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INFLUENCE OF DIAPHRAGM ON THE SEISMIC ANALYSIS OF REGULAR AND IRREGULAR FRAME STRUCTURES

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ABSTRACT

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. Each multi-storey building means a significant investment and as such multi-storey building analysis is generally performed using more sophisticated techniques and procedure. Therefore, accepting modern ways to seismic analysis of multi-storey buildings can be very valuable to structural engineers and researchers.

The intention of this study is therefore, to investigate the effect of different plan buildings with constant plan area in various seismic zones performance by comparing it with rigid diaphragm, semi-rigid diaphragm and without diaphragm including regular and irregular geometries. This study considered, comprehensive literature survey and analysis of different plan of buildings with various parameters like maximum bending moment, shear force, maximum displacement and storey displacement.

KEYWORDS— Seismic force, High rise Structure, Diaphragm, Rigid , Semi rigid etc.

INTRODUCTION

Reinforced concrete construction began in the early 1900s. But at that time reinforced concrete buildings were limited to only a few stories in height, since the structural system employed was the traditional beam-column frame system. Buildings taller than 30 stories were still uneconomical, since the shear walls, which were mostly located in the core of the building, were small in size, to give sufficient stiffness to resist transverse loads that is, the overall size of the shear walls were too small to economically provide the stability and stiffness for buildings over 30 stories. On the other hand the socio economic situations and an increasing demand for space in the growing U.S. cities created a strong need to the construction of tall buildings. The limit states design philosophy is the universally accepted philosophy, which is based on semi probabilistic approach for both structural properties and loading conditions. The ultimate Limit State is one of the two fundamental types of limit states, which must be considered in the design of high-rise buildings. Specially ultimate limit state caused by instability becomes a critical issue in such types of buildings. To provide safety against this type of failure an appropriate safety factor must be introduced. The other Limit State is the serviceability Limit State involving the appearance, efficiency and durability of the building throughout its design life. This can be achieved by controlling excessive deflection and crack width. As it is well known, the above design principles apply also to low-rise buildings. The main design requirement, for the ultimate Limit State is that the building should have adequate strength to resist and to remain stable throughout the lifetime of the building. To achieve this, analysis of the forces and stresses for the most critical load combinations has to be carried out and additional moments due to P-Delta effects have to be included. Critical members should be studied well, as their failure could initiate a progressive collapse of entire building. The design for stability of individual columns of high-rise structures is the same as for low-rise structures. The attention in this section is the stability of the building as a whole or with whole stories of the building. Instead, the more serious stability consideration is related to the second-order effects of gravity loading on lateral displacement caused by horizontal loading or acting on initial misalignments in the building. In case of lateral flexibility combined with exceptionally heavy gravity loading, the additional P-delta external moments may exceed the internal moments that the structure is capable of mobilizing by drift, due to which the structure would collapse because of instability. The additional displacement due to this effect might cause unacceptable total deflection, in which case the structure has to be stiffened. Therefore in the design of high rise structures it is advisable to access whether P-delta effect is significant. Limiting the lateral deflection is also a criterion of serviceability limit state design. The serviceability limit state criteria are to keep the lateral deflections at a low level, so that the non-structural elements can function properly to prevent excessive cracking and consequent loss of stiffness. The determination of a maximum permissible drift or lateral sway is based on the need to limit the adverse effects of the drift in the building. But, there are no universally confirmed values of drift index or any firm guidance to determine it. So, the designer will have to decide on an appropriate value based on the building usage the type of design criteria employed the form of construction, the materials employed, the transverse load considered and previous experience of similar buildings with good performance. People feel the movement and sense the twisting of the building, and some of them have feel motion sickness caused by building sway forces. Due to the above discussed problems a building may become undesirable or even un rentable.

Therefore, the reduction of such noticeable motion to an acceptable level is an important design criterion of tall buildings. As it is presented in, acceleration is the predominant parameter in determining human response to vibration. Other factors like period, amplitude, past experience, etc. can be also influential. Foundation deformations have two major influences on a building. The first is that the influence of the relative displacement on the forces in the horizontal elements. The second influence of foundation deformation on buildings occurs when an overall rotational settlement of the entire foundation occurs. Movement increases the maximum drift and a destabilising effect may be induced on the structure as a whole by increasing the P-delta effect.

