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Effect of Diaphragm Action on Moment Resisting Frames Under Seismic Load

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Abstract In the multi-storey R.C. frame buildings, brick masonry infill is common in practice. The analytical modelling of infill frame is a very complex. It shows a highly non-linear behaviour under the action of lateral forces. Also, the irregular distribution of infill in the building may cause the torsion or sway effect. This study's primary goal is to determine how these infill modelling methodologies affect the frame's overall reaction. Nonlinear static analysis is done and the infill is modelled as a single strut, double strut, shell element, etc. The various modelling approaches of infill are used in those building models. By comparing results, the suitability and accuracy of modelling method is examined. The effect of soft storey in building is also studied. This study demonstrates how the capacity of a building is increased by infill. The global behaviour of infill is satisfactorily represented by single strut method. The triple strut method is found to be explaining local failure of frames and frame-infill separation. The non-linear hinge formation pattern is also studied. The hinge formation pattern shows failure pattern of elements in frames.

Keywords *R.C. frame, infill frame, non-linear behaviour, static analysis, suitability and accuracy, soft storey, single strut method, non-linear hinge, failure pattern*

Introduction Vertical structural elements like shear walls and frames resist the generated internal forces that are transferred to frame elements through floor slabs when building structures are subjected to earthquake loadings. The floor slabs in this case serve as a diaphragm that is positioned in between the vertical elements. The diaphragms are often assumed to be fully rigid in the analysis and design of three-dimensional structures under seismic loadings, meaning that lateral forces must be distributed across various frames based on their stiffness. However, in some kinds of constructions, such as framewall structures, where the vertical components are made up of relatively flexible frames and shear walls with high story stiffness, this assumption is found to produce a considerable mismatch. The floor slab (diaphragm) joining two adjacent vertical elements would endure considerable plain shear when there is a substantial variation in their story stiffness. The floor slab would then bend in a plane as a result of the severe shear.

Floor diaphragm refers to the utilization of floor systems, which typically have considerable in-plane stiffness, to achieve the interaction of the lateral load with lateral-forceresisting vertical parts. Accordingly, the vertical loadresisting components will, in proportion to their inherent stiffness, contribute to the overall lateral load resistance. Floors' significant in-plane rigidity makes them suitable for use as a diaphragm. The primary purpose of the floor diaphragm is to transfer the inertial forces produced by the floor mass's ground motion at a certain level to the vertical parts that resist lateral forces caused by the ground motion. Considerable lateral loads must be transferred from one part to another at lower storey's, which results in the diaphragm experiencing considerable shear stresses and bending moments.

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A diaphragm is a structural system used in structural engineering that transfers lateral loads, mostly through inplane shear stress, to shear walls or frames. Typically, lateral loads are caused by earthquake and wind. Semi-rigid and rigid diaphragms are the two main varieties.

Rigid Diaphragm The vertical load-resisting elements

(frames, shear walls) in the rigid floor diaphragm receive the lateral forces in accordance to their respective stiffnesses. The in-plane displacement under lateral load is seen as being equal along its whole length in the rigid diaphragm idea. This rigid diaphragm idea makes sense for structures with approximately square floor plans. One type of rigid diaphragm is a concrete floor that is laid case-inplane.

Semi-rigid Diaphragm The diaphragm can never be completely flexible or rigid in reality. However, a semirigid diaphragm can be made as to a diaphragm's rigidity or flexibility in order to simplify the analysis with reasonable assumptions. In some cases, though, the diaphragm deflection and the vertical lateral load-resisting (VLLR) elements can only be of the same magnitude in semi-rigid diaphragms. Although the diaphragm's size and rigidity are crucial, they do not ultimately determine whether it will function in a rigid, flexible, or semi-rigid manner. Because of their relative stiffness, rigid diaphragms like steel decks can partially distribute lateral rigid forces among the VLLR elements.

Diaphragms classified as semi-rigid or semi-flexible exhibit notable deflections when subjected to stress, yet maintain adequate stiffness to allocate a portion of the load to the vertical elements corresponding to the rigidities of the vertical resisting elements. The behaviouris comparable to a continuous beam system on yielding supports with a noticeable degree of stiffness. The support reactions rely on the relative stiffness of the vertical resisting member and the diaphragm.

