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SEISMIC ANALYSIS OF MULTI-STOREY R.C. STRUCTURE USING BRACING SYSTEM AND FLOOR DIAPHRAGM

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ABSTRACT
Earthquakes are natural hazards which cause disasters are mainly caused by damage too or collapse of buildings and other manmade structures. Experience has shown that for new constructions, establishing seismic resistant controls and their implementation is the important safeguard against seismic induced damage. In this study, seismic analysis of multi storey RC building frames have been carried out considering different types of bracing systems. Bracing 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 3 parts I) Building frame without bracing systems diaphragm II) Building frames with Bracing systems and III) Building frame with floor diaphragm. Three different type of bracing systems i.e. X Bracing, K Bracing and V Bracing including bracing core and outer pattern have been considered. 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 arrangement of bracing in a structure and their effectiveness in reducing the lateral displacement ultimately to achieve economy in construction with similar structural frames.

KEYWORDS: Seismic ;Bracing; Maximum moment; Shear Force; Storey displacement; Peak storey displacement;.

INTRODUCTION
Steel braced frame is one of the structural systems used to resist wind loads in multi stories buildings. Many existing steel buildings need retrofit to overcome deficiencies to resist wind loads. The use of steel bracing systems for strengthening or retrofitting steel buildings frames is a viable solution for enhancing wind resistance. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness.The lateral stiffness of the building is controlled by different structural systems. These are:

- Using unbraced frame with moment-resisting connections.
- Using braced frame with moment-resisting connections.
- Using braced frame with pin-jointed connections.
- Using braced frame with both moment-resisting and pin-jointed connections.

Some of the prominent literature on the topic are as follows -
Kulkarni et.al. (2013) concluded that optimally braced frames are stiff, strong, and an economical structural system. According to them, a fully braced frame are very stiff and over safe in so far as lateral drift is concerned but uneconomical and at the contest optimally braced frames have least forces induced in the structure and produce maximum displacement but within prescribed limit. Kevadkar andKodag (2013) observed that the structuresheavily susceptible to lateral forces may be concerned to severe damage. In this they found that along with gravity load the frames are able to withstand to lateral load which can develop high stresses. For this purpose they used shear wall and steel bracing system to resist such type of loading like earthquake, wind, blast etc. Jesumi, and Rajendran (2013) studied on the major system providing lateral load resistance in steel lattice towers. They used different types of bracing systems on towers. The heights of towers varied from 20 to 500 meters. This study has focused on identifying the economical bracing system for a given range of tower heights. SeyedMehrdadNourbakhsh (2011) studied the performance of eccentric braces which is to some extent considered as a new subject amongst Civil Engineers. In this study nine frames were considered which were braced with three different eccentric braces (V, Inverted-V and Diagonal) in three different heights (4, 8 and 12 story). The frames were assessed by nonlinear static (pushover) analysis mainly based on FEMA 440. As a result of these frame analysis, it was observed that the plastic hinges firstly

occur at the fuse section of braces and then at the compressive members of the eccentric braces. But on the other hand using the eccentric diagonal braces for low and medium rise structures more logical and acceptable from economical point of view as this type of bracing system absorbs considerably more energy when compared with eccentric V and Inverted V bracing systems. Gajjar and DhavalP.Advani (2011) focused on the design of multi-storeyed steel buildings to have good lateral load resisting system along with gravity load system because it also governs the design. This paper was presented to show the effect of different types of bracing systems in multi storied steel buildings. For this purpose the 20 stories steel buildings models were used with same configuration and different bracings systems such as knee brace, X brace and V brace. Salehuddun (2011) focused on nonlinear geometric analysis to be compared with linear analysis. In this study, a six storey 2-D steel frame structure with 24 m height had been selected to be idealized as tall building model. The model was analyzed by using SAP2000 structural analysis software with the consideration of geometric nonlinear effect. This study showed that a steel frame with the consideration of wind load produce greater sway value as compared to the steel frame without wind load. Jayachandran and vidyanatham (2009) carried out study to enable optimization of initial structural systems for drift and stresses, based on gravity and lateral load. The design issues were efficiency of systems, rigidity, member depths, balance between sizes of beam and column, bracings, as well as spacing of columns, and girders, and areas and inertias of members. Ming Gu(2009) studied wind-resistance of steel tall buildings and structures. Wind tunnel tests were carried out on 27 typical tall building models by using wind pressure scanning and HFFB techniques. Interference effects on wind forces and wind pressures among two and three tall buildings were experimentally investigated with about 10,000 testing cases. Theoretical study on equivalent static wind loads of tall buildings and structures were then introduced. Especially, a new concept of “mode coupling factor” and a modified SRSS method for wind response and equivalent static wind load of complicated tall buildings and structures with consideration of multi-mode contributions and their coupling effects were considered. Ilyas Yildirim (2009) investigated optimal lateral bracing systems in steel structures under wind. For this purpose evolution strategies optimization method was used which is a member of the evolutionary algorithms search techniques. First optimum design of steel frames was introduced then evolution strategies technique was explained. This is followed by design loads and bracing systems and it is continued by the cost analysis of the models. Optimum designs of three different structures, comprising twelve different b0racing models were carried out. The calculations were carried out by a computer program (OPTSTEEL). Bo Dowswell (2000) presented an overview of lateral load resisting systems and how to implement them. In most commercial buildings, floor and roof diaphragms are used to distribute loads in the horizontal plane of the structure to the lateral load resisting system. Due to the open nature of most industrial frames, diaphragms are not present, and horizontal bracing is often used to distribute the loads in the horizontal plane. Horizontal bracing is also used in heavily-loaded commercial frames, where a diaphragm is not present, or where the strength or rigidity of the diaphragm is not adequate.

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 with and without bracing systems (X, K and V) including core and outer pattern to resist the seismic forces are critically analysed.

METHODOLOGY

Following steps have been adopted in this study-
Step-1 selection of building geometry, bays and story
Step-2 Selection of bracing model (X bracing frame, V bracing frame, K bracing frame, with core and outer bracing systems) and 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)

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 bracing system, 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.

STRUCTURAL MODELLING AND ANALYSIS

CASE-1: Bare frame without bracing and diaphragm of G+7 storey height.
CASE-2: K bracing at core of G+7 storey height.
CASE-3: K bracing at outer of G+7 storey height.
CASE-4: V bracing at core of G+7 storey height.
CASE-5: V bracing at outer of G+7 storey height.
CASE-6: X bracing at core of G+7 storey height.
CASE-7: X bracing at outer of G+7 storey height.
CASE-8: X bracing at core of G+7 storey height.
CASE-9: X bracing at outer of G+7 storey height.
CASE-10: Building frame with rigid diaphragm of G+7 storey height.
CASE-11: Building frame with semi-rigid diaphragm of G+7 storey height.