Diaphragm or horizontal bracing system is a horizontal system transmitting lateral forces to the vertical lateral load resisting elements. Under lateral loading floor slabs in reinforced concrete building perform as diaphragms to transfer lateral forces to load resisting frames. Two primary types of diaphragm are rigid and flexible. Flexible diaphragms resist lateral forces depending on the area, irrespective of the flexibility of the members that they are transferring force to. Rigid diaphragms transfer load to frames or shear walls depending on their flexibility and their location in the structure. Flexibility of a diaphragm affects the 2 distribution of lateral forces to the vertical components of the lateral force resisting elements in a structure. Reinforced concrete diaphragms (floors and roofs) of a structure tie the vertical structural elements (such as walls and frames) together to allow buildings to resist external loads such as gravity and lateral forces from seismic events or wind action. Floor diaphragms play an important role of transferring forces from the structure to the lateral force resisting elements which then transfer the forces from the structure to the ground.

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.

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Guoxin Wang et al. (2009) proposed an optimal assessment method for the design of accelero graph arrays to monitor the seismic response of high rise buildings. This method uses a FEM (finite element) model of the structure based on a simplified multi degree of freedom system model defined using the parameter identification method.

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).

A rigid floor diaphragm is a good assumption in most buildings. However, floor diaphragms in some buildings may have considerable flexibility in their own plane e.g., buildings that are long and narrow or buildings with stiff end walls. In such buildings, design force for a particular floor cannot be applied at one single point say, the CM or at some eccentricity! of that floor. If the floor slabs are completely flexible, the lateral load distribution is governed by the tributary mass concept and the issue of torsion does not enter the picture. However, when the floor slabs have intermediate flexibility, i.e., floor diaphragms that are neither rigid nor completely flexible, floor diaphragm flexibility must be explicitly accounted for in the analysis. Transfer forces are largest for frame-wall structures where the frame and wall elements are of similar stiffness as each element can resist the deformations by the other element. The forces are found to be smaller when the stiffness ratio for the frame-wall structure is either small or large as the more flexible element provides little resistances to induce the transfer forces.

The main objective of this thesis is to investigate the effectiveness of building, considering various geometries under different seismic parameters. This is achieved by doing comparative analysis of the building frames with rigid diaphragm, semi-rigid diaphragm and without diaphragm building frames.

METHODOLOGY

This thesis deals with comparative study of behaviour of high rise building frames considering different geometrical configurations and diaphragm constraints under earthquake forces. A comparison of results in terms of moments, shear force, displacements, and storey displacement has been made. 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 essential 3 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 all facilitated by tools contained in the program's graphical environment.

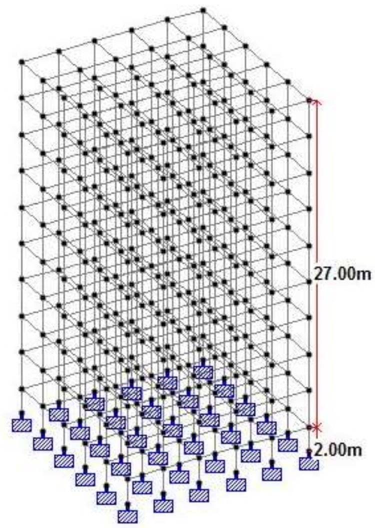

Figure 1: Isometric view of regular structure

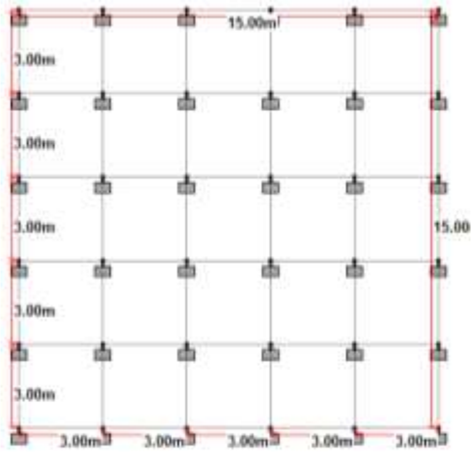

Figure 2: Plan of regular structure

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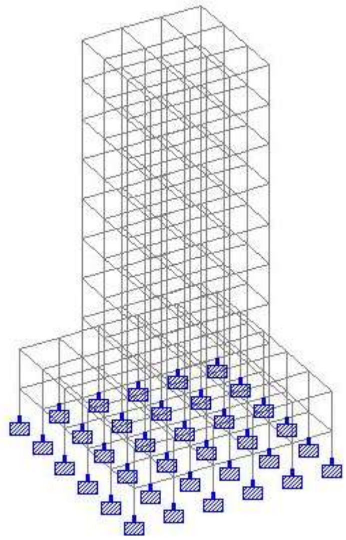