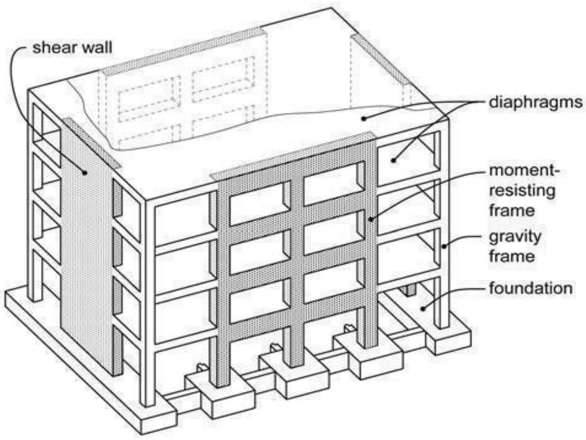


Fig 1.1 An isometric image of a fundamental building structural system made up of the base, walls, and frames as vertical spanning elements, and diaphragms as horizontal spanning elements.

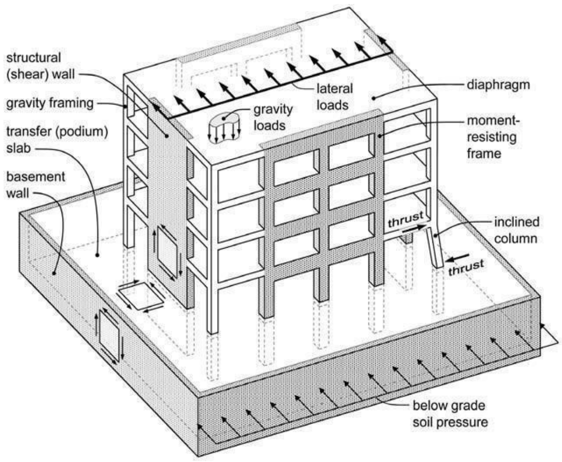


Fig 1.2 Diaphragm's function and action.

Literature Review

Rahul Chourasiya and RashmiSakalle (2015) the seismic analysis of frames for the building of numerous RC with structural elements was investigated, taking into account the various types of floor diaphragms. When it comes to resisting lateral forces, the floor diaphragm systems are more active. For analysis, the STAAD Pro programme is employed. A construction frame with a floor diaphragm is used to analyse building frames for most RC structures. Without diaphragm, solid diaphragm, and semisolid diaphragm are the three types of floor diaphragms employed. The conclusions are divided down into four categories: highest moments in beams, high displacement, shear force, axial force, and storey displacement. Each category is carefully examined to determine the outcomes of the different factors. These method of particular attention to on the many types of diaphragms found in structures, as well as their role in decreasing lateral displacement and, ultimately, the time to gain economics in construction using the same structural parts.

Miss. Reshma K Bagawan and Prof. M Q Patel (2017) the two types of diaphragm discontinuities that have been researched are mass irregularity and uneven stiffness in the slab section. Responses spectrum analysis and Time history analysis are used to examine this structure. The quantity of responses is the same; estimates are made for the time period, storey shear, story drift, and storey displacement; base force, joint displacement, and column forces are estimated; and these are compared with regular construction and non-diaphragm construction. According to the study's findings, buildings with diaphragm discontinuity have substantially more displacement and drift than conventional construction, and conventional construction that is subjected to higher shear stress and longer time periods results in an irregular structure. Thus, regular construction is less vulnerable to seismic activity.

Md Aziz Ur Rahman1, Asst. Prof. NavileshJamshetty (2019) examined the multi-RC constructions' structural seismic analysis in the stiff diaphragm. The most costeffective area to withstand lateral strength is the diaphragm floor system. Software from ETABS was utilised for analysis. The construction structure with diaphragm includes an examination of the RC building to construct the built-up area's frames. There are two varieties of diaphragms offered. Storey drift, maximum displacement, base shear, and time period are used to generate the results. They are basically dissected to evaluate the individualise parameter's outcome. This methodology focuses on the several kinds of diaphragm stomach nature that can be found in a structure and how well they work to lessen sideways removal and, in the end, achieve development economy with complimentary edges that are similar.

