International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 01 | Jan-2018 www.irjet.net p-ISSN: 2395-0072

COMPARATIVE STUDY OF RIGID AND FLEXIBLE FLOOR DIAPHRAGM

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Abstract - *In this study, seismic analysis of multistory reinforced concrete structure has been carried out by considering two types of floor diaphragm. The floor diaphragm means the interaction of the lateral load with lateral load resisting vertical elements is achieved by the use of floor system. For the analysis E-tabs software has been used, the analysis was carried out in structure with two different floor diaphragm, that is rigid floor diaphragm and flexible floor diaphragm. And this comparative study is done with two different type of structures, that is structure without shear wall and structure with shear wall and the results are collected in terms of Maximum storey displacement, Maximum storey drifts, Storey Shear, and Storey Stiffness for Z-II and Z-V.*

Index Terms *– Rigid diaphragm, flexible diaphragm, analysis using E-Tabs, storey displacement, storey drift, storey stiffness, storey shear.*

1. INTRODUCTION:

Diaphragm implies the interaction of the lateral load with lateral-force-resisting vertical components is accomplished by the utilization of floor frameworks that for the most part have substantial in-plane stiffness. Thus, the aggregate horizontal load resistance includes the vertical load resisting components in extent to their particular stiffness. Floors can go about as diaphragm as a result of its huge in-plane stiffness. Transmitting the inertial forces generated by the ground movement of floor mass at an level offered to horizontal force resisting vertical components produced by ground movement is the main capacity of the floor diaphragm. At bring down story, huge lateral load should be exchanged starting with one component then onto the next component causing noteworthy shear forces and bending moments in the diaphragm.

2. DIFFERENT TYPES OF DIAPHRAGM:

2.1 RIGID DIAPHRAGM: When the diaphragm is at midpoint displacement then it is considered as Rigid under lateral load and it is less than twice the average displacements at its ends. It also distributes the lateral forces to the vertical elements in direct proportion to the relative rigidities. It is based on the assumption that the each vertical will cause some deflection some amount and diaphragm does not deform itself. It will also transfer torsional, shear deflections and also forces based on the assumption, that the diaphragm and this will produce additional shear force in the shear wall that undergoes rigid body rotation.

2.2 SEMI-RIGID DIAPHRAGM: For the analysis the assumptions made that the semi-rigid diaphragm can be made as to a diaphragm's rigidity or flexibility because the diaphragm is neither perfectly rigid nor perfectly flexible, but in some cases the diaphragm deflection and the vertical lateral load-resisting elements can be of same magnitude only in semi-rigid diaphragm.

2.3 FLEXIBLE DIAPHRAGM: Diaphragms are considered as flexible when the midpoint displacement, under lateral load, exceeds twice the average displacement of the end supports and also when the maximum lateral deformation of the diaphragm is more than two times and the average story drift of the associated story. It may be determined by comparing the computed midpoint in-plane deflection of the diaphragm itself under lateral load with the drift to adjoining vertical elements under tributary lateral load.

3. PROBLEM MODELING:

Table 1: Structural details

SL. No.	Description	Details
01	Total height of building	90.5 m
02	No. of stories	30
03	Height of each storey	3.0 m
04	Height of ground storey	3.5 m
05	Grade of concrete	M30 for beams and columns M25 for slab
05	Grade of steel	Fe500
06	Depth of slab	125 mm
07	Size of beams	300 x 500 mm upto 10stories 250 x 400 mm 11-20 stories 200 x 350 mm 21- 30 stories
08	Size of columns	700 x 700 mm upto10 stories 600x 600 mm 11-20 stories 500 x 500 mm 21-30 stories
09	Codes	IS 456:2000, IS 875-1987 (Part II) - Live Loads/ Design Loads, IS 875 (Part III): 1987 - For Wind oads IS 1893 (Part 1): 2002 – For Earthquake designing

Table 3.2: Loading Details

Live Load	Typical floor - 1.4 kN/m Terrace Floor - 1.9 kN/m
Super imposed Dead Load (SIDL)	Typical floor - 1.8 kN/m Terrace Floor - 1.2 kN/m
Zones	Zone-II and Z-V
Zone factor	0.10 and 0.36
Importance factor	1
Response reduction	5
Soil type	III

4. MODELING OF STRUCTURE: The modeling of the structure was carried out in two cases for Zone-II and Zone-V with consideration of Rigid and Flexible diaphragm.