Figure 3: Isometric view of Plaza building

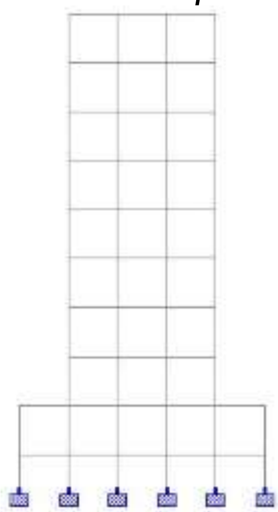

Figure 4: Front view of irregular plaza building

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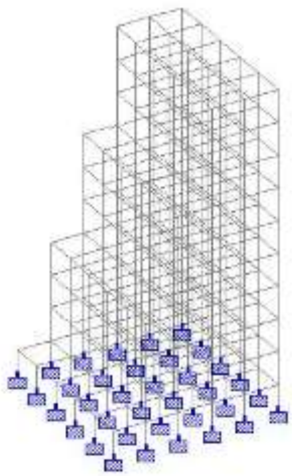

Figure 5: Isometric view of stepped building

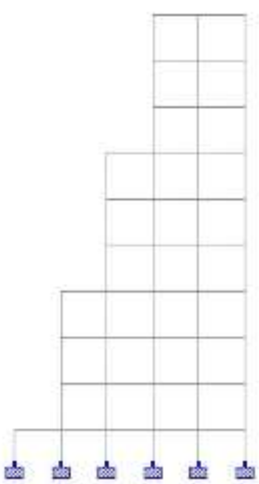

Figure 6: Front view of stepped building

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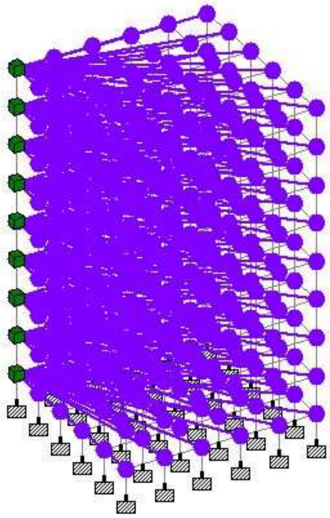

Figure 7: A typical isomeric diagram for diaphragm

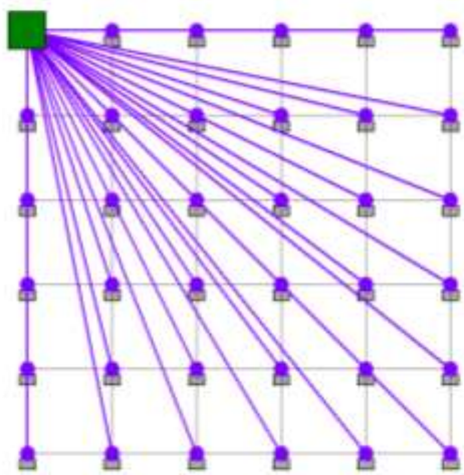

Figure 8:A typical plan diagram for diaphragm

RESULT ANALYSIS AND DISCUSSION

1. Maximum Displacement

Table 1: Max displacement X direction in Zone II

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	46.77	15.59	46.05
Stepped Frame	47.34	20.80	42.74
Plaza Frame	54.83	17.75	52.82

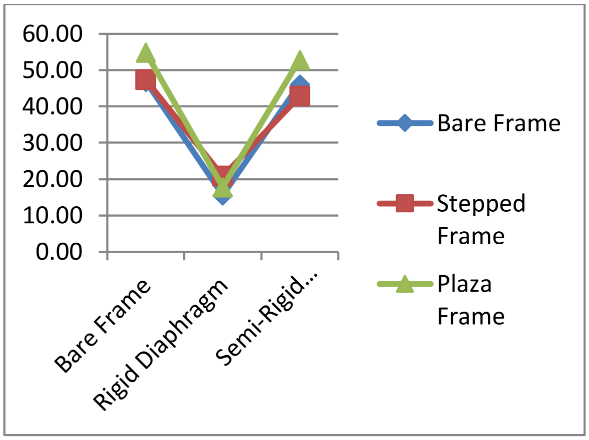

Figure 9: Max displacement X direction in Zone II

Table 2: Max displacement Z direction in Zone II

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	46.77	15.59	46.05
Stepped Frame	47.34	15.71	41.975
Plaza Frame	54.83	17.75	52.822

