SEISMIC EVALUATION OF MULTI-STOREY R.C. STRUCTURE USING DIFFERENT FLOOR DIAPHRAGMS

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Abstract-*In this study, seismic analysis of multi storey RC building frames have been carried out considering different types of floor diaphragm. Floor diaphragm systems are very efficient in resisting lateral forces. STAAD. Pro software has been used for analysis purpose. Analyses of multi storey RC building frames are carried out in building frame with floor diaphragm. Three different type of floor diaphragm are used i.e. without diaphragm, semi rigid diaphragm and rigid diaphragm. Results are collected in terms of maximum moments in beams, axial force, shear force, maximum displacement and storey displacement which are critically analysed to quantify the effects of various parameters. This approach focuses on the different type of floor diaphragm nature in a structure and their effectiveness in reducing the lateral displacement and moment ultimately to achieve economy in construction with similar structural frames*

Key words: Seismic, Floor diaphragm, Maximum moment, Shear Force, Storey displacement, Peak storey displacement

1. INTRODUCTION

Multi-storey buildings are a special class of structures with their own peculiar characteristics and necessities. Multi-storey buildings are occupied by a massive amount of population. Therefore, their accident and devastation can have very serious consequences on the life and economy. The intention of this study is therefore, to investigate the effect of buildings in various seismic zones performance by comparing it with rigid diaphragm, semi-rigid diaphragm and without diaphragm. The limit states design philosophy is the universally accepted philosophy, which is based on semi probabilistic approach for both structural properties and loading conditions. In this work we use STAAD Pro V8i which is one of the most popular structural engineering software products for 3D model generation, analysis and design. Some of the prominent literature on the topic are as follows -

Wakchaure M.R and Ped S. P (2012) analysed the effect of masonry walls on high rise building is studied. A various arrangements are analysis in linear dynamic is carried out. G+9 R.C.C. framed building is modelled for the analysis. Earthquake time history is applied to the framed building and various cases of analysis are taken. Approach to analyse this work is software (ETABS). Analysis is calculated and comparative result of all the models on the basis of various parameters like beam forces, column forces and displacements.

Kai Hu, et al. (2012) concluded that, the traditional software can no longer meet the needs of calculation and analysis. In this work, different type of analysis method is used by dynamic analysis were executed using in-house developed software.

Liang Chen and Lucia Tirca (2012) investigates the inelastic behaviour of the 4, 8 and 12 storey elastic zipper braced frame (E-ZBF) buildings located in a high risk seismic zone (Victoria, BC) under crustal, subduction, and near-field ground motion ensembles.

Rana Roy and Sekhar Chandra Dutta (2010) recognized that inelastic response for short period systems is very sensitive to reduction factors (R) and may be phenomenally amplified even for small R due to soil–structure interaction implying restrictive applicability of dual-design philosophy. Buildings shows that inelastic response of the asymmetric structure relative to its symmetric counterpart is not appreciably influenced due to soil structural interaction. The work also shows that equivalent single storey model characterised by the lowest period rather than the fundamental one of the real system tends to yield conservative estimation of inelastic demand at least for the short-period systems.

D. R. Gardineret al. (2008) research investigates the magnitude and trends of forces in concrete floor diaphragms, with an importance on transfer forces, under earthquake loading. This research considers the following items: inertial forces which develop from the acceleration of the floor mass; transfer forces which develop from the interaction of lateral force resisting elements with different displacement patterns, such as wall and frame elements; and difference of transfer forces due to different strengths and stiffness of the structural elements. The magnitude and trends of forces in the floor diaphragms have been determined using 2-dimensional in elastic time history analysis.

Ho Jung et al. (2007) discussed a simple method to more accurately estimate peak inter storey drifts that accounts for higher mode effects described for low-rise perimeter shear wall structures having flexible diaphragms or even for stiff diaphragms.

Wilkinson and Hiley (2006) analysed a materially non-linear plane-frame model subjected to earthquake forces. Storey of the building by an assembly of vertical and horizontal beam elements The model introduces yield hinges with ideal plastic properties in a regular plane frame. The displacements were described by the sway of each floor and the rotation of all beam–column intersections. Thus, the study go on with static condensation of the dynamic equations for the translations.