Ankan Kumar Nandi, Jairaj C (2020) in the past, is building systems with diaphragm floors required extensive seismic analysis. Knowing the ethics of any approved building plan should be a construction engineer's main duty. The diaphragm with a solid and semi-solid floor plate was one of the widely acknowledged structural systems for analysis among the internationally recognised structural systems. According to the high rise building code IS6700: 2016 for lower and upper rising buildings, the backstay effect, or the interaction of the podium building with the tower area, and the preservation of the wall as a constant increase in strength, were the main topics of this study. The low-rise floors in this research model have semi-solid and solid diaphragms processing the backstay diaphragm, which positions the tower in the corner and centre Earthquake.

Objectives of the Study

The main objective of the present work is to study the modeling effect of moment- resisting frames with diaphragm.

The study's particular goals are:

1. To investigate the structural behaviour of various types of diaphragms when subjected to earthquake loads.
2. To study the method for the seismic analysis of building frames with different kinds of diaphragm.
3. To study the failure modes and failure pattern of the moment-resisting frames with different types of diaphragms.
4. To study the seismic response parameters like storey shear, storey drift , story displacement s for various types of buildings like stiffness irregular, mass irregular etc.

Modeling of Moment Resisting Frames We are investigating a multi-story building under seismic stresses with various diaphragm types in this research. Reinforcing elements were taken from the building's model, which was created using ETABS software.

Problem Statement The effect of these modelling on different seismic responses of structures, such as storey shear, storey drift, storey displacement, and so on, is being investigated using 5 and 9 storey building models that are identical in plan. ETABS is used to perform the analysis. For comparison, the six models are evaluated. The following are the construction details:

Building Parameters	**Details**
Plan Size	15 × 25m
Number of bays in the X- direction	5
Number of bays in the Ydirection	3
Distance in the X direction	5m
Distance in the Y direction	5m
Height of Typical Storey	3m
No. of storey	(G+5) and (G+9)
Steel Grade	Fe 415
Concrete Grade	M-25
Zone of Seismic Activity	IV
Size of Column	350×350
Size of Beam	230×450
Thickness of Slab	150mm
Thickness of Wall	250mm

ETABS Model

Figures 1.3 and 1.4 display the layout of the building that was the subject of this investigation. An illustration of the structure in three dimensions can be found in Figures 1.5 and 1.6. These figures were drawn using ETABS.

The 5 storey and 9 storey building frame models are considered with different diaphragm. These frame models are analyzed with and without provision of diaphragm.