STAAD.Pro is used in modelling of building frames. STAAD.Pro is Structural Analysis and Design Program is a general purpose program for performing the analysis and design of a wide variety of structures. The basic three activities which are to be carried out to achieve this goal are -
a. Model generation
b. Calculations to obtain the analytical results
c. Result verification- These are allfacilitated by tools contained in the program's graphical environment.

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.

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.

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.

Semi-rigid or semi-flexible 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.

The rigidity of diaphragm can be ascertained by determining its flexibility factor (F). A slab isconsidered to be rigid diaphragm if it has a flexibility factor of less than one. A flexibility factorbetween 1 and 10 is considered to represent a semi-rigid diaphragm, and a factor greater than 10indicate a flexible diaphragm. The flexibility factor for a concrete diaphragm is defined as:

$$\mathbf{F} = \frac{10^6}{8.5\, h\, w_c^{1.5}\sqrt{f'_c}}$$

Where,

h = thickness of the slab, (in).

w_c= unit weight of the concrete, (pcf)

f'_c= compressive strength of the concrete at 28 days, (psi)

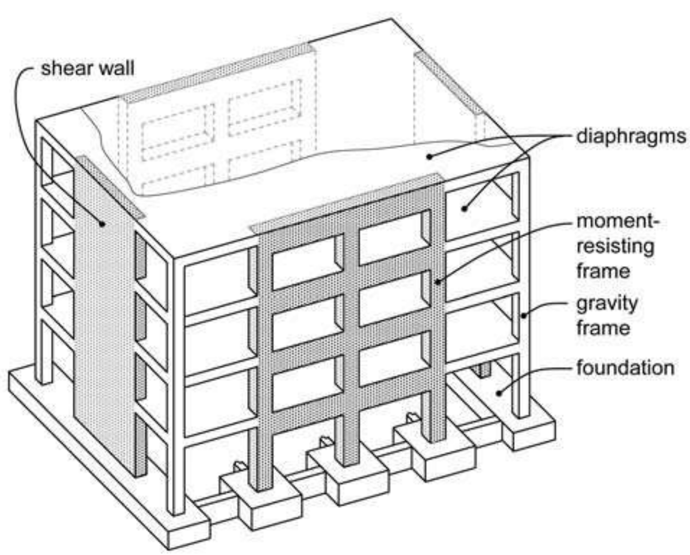


Figure 4.1: Isometric view of a basic building structural system comprising horizontal spanning elements (diaphragms), vertical spanning elements (walls and frames), and foundation

THE ROLES AND ACTION OF DIAPHRAGMS

A diaphragm is a flat structural unit acting like a deep, thin beam. The term "diaphragm" is usually applied to roofs and floors. A diaphragm structure results when a series of such vertical and horizontal diaphragms are properly tied together to form a structural unit.

Diaphragms serve multiple roles to resist gravity and lateral forces in buildings. Figure 4.2 illustrates several of these roles for a building with a podium level at grade and with below- grade levels. The main roles include:

- *Resist gravity loads* – Most diaphragms are part of the floor and roof framing and therefore support gravity loads.
- *Provide lateral support to vertical elements* – Diaphragms connect to vertical elements of the seismic force-resisting system at each floor level, thereby providing lateral support to resist buckling as well as second-order forces associated with axial forces acting through lateral displacements. Furthermore, by tying together the vertical elements of the lateral force-resisting system, the diaphragms complete the three-dimensional framework to resist lateral loads.
- *Resist out-of-plane forces* – Exterior walls and cladding develop out-of-plane lateral inertial forces as a building responds to an earthquake. Out-of-plane forces also develop due to wind pressure acting on exposed wall surfaces. The diaphragm-to-wall connections provide resistance to these out-of-plane forces.
- *Resist thrust from inclined columns* – Architectural configurations sometimes require inclined columns, which can result in large horizontal thrusts, acting within the plane of the diaphragms, due to gravity and overturning actions. The thrusts can act either in tension or compression, depending on orientation of the column and whether it isin compression or tension. The diaphragm or components within it need to be designed to resist these thrusts.
- *Transfer lateral inertial forces to vertical elements of the seismic force-resisting system* – The floor system commonly comprise most of the mass of the building. Consequently, significant inertial forces can develop in the plane of the diaphragm. One of the primary roles of the diaphragm in earthquake-resistant buildings is to transfer these lateral inertial forces, including those due to tributary portions of walls and columns, to the vertical elements ofthe seismic force-resisting system.
- *Transfer forces through the diaphragm* – As a building responds to earthquake loading, lateral shears often must be transferred from one vertical element of the seismic force-resisting system to another. The largest transfers commonly occur at discontinuities in the vertical elements, including in-plane and out-of-plane offsets in these elements. Figure 4.2 illustrates a common discontinuity at a podium slab. The tendency is for a majority of the shear in the structural walls above grade to transfer out of those walls, through the podium slab, and to the basement walls. Large diaphragm transfer forces can occur in this case.
- *Support soil loads below grade* – For buildings with subterranean levels, soil pressure bears against the basement walls out-of-plane. The basement walls span between diaphragms, producing compressive reaction forces at the edge of the diaphragms.

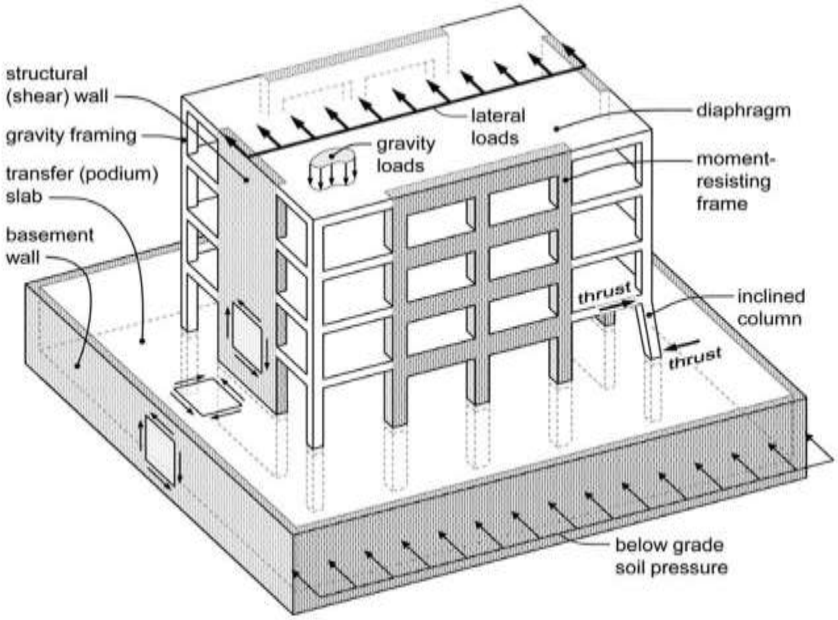
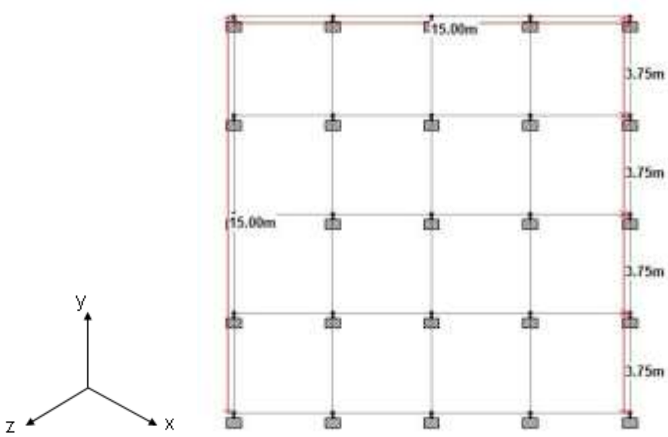


