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Non-Linear Pushover Analysis Of RCC Framed Structure By Providing Fluid Viscous Dampers At Different Locations

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ABSTRACT

The increasing need of shelter in urban cities due to overpopulated spaces and land inadequacy people are forced to keep space and their needs strictly limited. High-rise buildings are the best solution for providing people spaces for living and to work on. In this age of urban development and rapid modernization the need of high-rise structures is rapidly increasing. As structures have become higher, structural engineering has become more difficult to achieve appropriate stability criteria. In tall buildings, stiffness is the key to sustainability. Fluid Viscous Dampers (FVD) are one of the efficient solutions for tall structures. These are hydraulic devices that, when stroked, dissipate the energy placed on a structure by seismic events. The viscous dampers convert the kinetic energy of the structural movement into heat and then dissipate that energy into the air, thereby obeying the laws of physics through the conservation of energy. To determine effectiveness of FVDs as well as determine best location for FVDs in high-rise buildings subjected to seismic loads, the current research is being carried out.

In this study twelve (12) RCC framed structures of 15 storeys of which four (4) are square shaped in plan, four (4) are rectangle shaped in plan with sides of ratio 1.5:1 and the other four (4) are rectangle shaped in plan with sides of ratio 2:1. These three (3) different shaped buildings considered are having approximately same plan area and damper positions. A floor-to-floor height 3m is taken. The buildings are located in Zone III. By using ETABS 2017 software, which helps to analyse and design the models, the analysis method used for this study is the Push Over analysis. This research work presents the results of an investigation on different parameters like Base shear, Modal mass participation, Time period, Storey Drift, Storey Shear and Storey Stiffness.

Keywords: Dynamic analysis, non-liner static analysis, pushover analysis, fluid viscous dampers.

INTRODUCTION

1.1 General

An earthquake is considered to be one of the most destructive natural hazards that causes great loss to life and livelihood. It is the shaking of the earth surface that is violent enough to cause major damage and kill thousands of people. They are caused due to sudden release of energy from earth's crust resulting due to actions of tectonic plates. The energy released takes the form of seismic waves. Earthquakes are the most unpredictable natural disasters. The huge amount of energy released during an earthquake can do high damage or worst case destroys major structures. In this age of high-rise constructions damage from an earthquake to building/structure poorly designed to resist earthquake force may result in greater loss of lives and infrastructure. India is considered in the list of most disaster-prone countries in the world. From the past experiences of strong earthquakes, it is proved that initial conceptual design of a building is extremely important for the positive response of a building during an earthquake. Structure cannot withstand the large earthquakes, but one can develop the structure, there are different irregularities in the structure. To minimize the damage of the structure, dampers may be provided at appropriate places. Hence it is very essential to identify the behaviour of buildings during an earthquake.

1.2 Objective of the Study

The objectives of this study are described in the points below.,

1. To evaluate the response of structures subjected to Seismic loads and to assess its behaviour for Fluid Viscous Dampers.
2. Comparing the characteristics on structures without and with dampers in terms of base shear, time period, storey drift, storey shear, storey stiffness and displacement.
3. To find the optimum position of dampers for a high-rise structure under seismic loads.

II. LITERATURE REVIEW

2.1 Literature Review:

The overview of the journals and research papers studied under the survey for this study are given below.,

Sk. Hashmath Ali and B. Kesava Rao, (2022) (IRJET), in this study generated a model of a G+15 building and the design and analysis is done with the ETABS software as per Indian Standard codes. The response spectrum and time history analysis has been analysed and its structure is designed with ETABS software. The response spectrum, analysis of time history results and also the displacements, storey shears and storey stiffness of a building is generated by using the ETABS software. The structural elements like columns, beams, shear and slabs wall have been designed as per the Indian Standard codes. The results show that multi-storey structure built using standard code provisions which are subjected to the seismic events and generate the displacements, storey shears, and storey stiffness and also generated the response spectrum and time history curves so that it shows the variation between the plots and curves of multi-storey building, the structure is made to resist the seismic induced forces from previous records and also resist the lateral loads which are done using the ETABS software.