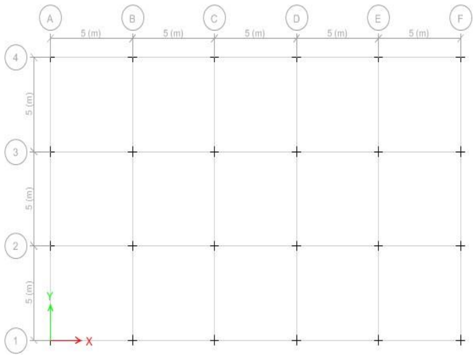


Fig 1.3 Plan of 5 Storey building

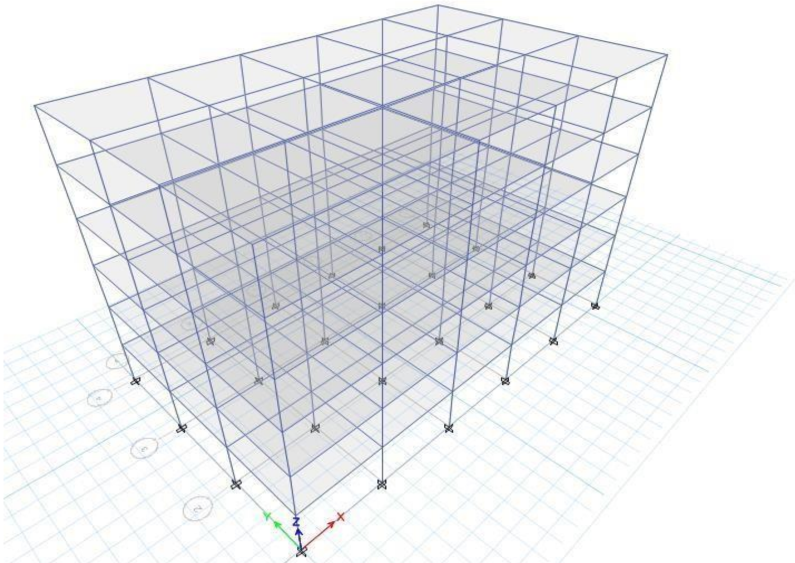


Fig 1.4 3D view of 5 Storey building

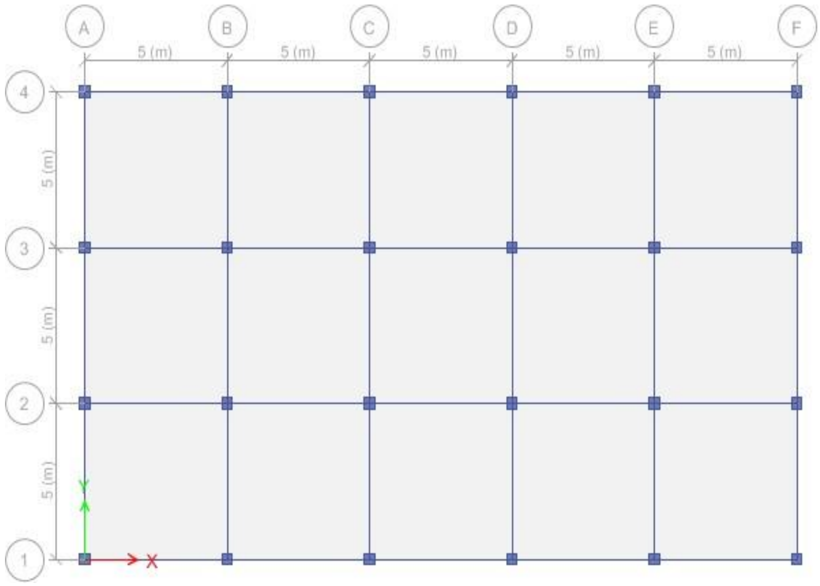


Fig 1.5 Plan of 9 Storeybuilding

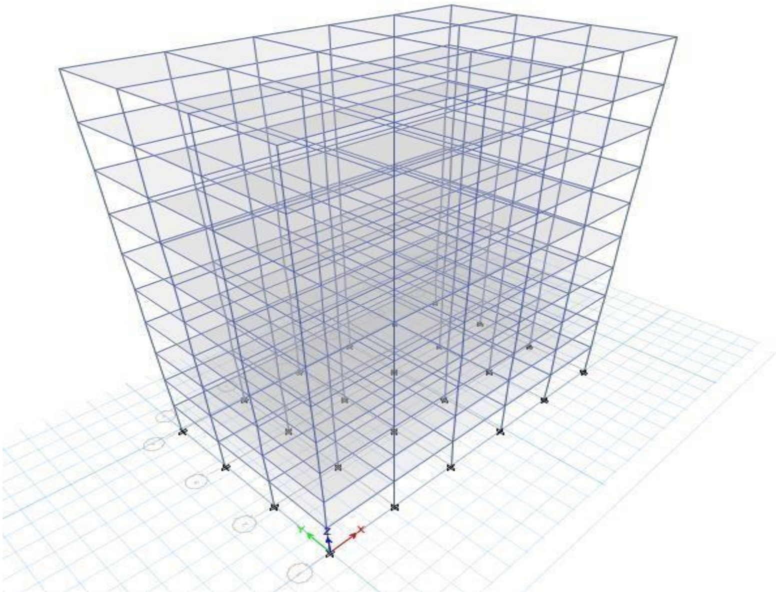


Fig 1.6 3D view of 9 Storey building

Methods of Analysis This is an effort to investigate the effects of the unique collection of robust, solid-structured models. This mostly focuses on the examination of a multistory building that is elevated and slightly off the grid. The multi-story RCC structure's R.C.C. will be created in the ETABS systems for examination. Following the structural assessment, all situations are taken into consideration, including Maximum Story Displacement, Base Shear, Story Drift, and time period.