Vipul Prakash (2004) gives the prospects for Performance Based Engineering (PBE) in our country. He records the pre-requisites that made the emergence of PBE possible in country of California, the criteria for earthquake resistant design of structures are given the Bureau of Indian Standards (BIS). IS 1893-2002 reduced the number of seismic zones to four by merging zone I with zone II and adopted a modified CIS-64 scale for seismic zoning.

Aim for this study is to understand the effect of seismic in multi storey structure and the remedial measures to control these effects. To do this, models are generated and analysed with the help of STAAD.Pro software, and the effect of floor diaphragm pattern to resist the seismic forces are critically analysed.

2. METHODOLOGY

Following steps have been adopted in this study-
Step-1 selection of building geometry, bays and story
Step-2 Selection of diaphragm (Rigid diaphragm, semi-rigid and without diaphragm)
Step-3 selection of 4 seismic zones (II,III,IV and V)
Step-4 Formation of load combination (13 load combinations)

Table 1- Load case details

Load case no.	Load cases details
1.	E.Q. IN X DIR.
2.	E.Q. IN Z DIR.
3.	DEAD LOAD
4.	LIVE LOAD
5.	1.5 (DL + LL)
6.	1.5 (DL + EQX)
7.	1.5 (DL - EQX)
8.	1.5 (DL + EQZ)
9.	1.5 (DL - EQZ)
10.	1.2 (DL + LL + EQX)
11.	1.2 (DL + LL - EQX)
12.	1.2 (DL + LL + EQZ)
13.	1.2 (DL + LL - EQZ)

Step-5 Modelling of building frames
Step-6 Analysis considering different diaphragm models, seismic zones and each load combinations
Step-7 Comparative study of results in terms of maximum moments in columns and beams, base shear, story displacement, peak story displacement.

3. STRUCTURAL MODELLING AND ANALYSIS

CASE-01: Bare frame without diaphragm of G+7 storey height.
CASE-02: Building frame with rigid diaphragm of G+7 storey height.
CASE-03: Building frame with semi-rigid diaphragm of G+7 storey height.

3.1 Diaphragms

According to Paulay and Priestley (1992), the interaction of the lateral load with lateral-force-resisting vertical elements is achieved by the use of floor systems that generally possess large in-plane stiffness. Thus, the vertical load resisting elements will contribute to the total lateral load resistance in proportion to their own stiffness. Floors can act as diaphragm because of its large in-plane stiffness. The main function of the floor diaphragm is to transmit the inertial forces generated by the ground motion of the floor mass at a given level to the lateral-force-resisting vertical elements generated by the ground motion. At lower story, significant lateral load need to be transferred from one element to another element causing significant shear forces and bending moments in the diaphragm.

3.2 Types of diaphragms

Floor and roof systems act as a diaphragm to transfer the lateral load to the vertical load supporting elements like beams, columns, walls etc. For the simplicity in the dynamic analysis of building, floors are assumed to be rigid in their own plane. This concept was developed 40 years ago which assumes that the whole floor moves as the rigid body motion; two translational and one rotational degree of freedom per each floor. This assumption is valid for many buildings but not valid for long, narrow or irregular buildings. Blume et al. conducted forced-vibration tests on several school buildings and reported long natural periods of roof or floor diaphragms.For the analysis purpose, diaphragm can be classified as rigid, semi rigid or semi flexible and flexible based on the relative rigidity.

3.2.1 Rigid diaphragm

In the rigid floor diaphragm, the lateral forces are distributed to the vertical load resisting elements (frames, shear walls) in proportion to their relative stiffnesses. In the rigid diaphragm concept, the in-plane displacement is considered to be equal along its entire length under lateral load. This rigid diaphragm concept is reasonable for building nearly square in plan. A case-in-plane concrete floor is an example of rigid diaphragm.

3.2.2 Semi-rigid diaphragm

In reality, the diaphragm can neither be perfectly rigid nor be perfectly flexible. However, in order to simplify the analysis with reasonable assumptions, the semi-rigid diaphragm can be made as to a diaphragm's rigidity or flexibility but in some cases the diaphragm deflection and the vertical lateral load-resisting (VLLR) elements can be of same magnitude only in semi-rigid diaphragm. The absolute size and stiffness are important in diaphragm but that is not the final determining factor whether it will behave as rigid, flexible, or semi-rigid. In rigid diaphragm, such as steel deck, is partly able to distribute the lateral forces into the VLLR elements based on their relative stiffness.