Figure 4.2: Role and action of diaphragm

STRUCTURAL MODELS

Structural models for different cases are shown in Fig. 4.1 to 4.4. No. of beams and columns in each cases are given in Table 4.1



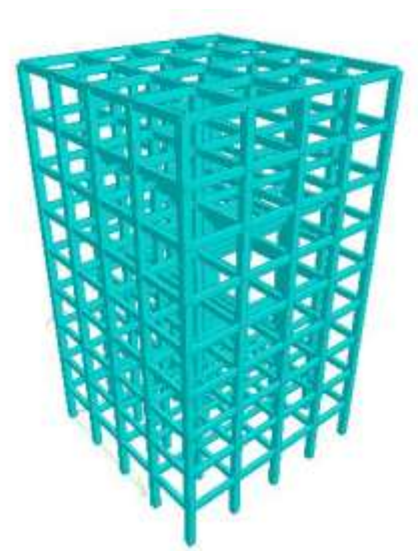


Figure 4.4: Plan of Bare frame

Figure 4.3: Structural model of Bare frame

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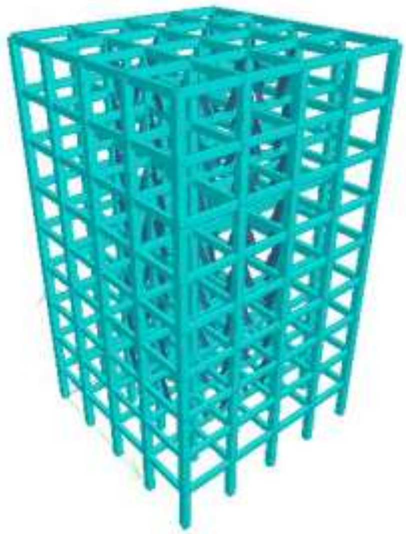
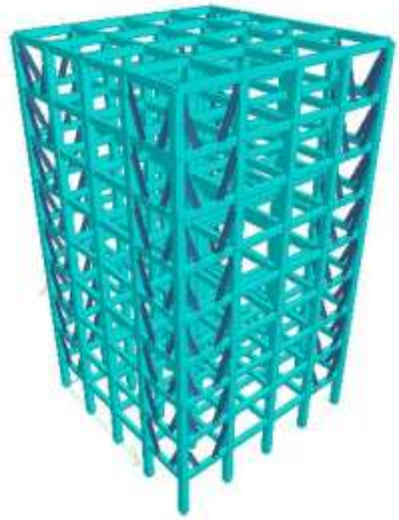

Figure 4.5: Structural model of K Bracing at Core Figure 4.7: Structural model of K bracing at outer

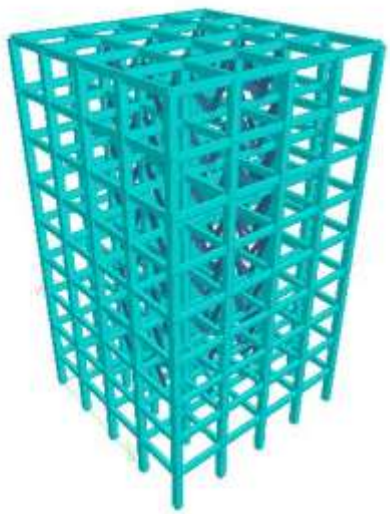
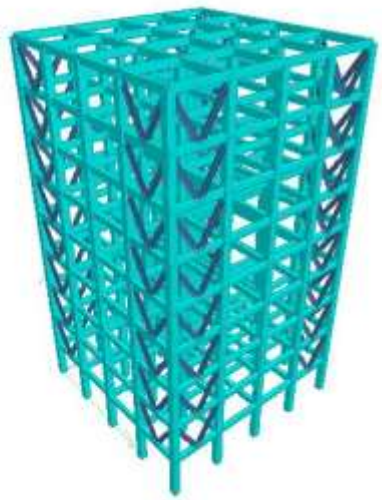

Figure 4.9: Structural model of V bracing at core   ***Figure 4.10: Structural model of V bracing at outer***

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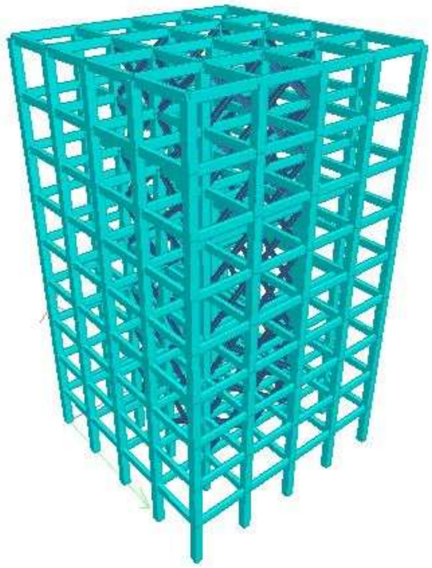
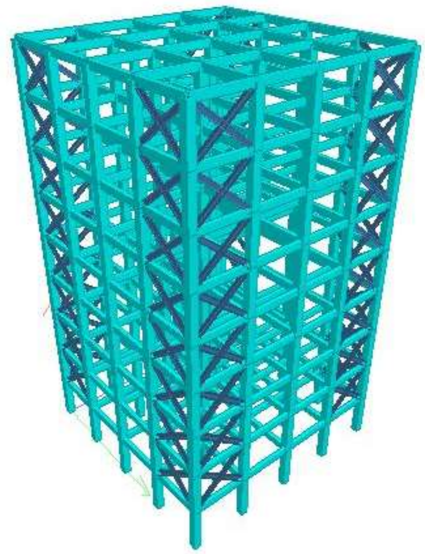
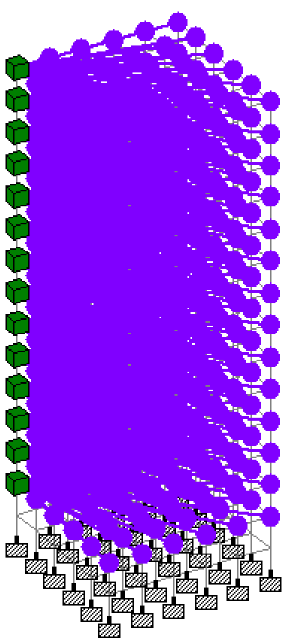