This study relates to the development of a high-rise building, and the structure identifies the floor height and other building features. In ETABS systems, the structural model is developed. The kind of soil is intermediate, and the seismic zone is regarded as zone IV. Completed in Indian Seismic Zone IV, IS 1893-2002, is the building exhibit. The included structure states that live load, seismic load, and dead load are all included in integrated loads, as specified in IS 875 I, part II and IS 1893-2002, respectively. ETABS systems are utilised for Response Spectrum Analysis to conclude investigations. The largest hub and base shear are removed after thorough examination. Following analysis, the findings are acquired. Methods for Seismic analysis of buildings may be classified as follows:

1. Equivalent Static Analysis
2. Response Spectrum Analysis
3. Time History Analysis

Results and Discussion

The analysis is performed in ETABS. Analysis yields numerous seismic responses like: base shear, storey drift, and storey displacement. This chapter discusses the findings of the analysis

Storey Shear

Storey	Elevation	Rigid Diaphragm		Semi-rigid Diaphragm		Without Diaphragm	
		X-KN	Y-KN	X-KN	Y-KN	X-KN	Y-KN
6	18.6	233.64	234.27	327.107	327.987	467.29	468.55
5	15.5	583.18	583.69	816.45	817.18	1166.3	1167.4
4	12.4	877.63	877.60	1228.68	1228.65	1755.2	1755.2
3	9.3	1109.62	1108.8	1553.47	1552.33	2219.2	2217.6
2	6.2	1269.25	1267.5	1776.96	1774.60	2538.5	2535.1
1	3.1	1344.01	1341.5	1881.63	1878.19	2688.0	2683.1

Result of G+5 Storey RC building frames

Storey	Elevation	Rigid Diaphragm		Semi-rigid Diaphragm		Without Diaphragm	
		X-KN	Y-KN	X-KN	Y-KN	X-KN	Y-KN
10	31	232.96	234.05	326.14	327.67	465.92	468.110
9	27.9	607.87	609.63	851.01	853.491	1215.7	1219.27
8	24.8	950.02	951.65	1330.03	1332.32	1900.0	1903.31
7	21.7	1259.68	1260.6	1763.56	1764.86	2519.3	2521.23
6	18.6	1534.37	1534.2	2148.13	2147.89	3068.7	3068.41
5	15.5	1771.51	1770.0	2480.12	2478.08	3543.0	3540.12
4	12.4	1968.39	1965.6	2755.75	2751.88	3936.7	3931.26
3	9.3	2120.12	2116.1	2968.17	2962.60	4240.2	4232.30
2	6.2	2222.23	2217.2	3111.13	3104.15	4444.4	4434.50
1	3.1	2267.63	2261.9	3174.70	3166.73	4535.2	4523.90

Result of G+9 Storey RC building frames

Story Drift

Storey	Elevation	Rigid Diaphragm		Semi-rigid Diaphragm		Without Diaphragm	
		X-KN	Y-KN	X-KN	Y-KN	X-KN	Y-KN
6	18.6	0.001071	0.001137	0.001500	0.001594	0.002143	0.002278
5	15.5	0.002291	0.002389	0.003207	0.003345	0.004582	0.004778
4	12.4	0.003424	0.003552	0.004794	0.004973	0.006848	0.007104
3	9.3	0.004306	0.004453	0.006029	0.006234	0.008613	0.008906
2	6.2	0.004764	0.004907	0.006673	0.006873	0.009533	0.009819
1	3.1	0.003489	0.003553	0.004886	0.004977	0.00698	0.007111