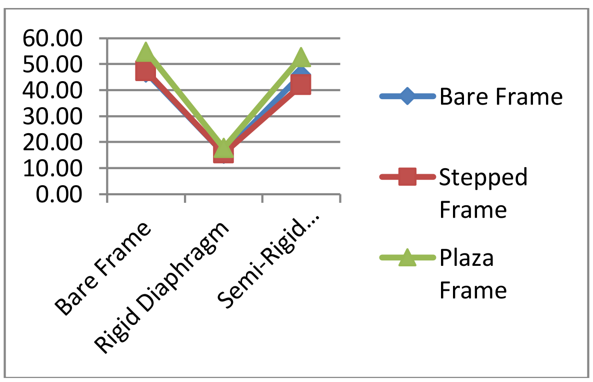

Figure 10: Max displacement Z direction in Zone II

Table 3: Max displacement X direction in Zone III

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	74.78	24.95	73.68
Stepped Frame	74.92	29.77	66.36
Plaza Frame	87.70	28.40	84.52

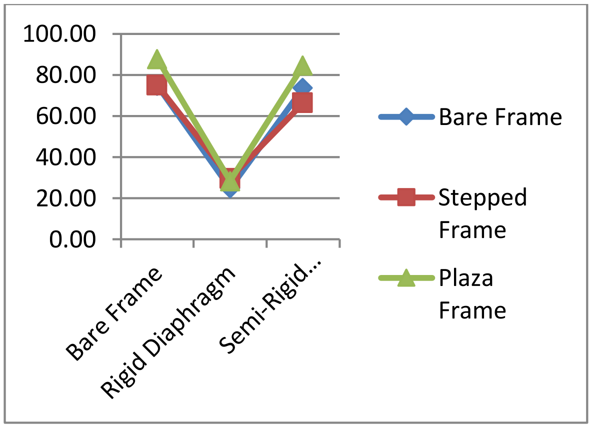

Figure 11: Max displacement X direction in Zone III

Table 4: Max displacement Z direction in Zone III

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	74.78	24.95	73.68
Stepped Frame	78.83	25.13	67.16
Plaza Frame	87.70	28.40	84.52

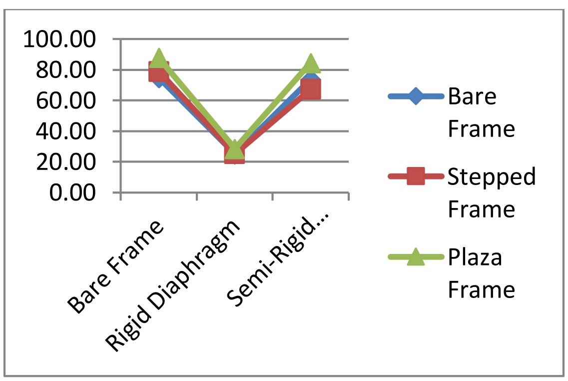

Figure 12: Max displacement Z direction in Zone III

Table 5: Max displacement X direction in Zone IV

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	112.13	37.42	110.52
Stepped Frame	111.71	41.73	97.85
Plaza Frame	131.53	42.59	126.77

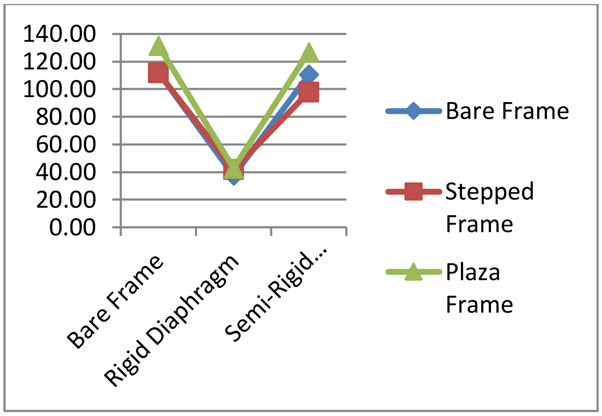

Figure 13: Max displacement X direction in Zone IV

Table 6: Max displacement Z direction in Zone IV

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	112.13	37.42	110.52
Stepped Frame	118.21	37.69	100.74
Plaza Frame	131.53	42.59	126.77