Structural model of X bracing at core



Structural model of X bracing at core



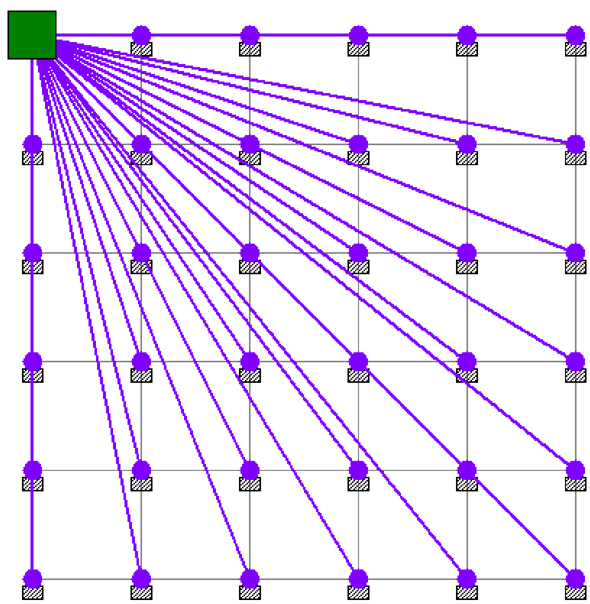


Figure 4.14:A typical isomeric diagram for diaphragm and Figure 4.15:A typical plan diagram for diaphragm

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

MATERIAL AND GEOMERICAL PROPERTIES

Following material properties have been considered in the modelling -
Density of RCC: 25 kN/m^3
Density of Masonry: 20 kN/m^3 (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/m^2 (slab thick. 150 mm assumed)
Floor Finish load = 1 kN/m^2
Water Proofing Load on Roof = 2.5 kN/m^2
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/m^2
Live Load on Roof = 1.5 kN/m^2
(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 [21]
g. Period in Z direction (PZ): $\frac{0.09*h}{\sqrt{dz}}$ seconds Clause 7.6.2 [21]
Where h = height of the building
dx= length of building in x direction
dz= length of building in z direction

RESULTS AND DISCUSSION

The results are discussed in bracing system and diaphragm system

BRACING MODELS

Results can be described under following heads -

Table 1: Maximum displacement in X direction of bracing system

Max Peak story deflection				
Structure type	Zone II	Zone III	Zone IV	Zone V
Bare Frame	38.465	61.488	92.186	138.232
X Bracing at Outer	23.555	37.307	55.909	83.812
X Bracing at Core	14.614	23.34	34.974	52.425
V Bracing at outer	35.166	56.207	84.262	128.344
V Bracing at core	34.784	55.492	83.101	124.516
K Bracing at outer	35.675	57.021	85.484	128.177
K Bracing at core	35.366	56.387	84.414	128.456

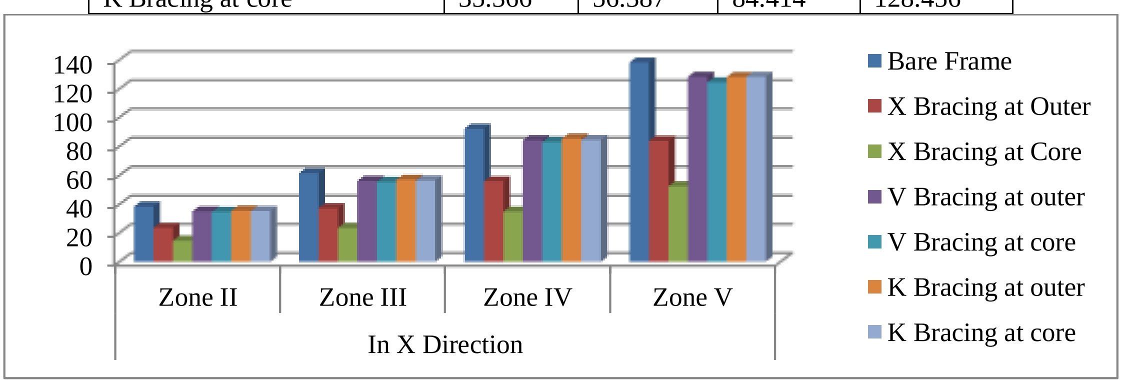


Fig 1: Maximum displacement in X direction of bracing system

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Table 3: Maximum Bending moment in bracing system

Structure type	Max Bending Moment			
	Zone II	Zone III	Zone IV	Zone V
Bare Frame	137.728	187.212	253.191	366.537
X Bracing at Outer	106.784	134.377	171.169	227.787
X Bracing at Core	91.016	118.454	155.038	209.914
V Bracing at outer	133.188	176.913	236.177	333.159
V Bracing at core	124.018	165.918	224.689	335.445
K Bracing at outer	131.481	179.09	238.83	337.871
K Bracing at core	125.652	168.535	225.712	332.573