Sairam Baikhan, K. Lakshmi Shiva Priya, N. V. N. Santhoshi Srija, CH. Nikhil Kumar and G. Sri Nath, (2020) (EJASR) in the current assessment has examined considering a (G+7) structure with the multiplication of seismic examination using SAP-2000. The plan is bankrupt down with the foundation of fluid viscous damper (FVD) arranged at various patterns, of complete 12 types have embraced being researched based. The suitability of the researched particular is obviously seen as the resultant essential lead, similar to time period, base reactions, displacement and story shear, etc. Out of 12 types, 3 kinds of plan are embraced and suggested a confident strategy for foundation of arrangement of dampers.

Ashwini L K, Nupur P Gowda, Padma V P, Parineetha M, Ramya B, (2019) (IRJET) in this study considered a G+9 located in Zone II. The material properties are M30 grade concrete, Fe-415 steel. The typical floor height is 3.65m. This study aims to focus on the modelling approach of building and the subsequent impacts on the structural performance under earthquake. In this study it is concluded that, Pushover analysis has been the preferred method for seismic performance due to its simplicity and has been viewed as an attractive alternative to the nonlinear time history analysis. Gross section model overestimates the Base Shear at performance point and ultimate capacity with large margin of safety which may not be the real scenario of the existing building as cracks exist due to service loads. Maximum displacement for the model with the moment of inertia value of, 0.35 is 50.347mm, 0.7 is 77.376mm, 1 is 178.248mm 4. Maximum Base Shear for the model with the moment of inertia value of 0.35 is 2082.89 KN, 0.7 is 2522.512 KN, 1 is 2943.707 KN

Giuseppe Marcantonio Del Gobbo, Anthony Blakeborough and Martin S. Williams, (2018) (BEE) in this study investigates the application of linear Fluid Viscous Dampers to improve total-building seismic performance considering repair costs. The energy-based method commonly used to calculate damper coefficients is modified to improve its accuracy. The optimal amount of damping with respect to repair costs (estimated using the FEMA P-58 procedure) is identified as 25–45%. This contrasts with a previously suggested optimal damping of 20–25%, based on structural parameters, that is frequently targeted. This study on the damping-repair cost relationship provides insight when selecting levels of damping for structural designs and retrofits. It also highlights that retrofit methods may be enhanced by using repair costs, rather than structural parameters. The Fluid Viscous Damper buildings significantly reduce both drift-sensitive and acceleration-sensitive damage. Structural damage is also negligible in the Fluid Viscous Damper buildings: a major step towards achieving building serviceability following an ultimate limit state level earthquake.

Saurabh P. Hete, Sanjay K. Bhadke, Amey Khedikar, (2018) (IRJET) conducted a study on RCC Framed regular and irregular structure with G+8 and G+12 subjected to earthquake forces in Zone II. Fundamental period of vibration of the frame with fixed support. In order to understand the effect of pushover analysis of existing RC frame structure base model using ETABS 2016, Response spectrum method and Pushover analysis of the models are performed. The study is based on frames which are plane and orthogonal with storey heights and bay widths. Different building geometries were taken for the study. These building geometries represent varying degree of irregularity or amount of existing. Three different width categories, ranging from 6 to 6 bays (in the direction of earthquake) with a uniform bay width of 4m were considered for this study. It should be noted that bay width of 4m – 4m is the usual case, especially in Indian and European practice. Similarly, four different height categories were considered for the study, ranging from 5 to 12 storeys.

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III. METHODOLOGY

3.1 General

In this study twelve (12) RCC framed structures of 15 storeys of which four (4) are square shaped (1:1) in plan, four (4) are rectangle shaped in plan with sides of ratio 1.5:1 and the other four (4) are rectangle shaped in plan with sides of ratio 2:1. These three (3) different shaped buildings considered are having approximately same plan area and damper positions. The location of the building assumed to be in Zone III. By using ETABS 2017 software, which helps to analyse and design the models, the analysis method used for this study is the Push Over analysis for dynamic analysis. This Study is focused on finding the best position of Fluid Viscous Dampers in high rise structures subjected to seismic loads with the help of ETABS 2017 Software.