Semi-rigid or semi-flexible diaphragms are those which have significant deflections under load, but which also have sufficient stiffness to distribute a portion of the load to the vertical elements in proportion to the rigidities of the vertical resisting elements. The action is analogous to a continuous beam system of appreciable stiffness on yielding supports. The support reactions are dependent upon the relative stiffness of both diaphragm and the vertical resisting element.

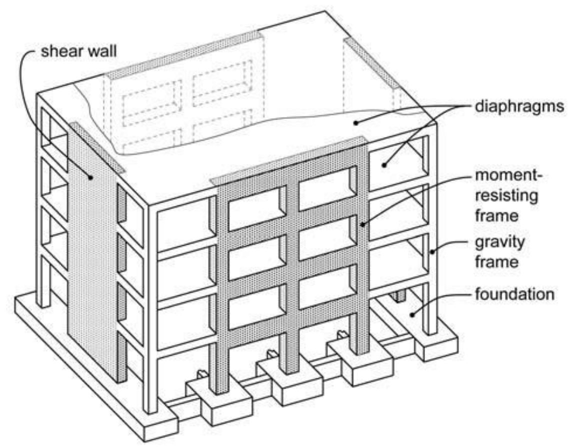

Figure 1- Isometric view of a basic building structural system comprising horizontal spanning elements (diaphragms), vertical spanning elements (walls and frames), and foundation