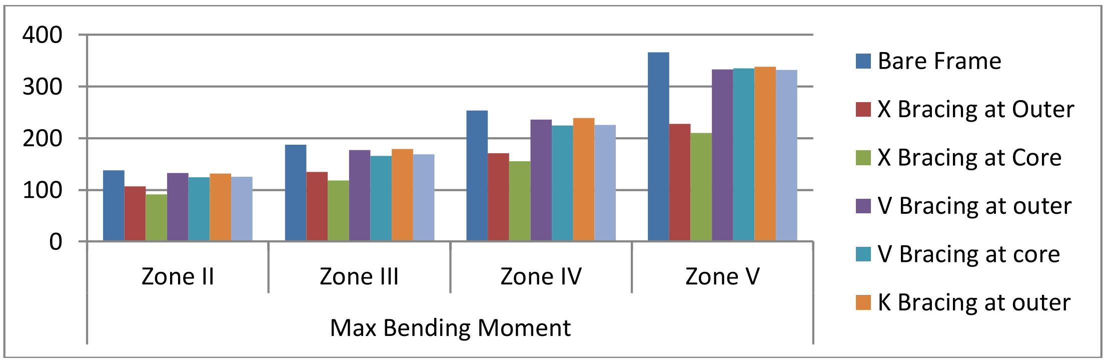

Fig 3: Maximum Bending moment in bracing system

Table 4: Maximum shear force in bracing system

Structure type	Max Shear force			
	Zone II	Zone III	Zone IV	Zone V
Bare Frame	115.938	141.473	175.52	226.59
X Bracing at Outer	106.815	114.256	131.221	162.403
X Bracing at Core	92.489	106.087	124.865	153.032
V Bracing at outer	113.703	136.219	166.75	213.261
V Bracing at core	109.377	131.711	161.49	206.34
K Bracing at outer	114.371	137.343	168.159	215.313
K Bracing at core	110.247	133.104	163.579	209.292

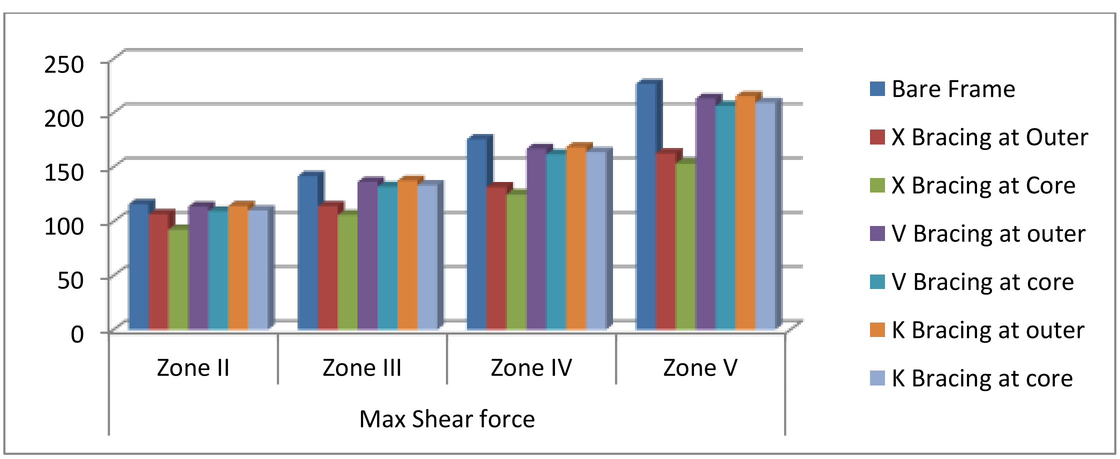

Fig 4: Maximum shear force in bracing system

Table 4: Max. storey displacement in zone-II in bracing system

Max story displacement in structure in Zone-II							
Floor	Bare Frame	X Bracing at Outer	X Bracing at Core	V Bracing at outer	V Bracing at core	K Bracing at outer	K Bracing at core
Base	0	0	0	0	0	0	0
GF	2.088	2.034	0.969	1.914	1.893	1.889	1.916
1st Floor	5.565	2.945	2.411	5.025	5.039	5.033	5.107
2nd Floor	9.239	3.973	3.806	8.243	8.357	8.355	8.483
3rd floor	12.828	5.139	5.132	11.383	11.597	11.597	11.787
4th floor	16.184	6.365	6.388	14.324	14.63	14.63	14.884
5th floor	19.162	7.594	7.546	16.947	17.329	17.33	17.643
6th floor	21.608	8.78	8.541	19.123	19.551	19.562	19.911
7th floor	23.362	9.885	9.28	20.723	21.15	21.197	21.546
8th floor	24.378	10.895	9.695	21.698	22.074	22.187	22.493

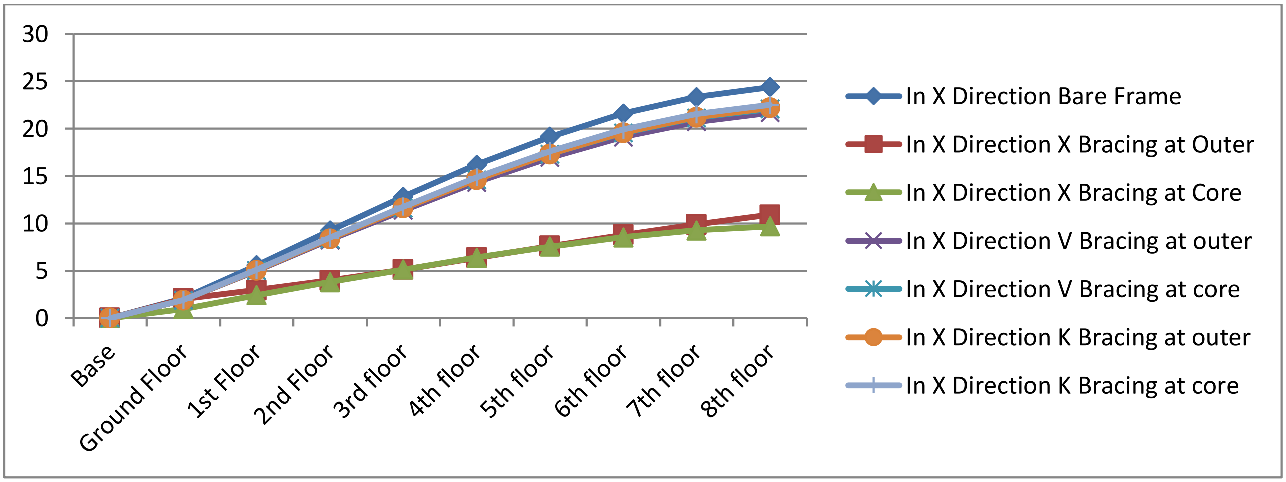

Fig 4: Max. storey displacement in zone-II in bracing system

Table 5: Max. storey displacement in zone-III in bracing system

Max story displacement in structure in Zone-III							
Floor	In X Direction						
	Bare Frame	X Bracing at Outer	X Bracing at Core	V Bracing at outer	V Bracing at core	K Bracing at outer	K Bracing at core
Base	0	0	0	0	0	0	0
GF	3.341	3.254	1.55	3.062	3.03	3.023	3.065
1st Floor	8.903	4.713	3.858	8.041	8.063	8.053	8.171
2nd Floor	14.782	6.356	6.09	13.189	13.372	13.367	13.573
3rd floor	20.525	8.23	8.211	18.212	18.555	18.556	18.86
4th floor	25.894	10.184	10.22	22.919	23.408	23.409	23.814
5th floor	30.66	12.151	12.073	27.116	27.726	27.727	28.225
6th floor	34.572	14.048	13.666	30.597	31.282	31.3	31.858
7th floor	37.379	15.815	14.848	33.157	33.84	33.916	34.474
8th floor	39.004	17.431	15.512	34.716	35.319	35.499	35.989