Case 1: RC Framed Structures

Case 2: Shear-wall structures

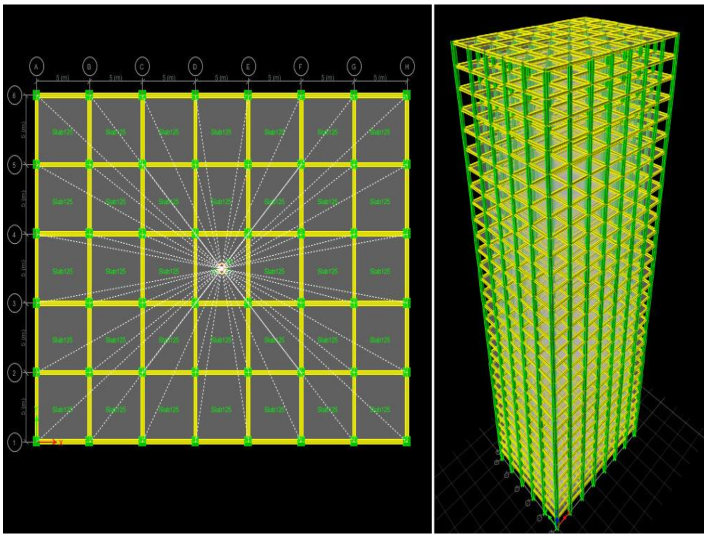

Fig.1: Extrude plan and 3D-view of structure

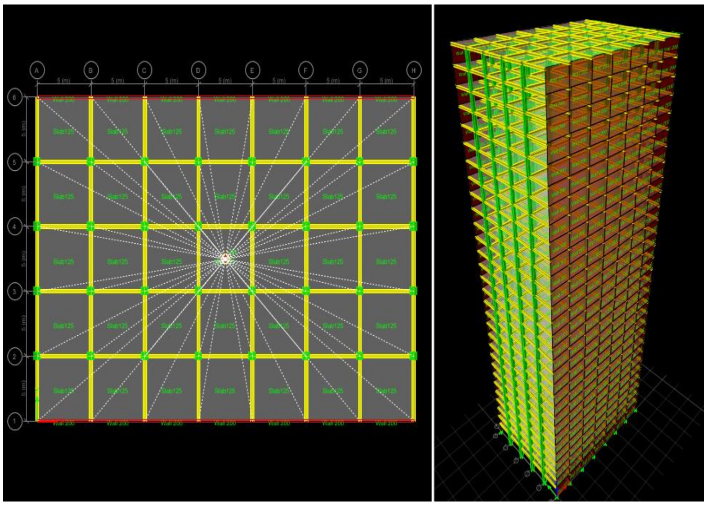

Fig.2: Extrude plan and 3D-view of shear wall structure (X-direction)

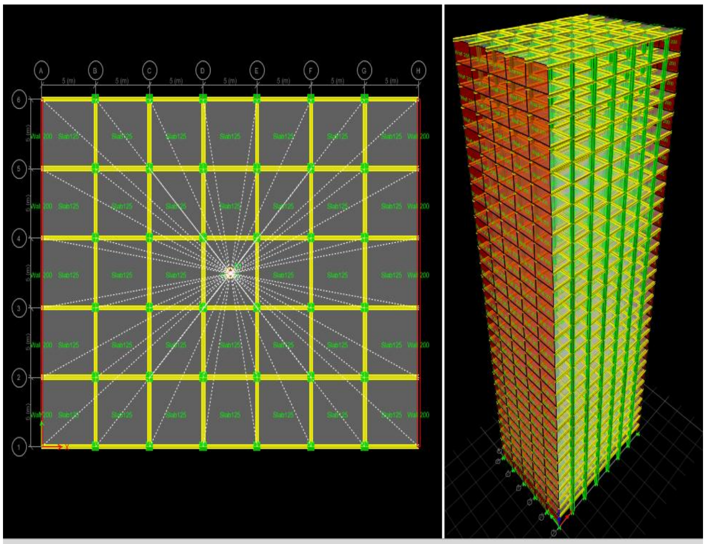

Fig.3: Extrude plan and 3D-view of shear wall structure (Y-direction)