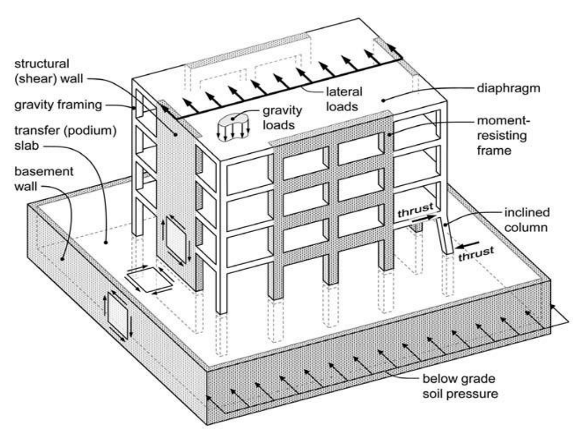

Figure 2- Role and action of diaphragm

4. STRUCTURAL MODELS

Structural models for different cases are shown in Figure 3 to 6

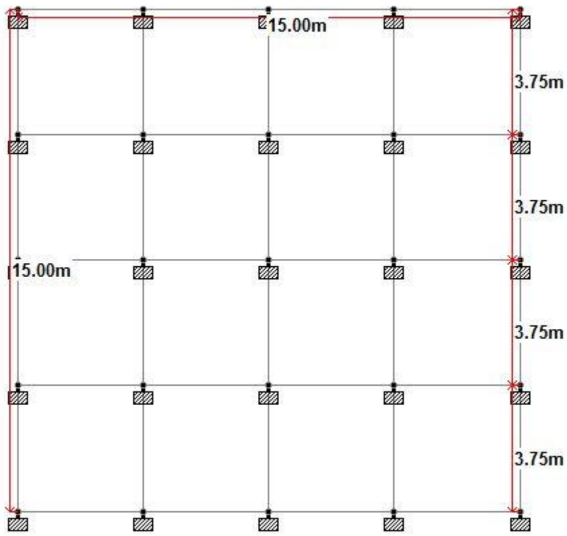

Figure 3- Plan of Bare frame

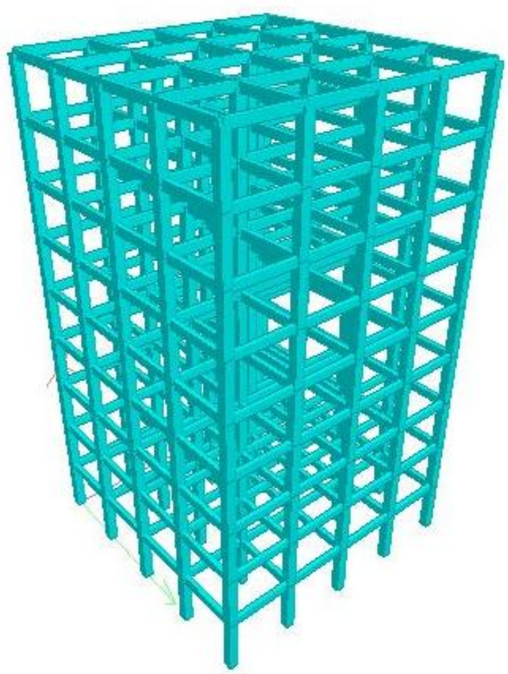

Figure 4- Structural model of Bare frame

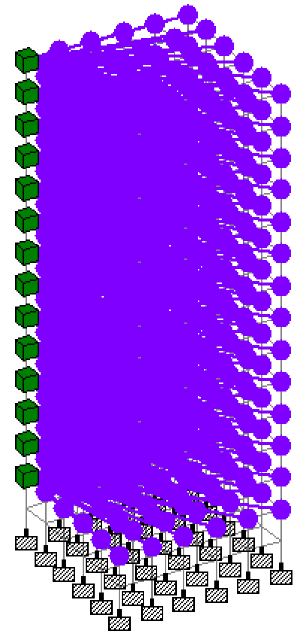

Figure 5- A typical isomeric diagram for diaphragm

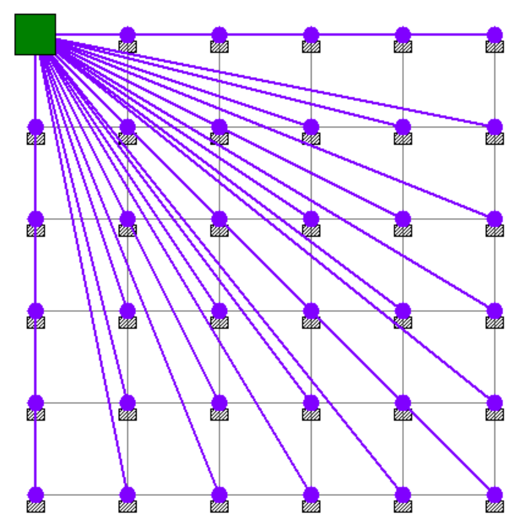

Figure 6- A typical plan diagram for diaphragm

The column size is of 450MM x 450MM, and the beam size is 230MM x 450MM.

5. MATERIAL AND GEOMETRICAL PROPERTIES

Following material properties have been considered in the modelling -
Density of RCC: 25 kN/m3

Density of Masonry: 20 kN/m3 (Assumed)
Young's modulus of concrete: $5000\sqrt{fck}$
Poisson'sratio: 0.17
The foundation depth is considered at 2.0m below ground level and the typical storey height is 3.0 m.
Loading conditions
Following loadings are considered for analysis -
(a) Dead Loads: as per IS: 875 (part-1) 1987
Self wt. of slab considering 150 mm thick. Slab = 0.15 x 25 = 3.75 kN/m2 (slab thick. 150 mm assumed)
Floor Finish load = 1 kN/m2
Water Proofing Load on Roof = 2.5 kN/m2
Masonry Wall Load = 0.25 x 2.55 x 20 = 12.75 kN/m
(b) Live Loads: as per IS: 875 (part-2) 1987
Live Load on typical floors = 2 kN/m2
Live Load on Roof = 1.5 kN/m2
(c) Earth Quake Loads:
All the building frames are analyzed for 4 seismic zones
The earth quake loads are derived for following seismic parameters as per IS: 1893 (2002) [21]
a. Earth Quake Zone-II,III,IV,V (Table - 2)
b. Importance Factor: 1 (Table - 6)
c. Response Reduction Factor: 5 (Table - 7)
d. Damping: 5% (Table - 3)
e. Soil Type: Medium Soil (Assumed)
f. Period in X direction (PX): $\frac{0.09 * h}{\sqrt{dx}}$ seconds Clause 7.6.2
g. Period in Z direction (PZ): $\frac{0.09 * h}{\sqrt{dz}}$ seconds Clause 7.6.2
Where h = height of the building
dx= length of building in x direction
dz= length of building in z direction