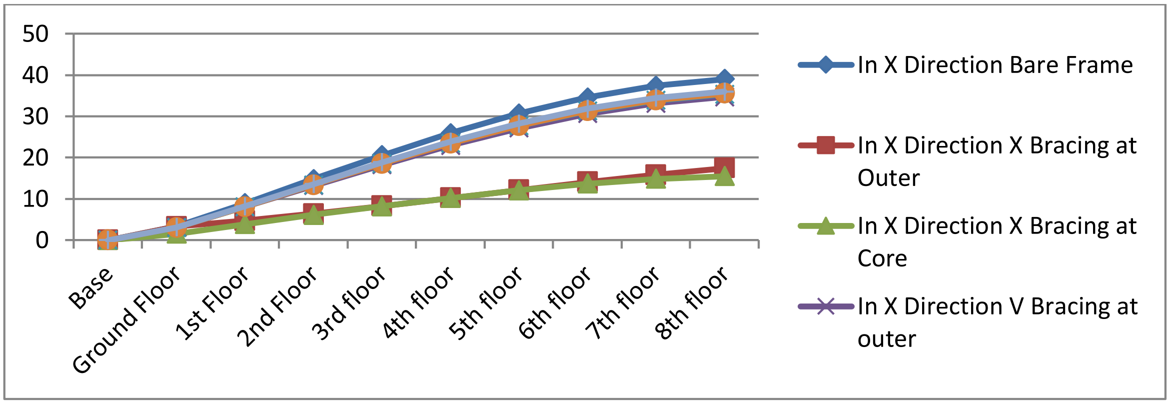

fig. 5: Max. storey displacement in zone-III in bracing system

Table 6: Max. storey displacement in zone-IVin bracing system

Max story displacement in structure in Zone-IV							
Floor	In X Direction						
	Bare Frame	X Bracing at Outer	X Bracing at Core	V Bracing at outer	V Bracing at core	K Bracing at outer	K Bracing at core
Base	0	0	0	0	0	0	0
GF	5.012	4.881	2.325	4.593	4.544	4.534	4.598
1st Floor	13.355	7.069	5.787	12.061	12.095	12.08	12.257
2nd Floor	22.174	9.535	9.135	19.783	20.057	20.051	20.36
3rd floor	30.788	12.334	12.316	27.319	27.833	27.834	28.29
4th floor	38.841	15.275	15.331	34.378	35.111	35.113	35.721
5th floor	45.99	18.226	18.109	40.674	41.589	41.591	42.337
6th floor	51.858	21.071	20.499	45.895	46.923	46.95	47.787
7th floor	56.069	23.723	22.271	49.735	50.76	50.874	51.711
8th floor	58.508	26.147	23.268	52.074	52.978	53.248	53.983

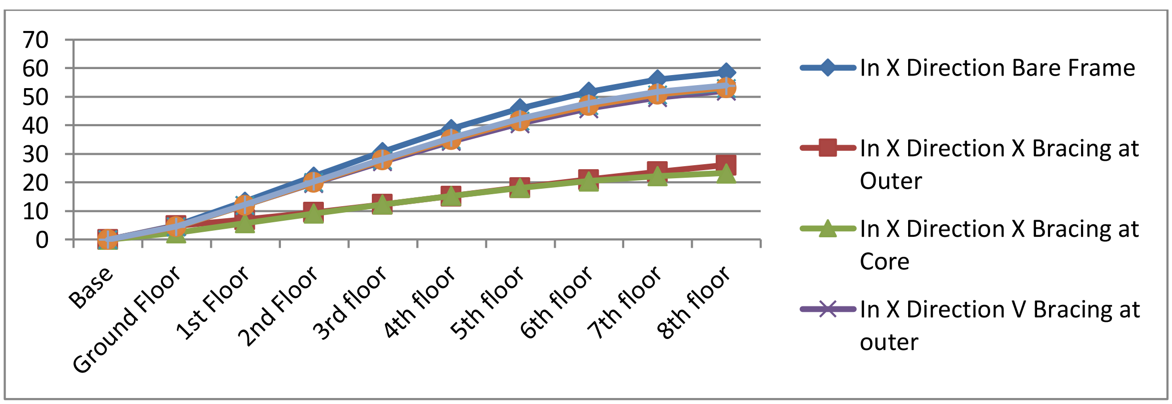

Fig. 6: Max. storey displacement in zone-IV in bracing system

Table 7: Max. storey displacement in zone-V in bracing system

Max story displacement in structure in Zone-V							
Floor	In X Direction						
	Bare Frame	X Bracing at Outer	X Bracing at Core	V Bracing at outer	V Bracing at core	K Bracing at outer	K Bracing at core
Base	0	0	0	0	0	0	0

GF	7.517	7.321	3.488	6.889	6.817	6.801	6.897
1st Floor	20.033	10.6032	8.68	18.092	18.142	18.12	18.385
2nd Floor	33.26	14.302	13.703	29.675	30.086	30.077	30.54
3rd floor	46.182	18.501	18.474	40.978	41.749	41.757	42.435
4th floor	58.262	22.913	22.996	51.568	52.667	52.67	53.581
5th floor	68.985	27.339	27.164	61.011	62.383	62.387	63.506
6th floor	77.787	31.607	30.748	68.842	70.384	70.424	71.681
7th floor	84.103	35.585	33.407	74.603	76.41	76.31	77.566
8th floor	87.759	39.22	34.902	78.111	79.467	79.873	80.975