3.2 Building Description in the Study

The models used for this analysis are as follows-
Model 1(a)*:* First model is a square building with the ratio of sides to be 1:1 which is modelled without Fluid Viscous Dampers.
Model 2(a)*:* Second model is a square building with the ratio of sides to be 1:1 which is modelled with Fluid Viscous Dampers installed at extreme corner columns
Model 3(a)*:* Third model is a square building with the ratio of sides to be 1:1 which is modelled with Fluid Viscous Dampers installed
Model 4(a)*:* Fourth model is a square building with the ratio of sides to be 1:1 which is modelled with Fluid Viscous Dampers installed
Model 1(b)*:* Fifth model is a rectangular building with the ratio of sides to be 1.5:1 which is modelled without Fluid Viscous Dampers
Model 2(b)*:* Sixth model is a rectangular building with the ratio of sides to be 1.5:1 which is modelled with Fluid Viscous Dampers installed at extreme corner columns
Model 3(b)*:* Seventh model is a rectangular building with the ratio of sides to be 1.5:1 which is modelled with Fluid Viscous Dampers installed
Model 4(b)*:* Eighth model is a rectangular building with the ratio of sides to be 1.5:1 which is modelled with Fluid Viscous Dampers installed
Model 1(c)*:* Ninth model is a rectangular building with the ratio of sides to be 2:1 which is modelled without Fluid Viscous Dampers
Model 2(c)*:* Tenth model is a rectangular building with the ratio of sides to be 2:1 which is modelled with Fluid Viscous Dampers installed at extreme corner columns
Model 3(c)*:* Eleventh model is a rectangular building with the ratio of sides to be 2:1 which is modelled with Fluid Viscous Dampers installed
Model 4(c)*:* Twelfth model is a rectangular building with the ratio of sides to be 2:1 which is modelled with Fluid Viscous Dampers installed

IV. RESULTS AND DISCUSSION

4.1 General

The chapter explores the earthquake response of 15 storey buildings without and with Fluid Viscous Dampers installed at different positions. The behaviour of all the buildings are studied and compared. To understand the efficacy of all these structures, the parameters like base shear, storey shears, storey drift, overturning moments, time period and storey stiffness of the structure are incorporated from the dynamic analysis and pushover curves are plotted using ETABS 2017 and performing pushover analysis. This chapter goes into great depth on the model analysis's findings. These findings have also been used to study of how these structures operate when subjected to lateral stresses.

4.2 Base Shear

Base shear is the maximum lateral force which occur at the base of a structure due ground motion during the earthquake. Due to seismic activities, the ground start moving. Due to the movement of ground, lateral force is developed in opposite direction of motion. That developed lateral force due seismic motion at the base of the structure is called base shear.

4.2.1 Comparison of Base Shear Results for Model 1(a), 2(a), 3(a) & 4(a)

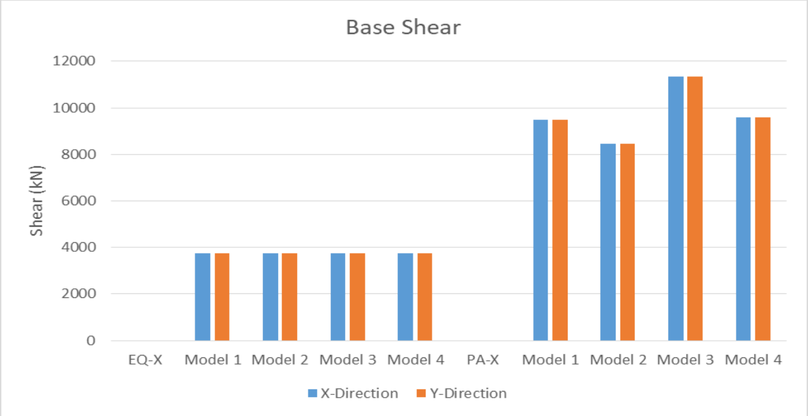

Fig 1 Graph showing Comparison of Base Shear Results for Model 1(a), 2(a), 3(a) & 4(a)

Fig 1 showing the base shear results of different models used for the comparative study it can be observed that the model 2(a) is having 11.25% less base shear than model 1(a), 28.83% less base shear than model 3(a) and 12.5% less base shear than model 4(a).