5. RESULTS AND DISCUSSION:

5.1 RESLTS FOR DISPLACEMENT:

Table 3: Displacement values for Z-II in X and Y directions

STOREY DISPLACEMENT VALUES FOR Z-II				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	132.209	94.021	119.809	84.815
SHEAR WALLS IN X-DIRECTION	8.947	8.657	113.723	80.378
SHEAR WALLS IN Y-DIRECTION	126.519	90.08	12.714	13.738

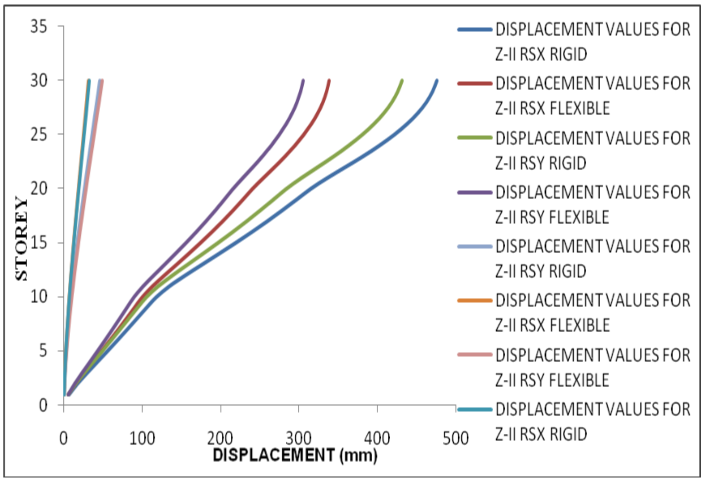

Fig. 4: Displacement comparison for Z-II

Table 4: Displacement values for Z-V in X and Y directions

STOREY DISPLACEMENT VALUES FOR Z-V				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	475.951	338.453	431.312	305.318
SHEAR WALLS IN X-DIRECTION	32.21	31.165	409.401	289.36
SHEAR WALLS IN Y-DIRECTION	455.486	324.288	45.772	49.457

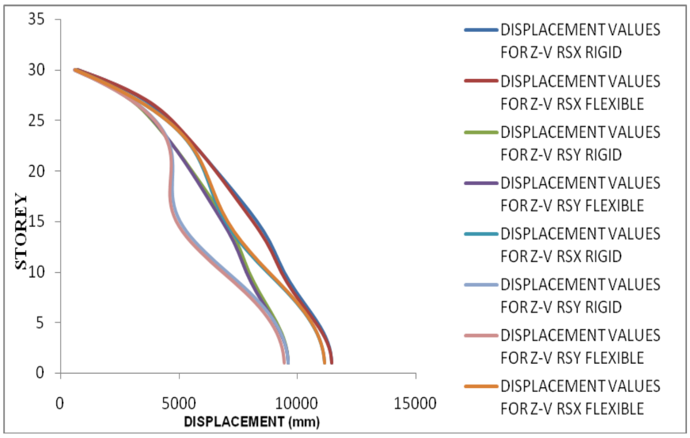

Fig. 5: Displacement comparison for Z-V

5. Discussion on Displacement Values

For the framed structures the displacement in both directions reduced for flexible diaphragm as compared to rigid diaphragm. The displacement at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 30% less than the rigid diaphragm models.

For the models with shear walls in X-direction in both Z-II and Z-V, The displacement at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 3.5% and 29% less than the rigid diaphragm model respectively. And the structures in which the shear walls are placed in Y-direction in both Z-II and Z-V, the displacement at 30th floor for SPEC-X and SPEC-Y values for flexible diaphragm models it is 29% and 7.5% less than the rigid diaphragm models.