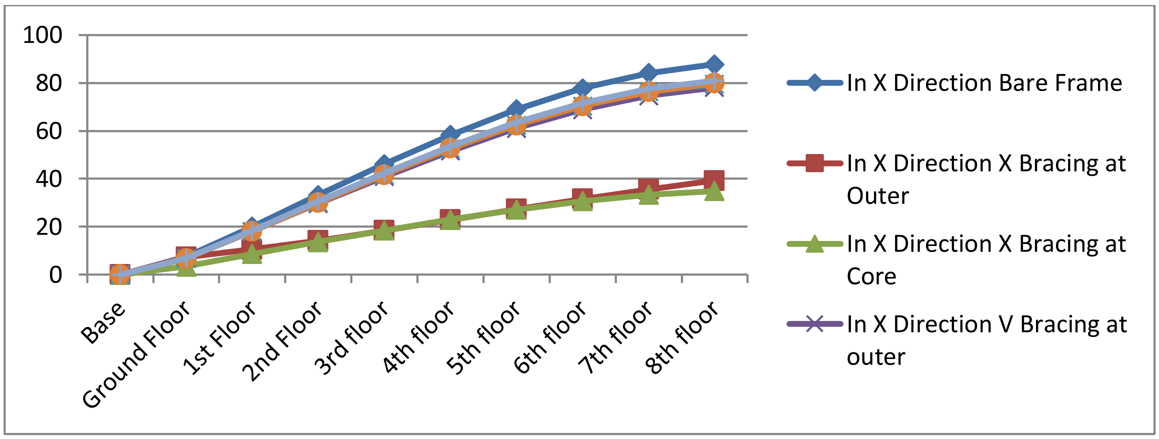

Fig. 7: Max. storey displacement in zone-V in bracing system

DIAPHRAGM MODELS

Results can be described under following heads -

Table 8: Maximum displacement in diaphragm system

Maximum displacement				
Structure type	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

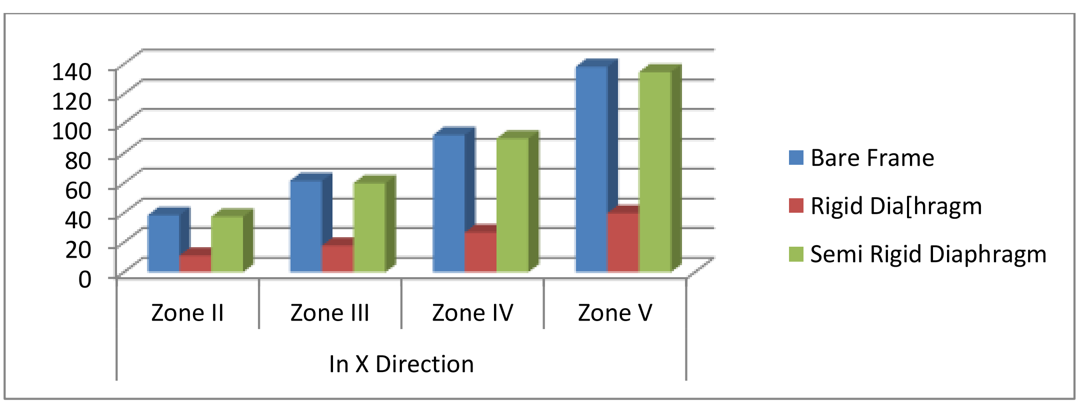

Table 8: Maximum displacement in diaphragm system

Table 10: 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

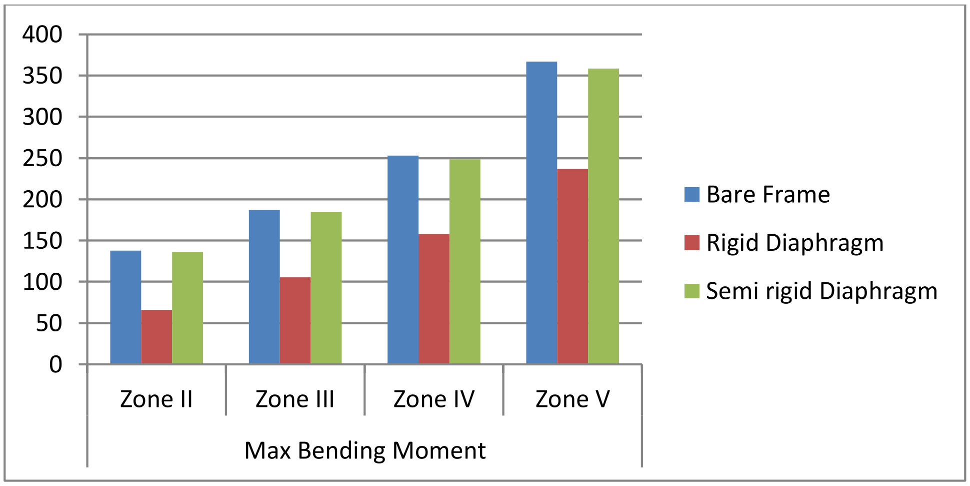

Fig. 10: Maximum bending moment in diaphragm system

Table 11: 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

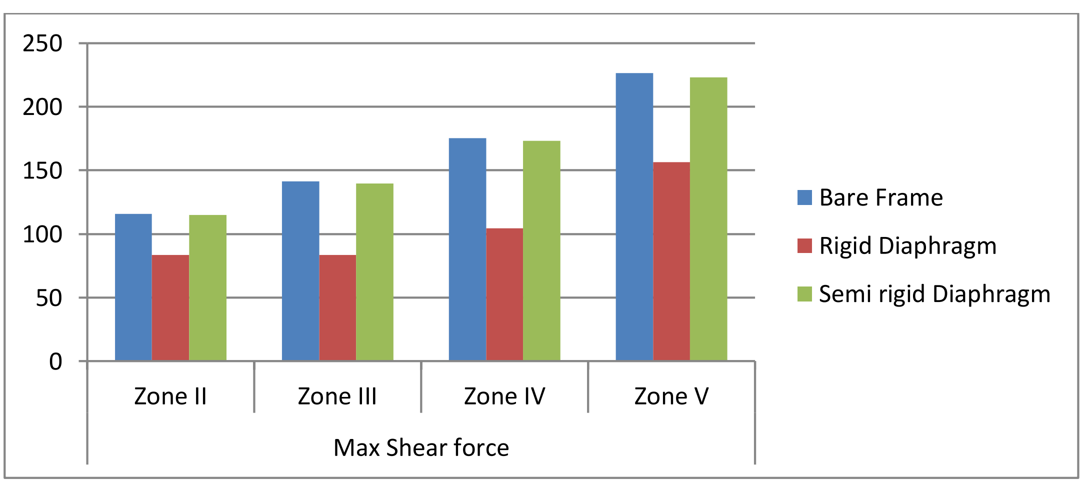

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Fig. 11: Maximum shear force in diaphragm system