Result of G+5 Storey RC building frames

Storey	Elevation	RigidDiaphragm		Semi-rigid Diaphragm		WithoutDiaphragm	
		X-KN	Y-KN	X-KN	Y-KN	X-KN	Y-KN
10	31	0.001217	0.001379	0.001706	0.001933	0.002437	0.002761
9	27.9	0.002537	0.002735	0.003552	0.003830	0.005074	0.005471
8	24.8	0.003867	0.004105	0.005414	0.005747	0.007734	0.008210
7	21.7	0.005078	0.005348	0.007109	0.007487	0.010156	0.010696
6	18.6	0.006149	0.006442	0.008609	0.009019	0.012298	0.012885
5	15.5	0.007067	0.007374	0.009894	0.010324	0.014135	0.014749
4	12.4	0.007818	0.008129	0.010945	0.011381	0.015636	0.016259
3	9.3	0.008360	0.008663	0.011704	0.012129	0.016720	0.017326
2	6.2	0.008464	0.008729	0.011855	0.012229	0.016936	0.017469

1	3.1	0.005957	0.006070	0.008343	0.008504	0.011918	0.012149

Result of G+9 Storey RC building frames

Storey Displacement

Storey	Elevation	Rigid Diaphragm		Semi-rigid Diaphragm		Without Diaphragm	
		X-KN	Y-KN	X-KN	Y-KN	X-KN	Y-KN
6	18.6	59.4	61.4	83.2	86	118.9	122.8
5	15.5	56.3	58	78.8	81.3	112.5	116.1
4	12.4	49.3	50.8	69.1	71.2	98.7	101.7
3	9.3	38.9	40	54.4	55.9	77.7	79.9
2	6.2	25.6	26.2	35.8	36.7	51.1	52.4
1	3.1	10.8	11	15.1	15.4	21.6	22

Result of G+5 Storey RC building frames

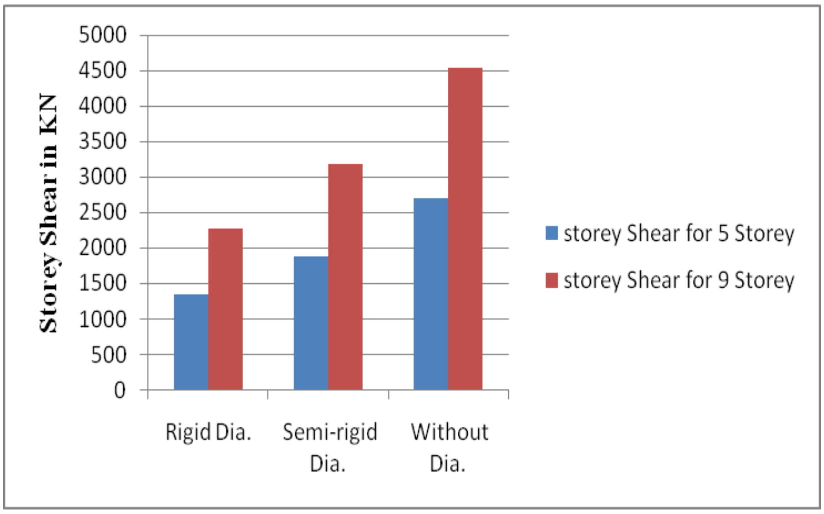
Storey	Elevation	Rigid Diaphragm		Semi-rigid Diaphragm		Without Diaphragm	
		X-KN	Y-KN	X-KN	Y-KN	X-KN	Y-KN
10	31	173.5	181.1	242.9	253.5	347.0	362.2
9	27.9	169.9	177	237.9	247.8	339.8	354.0
8	24.8	162.4	168.8	227.3	236.4	324.7	337.7
7	21.7	150.7	156.5	211.0	219.1	301.5	313.0
6	18.6	135.3	140.2	189.4	196.3	270.6	280.5
5	15.5	116.5	120.5	163.1	168.7	233.0	241.0
4	12.4	94.7	97.8	132.6	136.9	189.5	195.6
3	9.3	70.6	72.7	98.8	101.8	141.2	145.4
2	6.2	44.7	45.9	62.6	64.2	89.4	91.8
1	3.1	18.5	18.8	25.9	26.4	36.9	37.7