4.2.2 Comparison of Base Shear Results for Model 1(b), 2(b), 3(b) & 4(b)

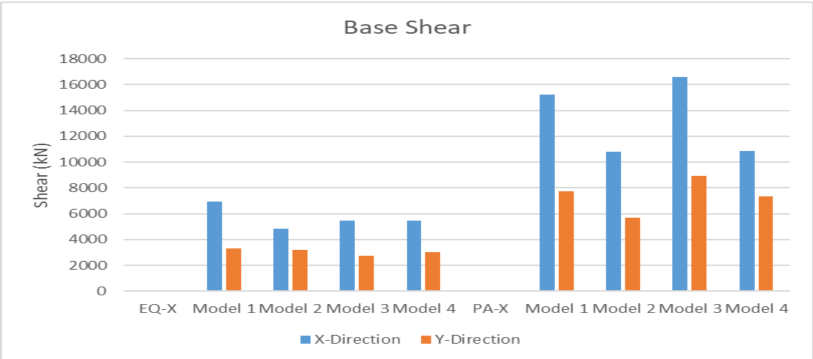

Fig 2 Graph showing Comparison of Base Shear Results for Model 1(b), 2(b), 3(b) & 4(b)

Fig 2 showing the base shear results of different models used for the comparative study it can be observed that the model 2(b) is having 34.05% less base shear than model 1(b), 42.37% less base shear than model 3(b) and 0.55% less base shear than model 4(b) in X direction and 30.01% less base shear than model 1(b), 43.93% less base shear than model 3(b) and 24.85% less base shear than model 4(b) in Y direction.

4.2.3 Comparison of Base Shear Results for Model 1(c), 2(c), 3(c) & 4(c)

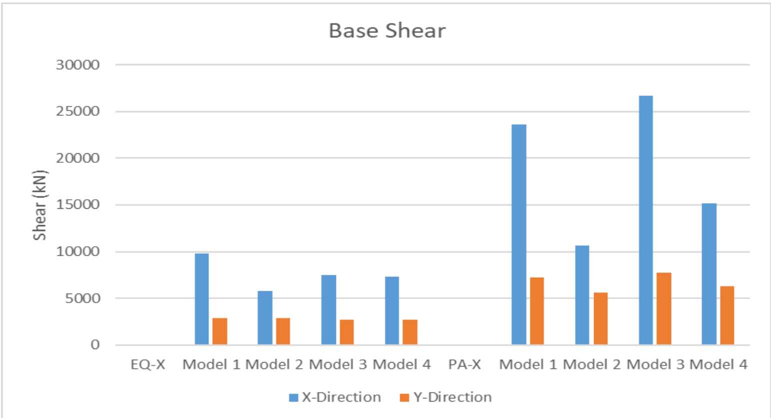

Fig 3Graph showing Comparison of Base Shear Results for Model 1(c), 2(c), 3(c) & 4(c)

Fig 3 showing the base shear results of different models used for the comparative study it can be observed that the model 2(c) is having 75.67% less base shear than model 1(c), 85.98% less base shear than model 3(c) and 35% less base shear than model 4(c) in X direction and 25.14% less base shear than model 1(c), 31.49% less base shear than model 3(c) and 10.88% less base shear than model 4(c) in Y direction.