Table 12: 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

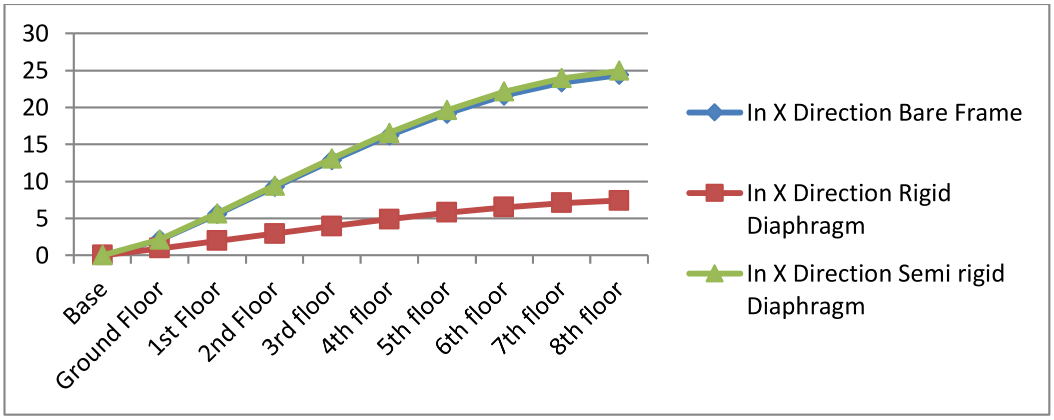

Fig. 12: Max. storey displacement in zone-II in diaphragm system

Table 13: 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

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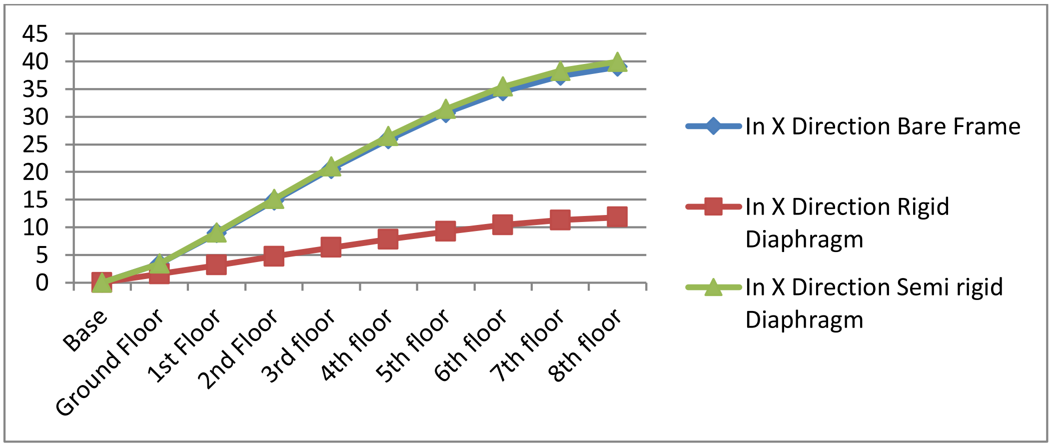

Fig. 13: Max. storey displacement in zone-III in diaphragm system

Table 14: 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
Ground Floor	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

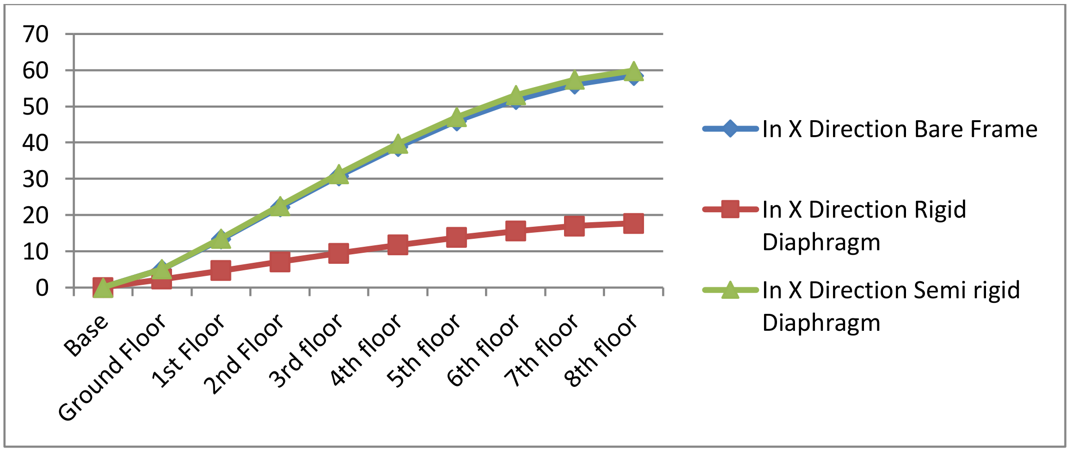

Fig. 14: Max. storey displacement in zone-IV in diaphragm system

Table 15: 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

Ground Floor	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

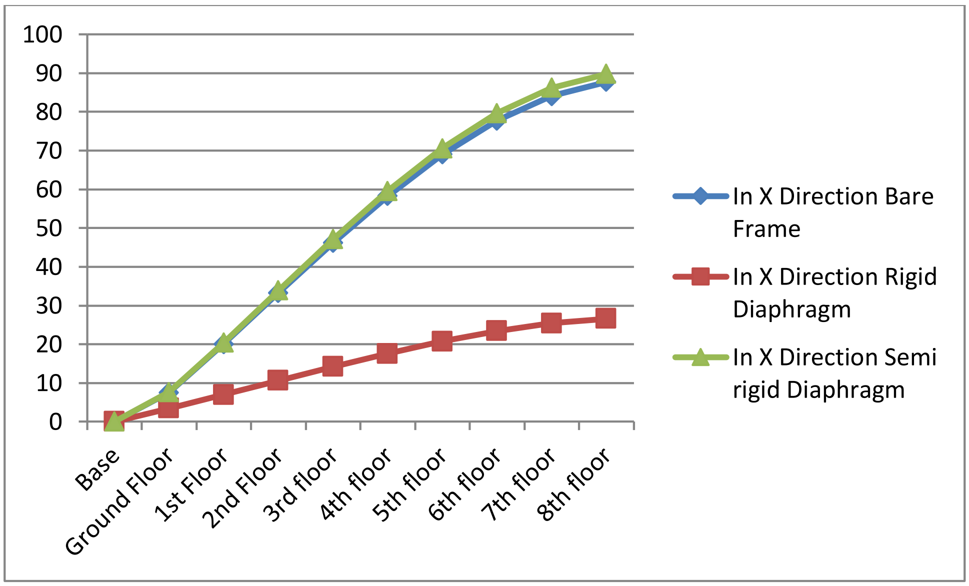

Fig. 15: Max. storey displacement in zone-V in diaphragm system

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 and bracing system in reducing moment, storey displacement, peak displacement. The analysis done in the present study clearly shows that semi-rigid diaphragm and bracing models produce more frame displacement and moments than the rigid diaphragm models. It has been found from the analysis of various building the rigid diaphragm is more effective than bracing system. 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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