Table 5: Drift values for Z-II in X and Y directions

STOREY DRIFT VALUES FOR Z-II				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	0.000666	0.000385	0.000632	0.000375
SHEAR WALLS IN X-DIRECTION	0.000121	0.000115	0.000567	0.000312
SHEAR WALLS IN Y-DIRECTION	0.000653	0.000348	0.000185	0.000196

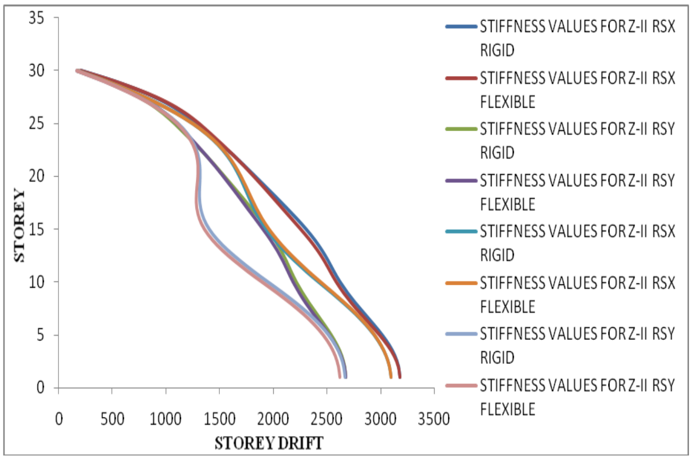

Fig. 6: Drift comparison for Z-II

Table 6: Drift values for Z-V in X and Y directions

STOREY DRIFT VALUES FOR Z-V				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	0.002399	0.001376	0.002277	0.001342
SHEAR WALLS IN X-DIRECTION	0.000436	0.000416	0.00204	0.00124
SHEAR WALLS IN Y-DIRECTION	0.002349	0.001252	0.000664	0.000707

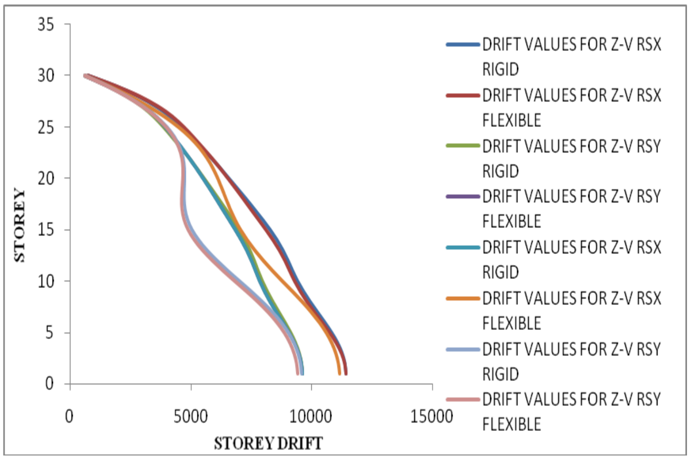

Fig. 7: Drift comparison for Z-V

6. Discussion on Drift Values

In framed structures it reaches the highest value in the middle portion of the building that is 14th and 22nd floor in both directions for both Z-II and Z-V. The drift values at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 42% and 41% less than the rigid diaphragm models respectively.

In case of shear wall structures where as shear walls are placed in X-direction the drift values at SPEC-X are gradually increases upto 24th floor and above that the values are decreased gradually, For those models in both Z-II and Z-V, The drift vale at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 5% and 45% less than the rigid diaphragm model respectively. In another case shear walls are placed in Y-direction the values for SPEC-Y are gradually increases upto 25th floor and after that it is decreased, And the structures in which the shear walls are placed in Y direction in both Z-II and Z-V, the drift at 30th floor for SPEC-X and SPEC-Y values for flexible diaphragm models it is 46% and 6% less than the rigid diaphragm models.