6. RESULTS AND DISCUSSION

The results are discussed in bracing system and diaphragm system

6.1 Diaphragm models

Results can be described under following heads -

Table 2- Maximum displacement in diaphragm system

Structure type	Maximum displacement			
	Zone II	Zone III	Zone IV	Zone V
Bare Frame	38.465	61.488	92.186	138.232
Rigid Diaphragm	11.074	17.718	26.577	39.865
Semi Rigid Diaphragm	37.434	59.894	89.842	134.762

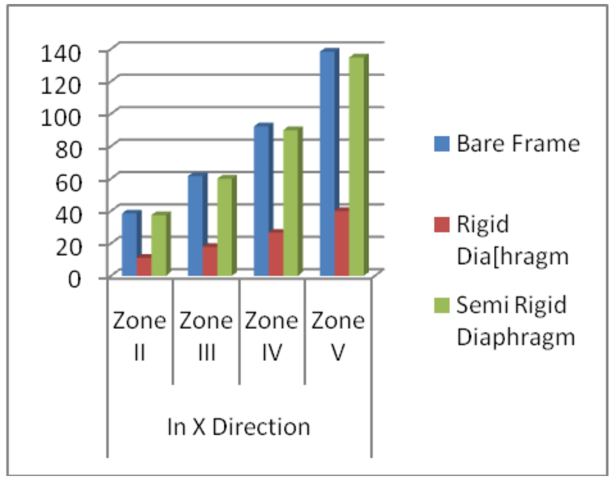

Fig. 7- Maximum displacement in diaphragm system

Table 3- Maximum bending moment in diaphragm system

Structure type	Max Bending Moment			
	Zone II	Zone III	Zone IV	Zone V
Bare Frame	137.728	187.212	253.191	366.537
Rigid Diaphragm	65.779	105.246	157.869	236.803
Semi rigid Diaphragm	135.768	184.114	248.575	358.501

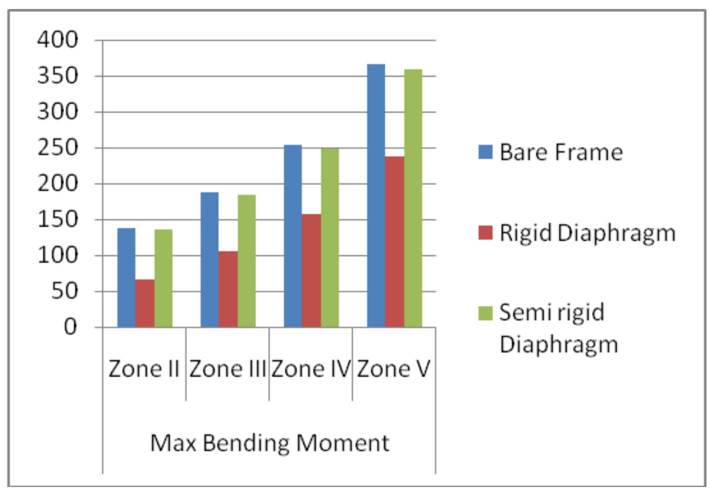

Figure 8-Maximum bending moment in diaphragm system

Table 4- Maximum shear force in diaphragm system

Structure type	Max Shear force			
	Zone II	Zone III	Zone IV	Zone V
Bare Frame	115.938	141.473	175.52	226.59
Rigid Diaphragm	83.587	83.587	104.454	156.682