4.2.4 Comparison of Base Shear Results for Model 1(a), 1(b) & 1(c)

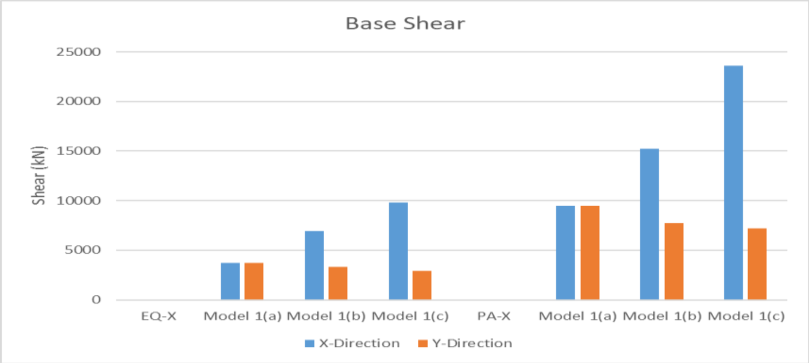

Fig 4 Graph showing Comparison of Base Shear Results for Model 1(a), 1(b) & 1(c)

Fig 4 showing the base shear results of different models used for the comparative study it can be observed that the model 1(a) is having 46.34% less base shear than model 1(b) and 85.38% less base shear than model 1(c) in X direction and model 1(c) is having 26.93% less base shear than model 1(a) and 6.47% less base shear than model 1(b) in Y direction.

4.2.5 Comparison of Base Shear Results for Model 2(a), 2(b) & 2(c)

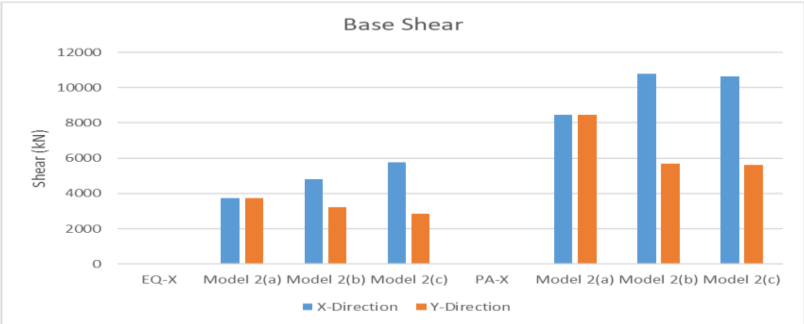

Fig 5 Graph showing Comparison of Base Shear Results for Model 2(a), 2(b) & 2(c)

Fig 5 showing the base shear results of different models used for the comparative study it can be observed that the model 2(a) is having 23.95% less base shear than model 2(b) and 22.76% less base shear than model 2(c) in X direction and model 2(c) is having 40.54% less base shear than model 2(a) and 1.52% less base shear than model 2(b) in Y direction.

4.2.6 Comparison of Base Shear Results for Model 3(a), 3(b) & 3(c)

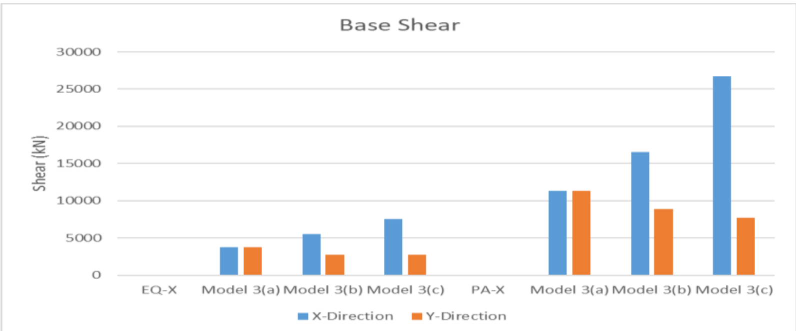

Fig 6 Graph showing Comparison of Base Shear Results for Model 3(a), 3(b) & 3(c)

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Fig 6 showing the base shear results of different models used for the comparative study it can be observed that the model 3(a) is having 37.6% less base shear than model 3(b) and 80.88% less base shear than model 3(c) in X direction and model 3(c) is having 37.93% less base shear than model 3(a) and 14.4% less base shear than model 3(b) in Y direction.