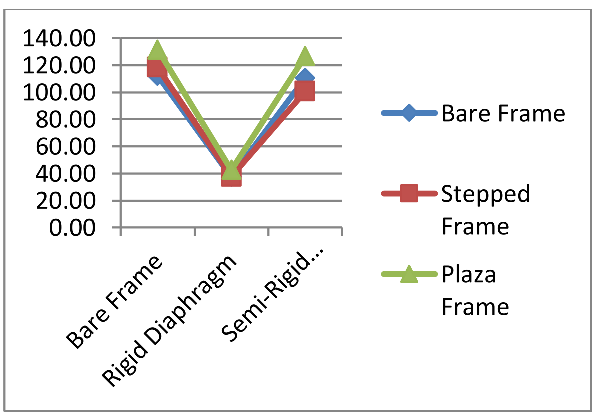

Figure 14: Max displacement Z direction in Zone IV

Table 7: Max displacement X direction in Zone V

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	168.16	56.14	165.79
Stepped Frame	166.88	59.68	145.09
Plaza Frame	197.27	63.89	190.16

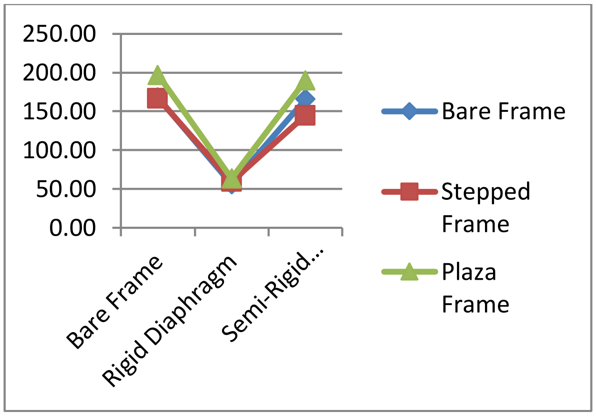

Figure 15: Max displacement X direction in Zone V

Table 8: Max displacement Z direction in Zone V

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	168.16	56.14	165.79
Stepped Frame	177.28	56.54	151.09
Plaza Frame	197.27	63.89	190.16

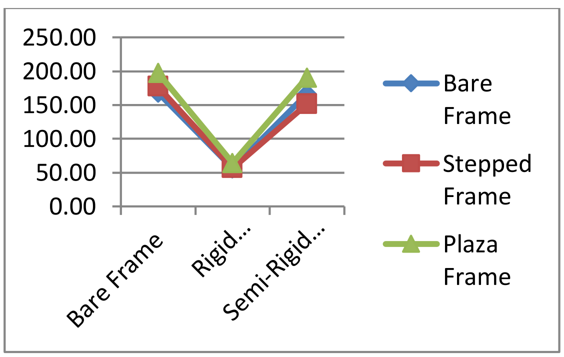

Figure 16: Max displacement Z direction in Zone V

2. Axial Force

Table 9: Max Axial forces in Zone II

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	2472.90	2053.69	2471.74
Stepped Frame	2332.05	2195.46	2006.08
Plaza Frame	2281.41	1622.28	2280.76

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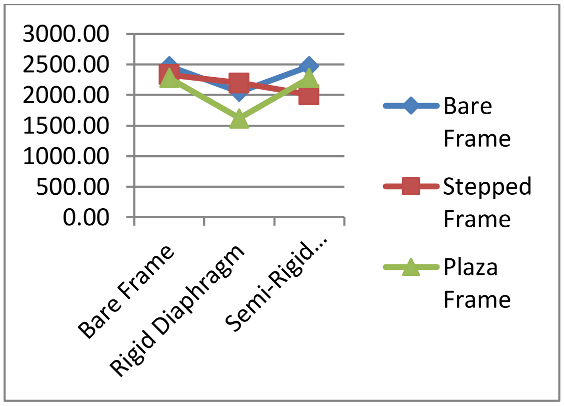

Figure 17: Max Axial forces in Zone II

Table 10: Max Axial forces in Zone III

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	2472.90	2260.57	2471.74
Stepped Frame	2332.05	2252.53	2231.88
Plaza Frame	2296.98	1868.86	2297.74