Result of G+9 Storey RC building frames

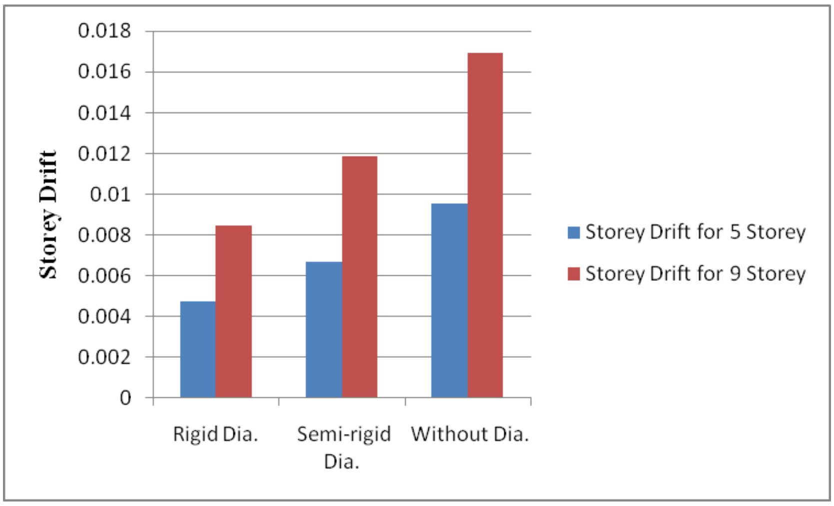
Comparative Results for RC Building Frames

G+5 Storey	**Rigid Diaphragm**	**Semi-rigid Diaphragm**	**Without Diaphragm**
Storey Shear (KN)	1344.013	1881.6315	2688.045
Storey Drift	0.004764	0.006673	0.009533
Storey Displacement (mm)	59.4	83.2	118.9

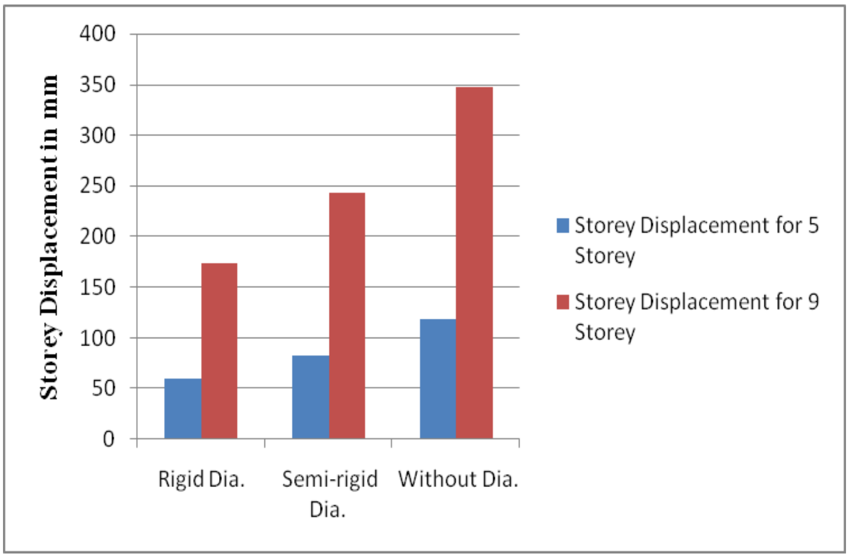
G+9 Storey	**Rigid Diaphragm**	**Semi-rigid Diaphragm**	**Without Diaphragm**
Storey Shear (KN)	1344.013	1881.6315	2688.045
Storey Drift	0.004764	0.006673	0.009533
Storey Displacement (mm)	59.4	83.2	118.9



Comparative results of Storey shear



Comparative results of Storey drift



Comparative results of Storey displacement

The rigid floor model is as accurate as the semi-rigid model and without diaphragm, as can be seen in the above image.

Conclusion

1. As storey of structure increases the storey shear is decreasing.

2. Maximum storey shear is carried out on the ground, because of the direct contact between the building and the ground.

3. Maximum storey drift is usually average level and the decrease in the average height of the roof. 4.More displacement is produced by semi-rigid and nonrigid diaphragm models than by rigid diaphragm models.

5. All three diaphragm models—the semi-rigid, the without, and the rigid—have the same level of accuracy.

6. In comparison to semi-rigid and non-rigid diaphragm buildings, it is concluded that the rigid diaphragm building is a good assumption.

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