Table 7: storey stiffness values for Z-II in X and Y directions

STOREY STIFFNESS VALUES FOR Z-II				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	102224.183	176081.176	90421.296	151502.182
SHEAR WALLS IN X-DIRECTION	481326.345	501339.656	123127.2	210513.8
SHEAR WALLS IN Y-DIRECTION	132455.528	228829.244	305282.316	284918.728

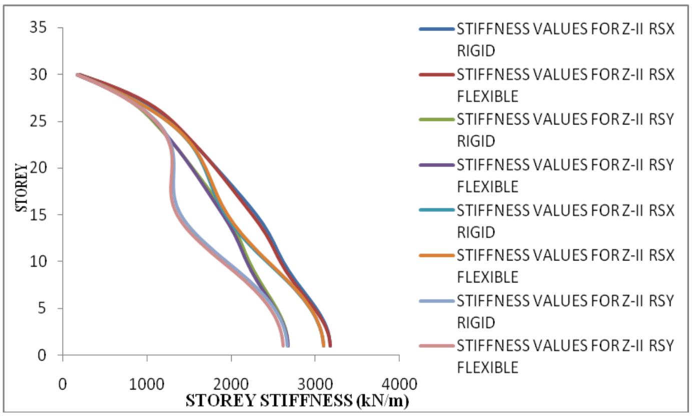

Fig. 8: storey stiffness comparison for Z-II

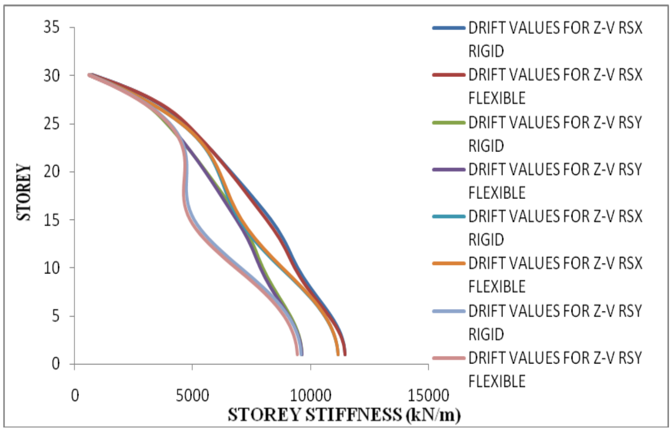

Fig. 9: storey stiffness comparison for Z-V

Table 8: storey stiffness values for Z-V in X and Y directions

STOREY STIFFNESS VALUES FOR Z-V				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	102224.183	176396.004	90421.296	151708.87
SHEAR WALLS IN X-DIRECTION	481326.345	501339.656	123127.202	210513.792
SHEAR WALLS IN Y-DIRECTION	132455.528	228829.244	305282.3	284918.7

7. Discussion on Stiffness Values:

In framed structures it reaches the highest value in the ground floor of the building that is 1st floor in both directions for both Z-II and Z-V. The stiffness values at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 42% and 40% more than the rigid diaphragm models respectively.

In case of shear wall structures for those models in both Z-II and Z-V, The stiffness value at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 4% and 42% more than the rigid diaphragm model respectively. And the structures in which the shear walls are placed in Y-direction in both Z-II and Z-V, the stiffness value at 30th floor for SPEC-X and SPEC-Y values for flexible diaphragm models it is 42% and 7% more than the rigid diaphragm models.

Table 9: storey shear values for Z-II in X and Y directions

STOREY SHEAR VALUES FOR Z-II				
MODEL	SPEC-X		SPEC-Y	
	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	204.360	202.321	171.573	169.7133
SHEAR WALLS IN X-DIRECTION	174.724	173.618	209.361	197.177
SHEAR WALLS IN Y-DIRECTION	259.293	238.768	169.027	167.885