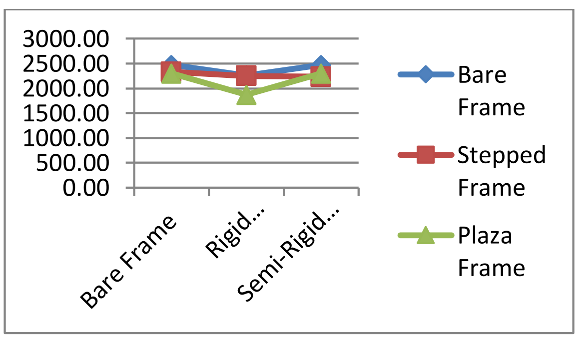

Figure 18: Max Axial forces in Zone III

Table 11: Max Axial forces in Zone IV

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	2648.08	2536.41	2636.24
Stepped Frame	2621.23	2428.89	2532.94
Plaza Frame	2636.05	2197.62	2637.52

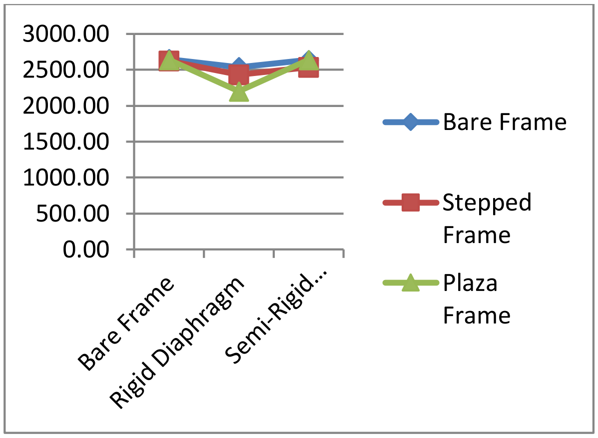

Figure 19: Max Axial forces in Zone IV

Table 12: Max Axial forces in Zone V

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	3186.08	2950.17	3168.20
Stepped Frame	3141.87	2693.43	2984.53
Plaza Frame	3144.66	2690.77	3147.17

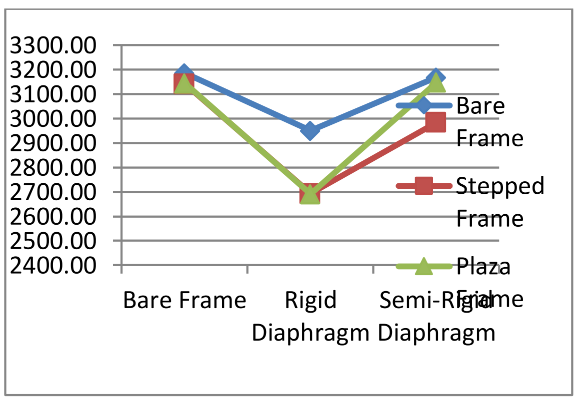

Figure 20: Max Axial forces in Zone V

3 Beam force

3.1 Maximum Bending Moment

Table 13: Max Bending moment in zone-II

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	141.33	33.46	140.03

Stepped Frame	157.09	33.46	141.69
Plaza Frame	164.50	33.46	164.78

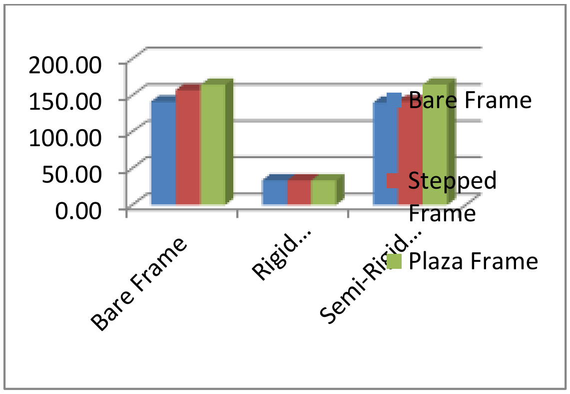

Figure 21: Max Bending moment in zone-II

Table 14: Max Bending moment in zone-III

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	204.67	33.46	202.58
Stepped Frame	223.01	33.46	201.56
Plaza Frame	240.86	33.46	241.28