Semi rigid Diaphragm	114.929	139.875	173.137	223.031

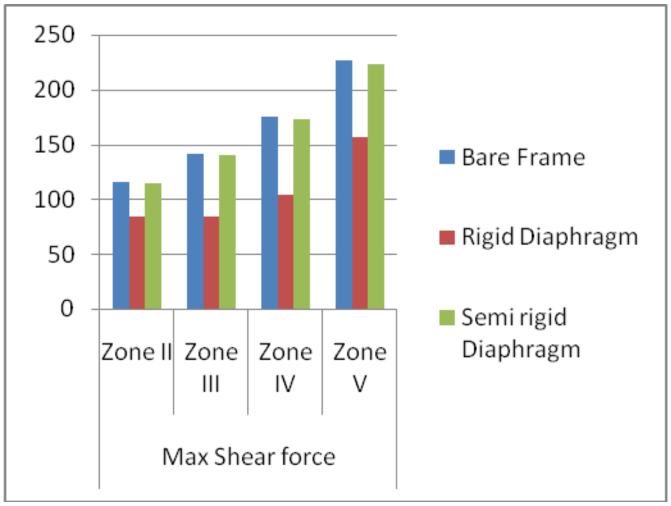

Figure 9- Maximum shear force in diaphragm system

Table 5- Max. storey displacement in zone-II in diaphragm system

Max story displacement in structure in zone-II			
Floor	Bare Frame	Rigid Diaphragm	Semi rigid Diaphragm
Base	0	0	0
Ground Floor	2.088	0.954	2.13
1st Floor	5.565	1.941	5.667
2nd Floor	9.239	2.944	9.418
3rd floor	12.828	3.937	13.096
4th floor	16.184	4.888	16.546
5th floor	19.162	5.758	19.619
6th floor	21.608	6.5	22.144
7th floor	23.362	7.061	23.945
8th floor	24.378	7.382	24.956

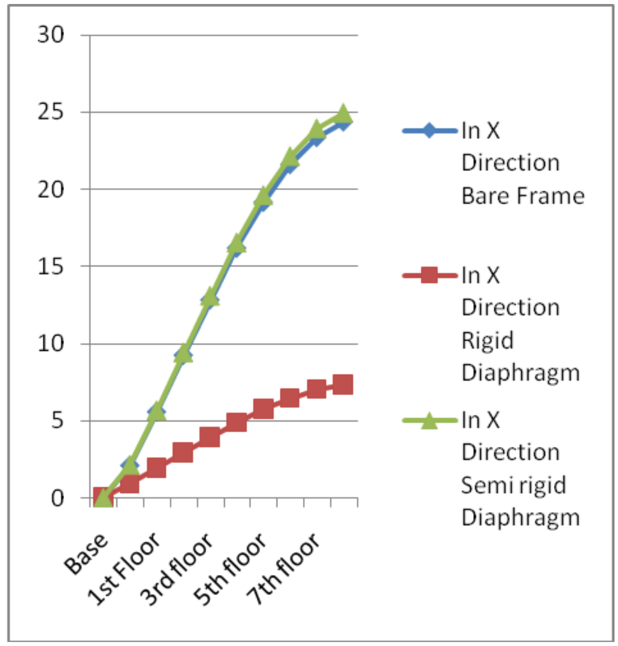

Figure 10-Max. storey displacement in zone-II in diaphragm system

Table 6- Max. storey displacement in zone-III in diaphragm system

Max story displacement in structure in zone-III			
Floor	Bare Frame	Rigid Diaphragm	Semi rigid Diaphragm
Base	0	0	0
GF	3.341	1.527	3.408
1st Floor	8.903	3.106	9.067
2nd Floor	14.782	4.71	15.07
3rd floor	20.525	6.299	20.953
4th floor	25.894	7.821	26.474
5th floor	30.66	9.213	31.391
6th floor	34.572	10.4	35.43
7th floor	37.379	11.298	38.311
8th floor	39.004	11.812	39.93

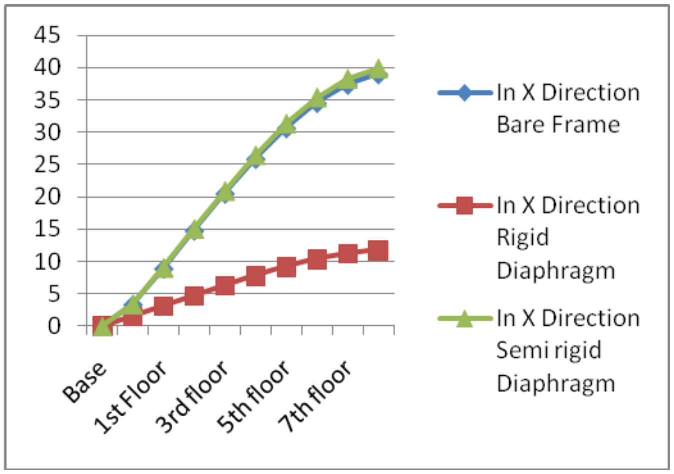

Figure 11- Max. storey displacement in zone-III in diaphragm system

Table 7- Max. storey displacement in zone-IV in diaphragm system

Max story displacement in structure in zone-IV			
Floor	In X Direction		
	Bare Frame	Rigid Diaphragm	Semi rigid Diaphragm
Base	0	0	0
GF	5.012	2.29	5.112
1st Floor	13.355	4.659	13.601
2nd Floor	22.174	7.066	22.604
3rd floor	30.788	9.449	31.43
4th floor	38.841	11.732	39.711
5th floor	45.99	13.819	47.086
6th floor	51.858	15.6	53.146
7th floor	56.069	16.947	57.467
8th floor	58.508	17.718	59.894