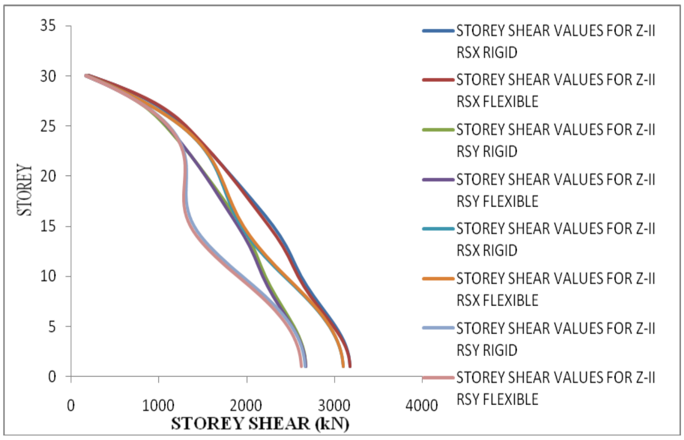

Fig. 10: storey shear comparison for Z-II

Table 10: storey shear values for Z-V in X and Y directions

STOREY SHEAR VALUES FOR Z-V				
	SPEC-X		SPEC-Y	
MODEL	RIGID	FLEXIBLE	RIGID	FLEXIBLE
FRAMED STRUCTURE	735.699	728.364	617.665	610.975
SHEAR WALLS IN X-DIRECTION	629.010	625.027	753.700	709.837
SHEAR WALLS IN Y-DIRECTION	933.493	859.5659	608.500	604.3866

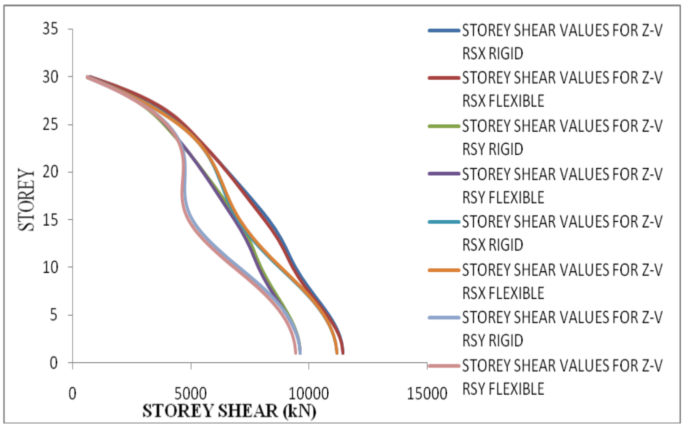

Fig. 11: storey shear comparison for Z-V

8. Discussion on Storey Shear Values:

In framed structures for both Z-II and Z-V, The storey shear values at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 1% and 1.5% less than the rigid diaphragm models respectively.

In case of shear wall structures for those models in both Z-II and Z-V, The storey shear value at 30th floor for both SPEC-X and SPEC-Y values for flexible diaphragm models, it is 1% and 6% less than the rigid diaphragm model respectively. And the structures in which the shear walls are placed in Y-direction in both Z-II and Z-V, the storey shear value at 30th floor for SPEC-X and SPEC-Y values for flexible diaphragm models it is 8% and 1% less than the rigid diaphragm models.

9. CONCLUSION

- Rigid floor diaphragm posse's high displacement and the risk of deflection during earthquake is more as compared to flexible floor diaphragm and displacement in the framed structure is more as compared to the shear wall structures.
- The drift will be more in framed structures as compared to the shear wall structures due to lack of stiffness in structure and flexible floor diaphragm posses less drift than rigid floor diaphragm.
- The building stiffness is more in the shear wall structures due to the presence of shear wall in the structure and the flexible floor diaphragm will provide more stiffness to the structure than rigid floor diaphragm.
- Storey shear is mainly depends on the type of soil and the flexible floor diaphragm will have less storey shear than rigid floor diaphragm in both framed structures and shear wall structures.

10. SCOPE OF FUTURE WORK

- We can also study the Shear force and bending moment, time period etc.
- We can study other type of floor diaphragm that is without diaphragm and semi rigid Diaphragm, in different Zones and different type of soil condition.
- We can also study for the various kinds of structures, that are irregular structures, vertical irregular structures etc.

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