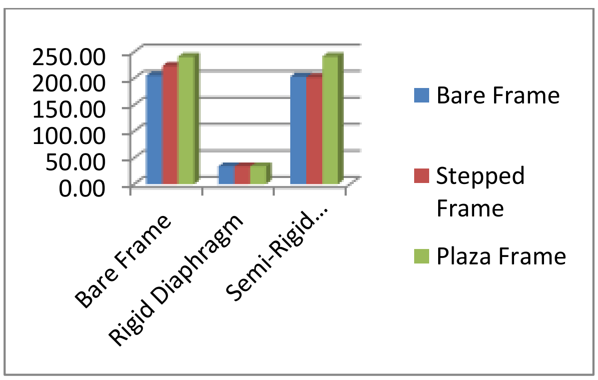

Figure 22: Max Bending moment in zone-III

Table 15: Max Bending moment in zone-IV

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	289.12	33.46	285.99

Stepped Frame	310.90	33.46	286.69
Plaza Frame	342.67	33.46	343.27

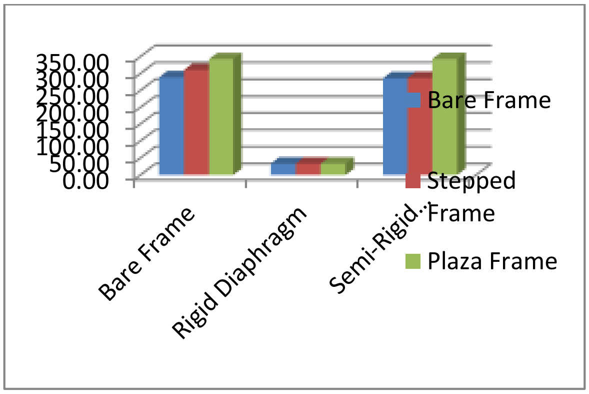

Figure 23: Max Bending moment in zone-IV

Table 16: Max Bending moment in zone-V

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	415.80	33.46	411.11
Stepped Frame	442.73	33.46	419.27
Plaza Frame	495.39	33.46	496.27

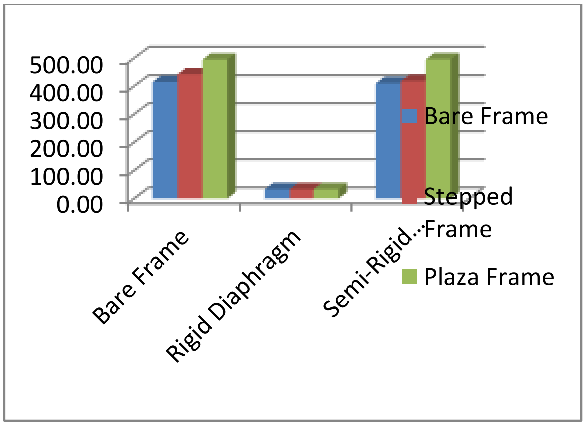

Figure 24: Max Bending moment in zone-V

3.2 Maximum Shear Forces

Table 17: Max shear force in zone-II

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	124.25	60.33	123.42
Stepped Frame	134.55	60.33	124.29
Plaza Frame	139.21	60.33	139.39

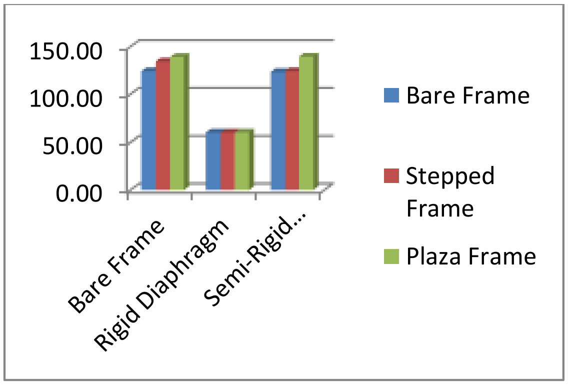

Figure 25: Max shear force in zone-II

Table 18: Max shear force in zone-III

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	164.77	60.33	163.45
Stepped Frame	176.53	60.33	162.54
Plaza Frame	188.10	60.33	188.37