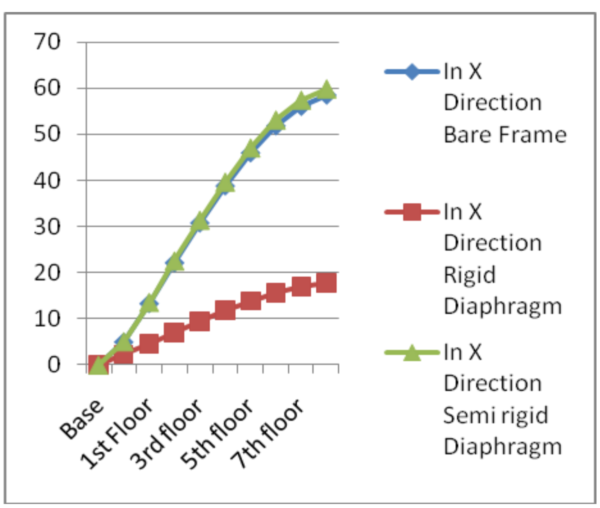

Figure 12- Max. storey displacement in zone-IV in diaphragm system

Table 8- Max. storey displacement in zone-V in diaphragm system

Max story displacement in structure in zone-V			
Floor	In X Direction		
	Bare Frame	Rigid Diaphragm	Semi rigid Diaphragm
Base	0	0	0
GF	7.517	3.435	7.669
1st Floor	20.033	6.989	20.402
2nd floor	33.26	10.598	33.907
3rd floor	46.182	14.173	47.144
4th floor	58.262	17.597	59.567
5th floor	68.985	20.729	70.63
6th floor	77.787	23.4	79.718
7th floor	84.103	25.42	86.201
8th floor	87.759	26.577	89.842

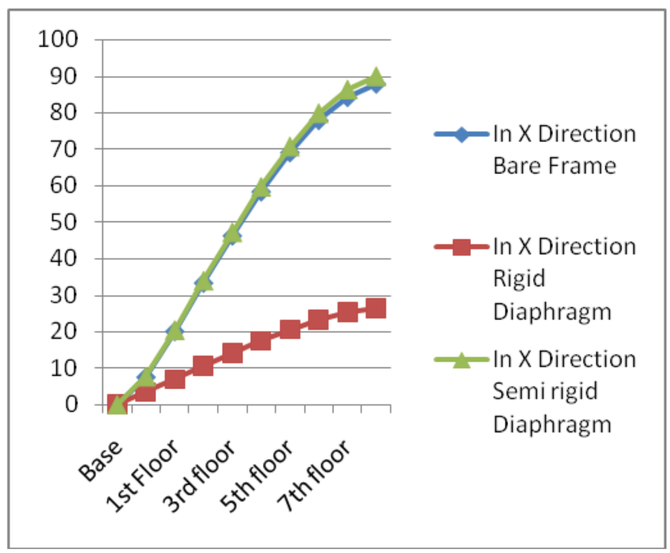

Figure 13- Max. storey displacement in zone-V in diaphragm system

7. CONCLUSION

Following are the salient conclusions of this study-
From the present study it is seen that rigid diaphragm is much efficient in compared to other diaphragms system in reducing moment, storey displacement, peak displacement. The analysis done in the present study clearly shows that semi-rigid diaphragm and without diaphragm models shows almost same results means we can say nature of without diaphragm structures is same of

semi rigid diaphragm structure. And semi rigid diaphragm and without diaphragm produces more displacement, shear force and moments than the rigid diaphragm models. And rigid diaphragm reduces displacement thrice, moment twice and shear force almost one and half means it helps in reducing frame section and area of steel. So, It has been observed from the analysis of various building the rigid diaphragm is more effective. It is concluded that the building with rigid diaphragms will be structurally economic resulting into a great deal of saving in reinforcement steel.

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