid slabs and the damage caused by the earthquake to the diagonal grid slab structure will be higher.

The result also reflects that the studied properties of the square grid slab lie in between the rectangular and diagonal grid slab.

Hence Rectangular and Square grid slab should be preferred over the Diagonal grid slab.

Scope for Future Work

- The analysis and design of grid slab structures can be done by using linear static analysis, non-linear static analysis and non-linear dynamic analysis.
- The earthquake resisting structure can be used for analysis to increase the effectiveness of the structure.
- Check the stability of the grid slab structure for wind analysis for different shape of grid slab.
- The analysis and design of grid slab structure with regular and irregular shape buildings.
- Check the stability of the grid slab for composite structure.

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