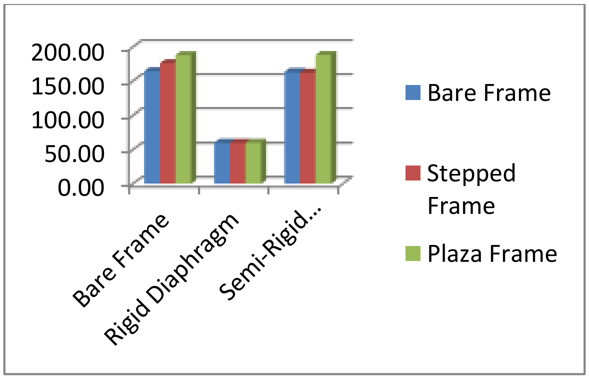

Figure 26: Max shear force in zone-III

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Table 19: Max shear force in zone-IV

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	218.81	60.33	216.82
Stepped Frame	232.51	60.33	213.53
Plaza Frame	253.30	60.33	253.68

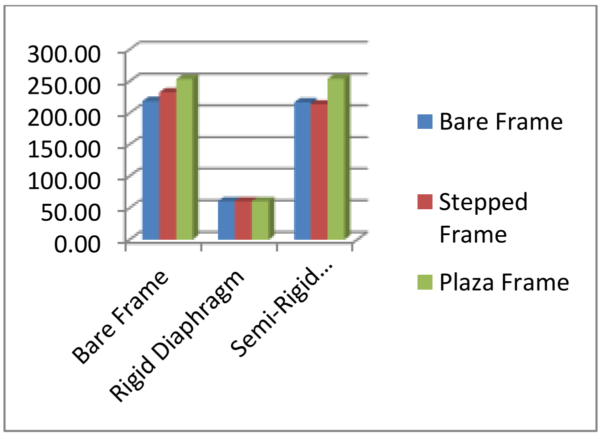

Figure 27: Max shear force in zone-IV

Table 20: Max shear force in zone-V

Structure type	Bare Frame	Rigid Diaphragm	Semi-Rigid Diaphragm
Bare Frame	299.86	60.33	296.88
Stepped Frame	316.49	60.33	297.67
Plaza Frame	351.08	60.33	351.64

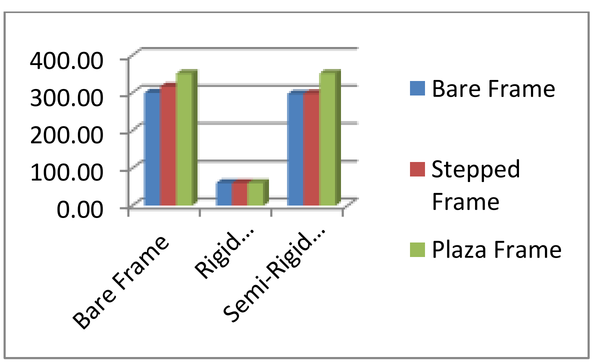

Figure 28: Max shear force in zone-V

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CONCLUSIONS

Following are the salient conclusions of this study-

Maximum Displacement

- In maximum displacement, it is seen that without diaphragm and semi rigid diaphragm has almost same results means semi rigid diaphragm is equivalent to without diaphragm structure.
- In maximum displacement, It is seen that without diaphragm is maximum and rigid diaphragm is minimum means bare frame is critical and rigid diaphragm is efficient.
- In comparison to all diaphragms, rigid diaphragm reduces thrice the displacement among other diaphragms

Beam forces

- In bending moment, it is seen that without diaphragm and semi rigid diaphragm has almost same results means semi rigid diaphragm is equivalent to without diaphragm structure.
- In bending moment, It is seen that without diaphragm is maximum and rigid diaphragm is minimum means bare frame is critical and rigid diaphragm is efficient.
- In shear force, it is seen that without diaphragm and semi rigid diaphragm has almost same results means semi rigid diaphragm is equivalent to without diaphragm structure.
- In shear force, It is seen that without diaphragm is maximum and rigid diaphragm is minimum means bare frame is critical and rigid diaphragm is efficient.

Maximum Storey displacement

- In maximum storey displacement, it is seen that without diaphragm and semi rigid diaphragm has almost same results means semi rigid diaphragm is equivalent to without diaphragm structure.
- In maximum storey displacement, It is seen that without diaphragm is maximum and rigid diaphragm is minimum means bare frame is critical and rigid diaphragm is efficient.
- In comparison to all diaphragms, rigid diaphragm reduces thrice the displacement among other diaphragms.

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