4.2.7 Comparison of Base Shear Results for Model 4(a), 4(b) & 4(c)

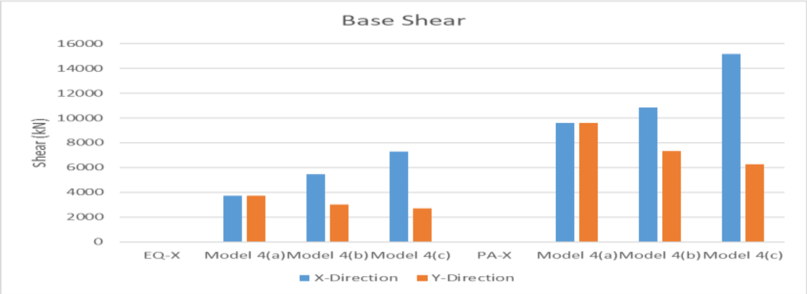

Fig 7 Graph showing Comparison of Base Shear Results for Model 4(a), 4(b) & 4(c)

Fig 7 showing the base shear results of different models used for the comparative study it can be observed that the model 4(a) is having 12.06% less base shear than model 4(b) and 44.91% less base shear than model 4(c) in X direction and model 4(c) is having 42.12% less base shear than model 4(a) and 15.57% less base shear than model 4(b) in Y direction.

4.3 TIME PERIOD

Due to the movement of tectonic plates beneath the surface of earth there are massive waves generated due to the sliding of plates which are known as seismic waves and these seismic waves collaborate together and reach the surface of earth and give a massive vibration in their duration of occurrence this makes the earth tremble, the foot of the structure vibrates with the earth and the structure oscillates back and forth, the time taken by the structure for each complete cycle of oscillation is the same, and it is called fundamental natural period T of the building. The lesser the time period, the more rigid will be the structure.

4.3.1 Comparison of Time Period Results for Model 1(a), 2(a), 3(a) & 4(a)

Comparison of Time Period Results for Model 1(a), 2(a), 3(a) & 4(a) in X and Y directions are shown in Table 1

Table 1 Comparison of Time Period Results for Model 1(a), 2(a), 3(a) & 4(a)

Time Period	X-Direction	Y-Direction
Model 1	5.136	5.136
Model 2	4.165	4.165
Model 3	4.137	4.137
Model 4	4.037	4.037

From Table 1 showing the time periods of different models used for the comparative study it can be observed that the model 4(a) is having 23.96% less time period than model 1(a), 3.12% less time period than model 2(a) and 2.45% less time period than model 3(a).

4.3.2 Comparison of Time Period Results for Model 1(b), 2(b), 3(b) & 4(b)

Comparison of Time Period Results for Model 1(b), 2(b), 3(b) & 4(b) in X and Y directions are shown in Table 2

Table 2 Comparison of Time Period Results for Model 1(b), 2(b), 3(b) & 4(b)

Time Period	X-Direction	Y-Direction
Model 1	7.30	4.49
Model 2	5.79	4.89
Model 3	5.95	3.25
Model 4	5.28	3.40

From Table 2 showing the time periods of different models used for the comparative study it can be observed that the model 4(b) is having 32.11% less time period than model 1(b), 9.21% less time period than model 2(b) and 11.93% less time period than model 3(b) in X direction and model 3(b) is having 32.04% less time period than model 1(b), 40.29% less time period than model 2(b) and 4.51% less time period than model 4(b) in Y direction.

4.3.3 Comparison of Time Period Results for Model 1(c), 2(c), 3(c) & 4(c)

Comparison of Time Period Results for Model 1(c), 2(c), 3(c) & 4(c) in X and Y directions are shown in Table 3

Table 3 Comparison of Time Period Results for Model 1(c), 2(c), 3(c) & 4(c)

Time Period	**X-Direction**	**Y-Direction**
Model 1	8.55	3.87
Model 2	6.54	3.07
Model 3	6.55	3.12
Model 4	7.88	2.93

From Table 3 showing the time periods of different models used for the comparative study it can be observed that the model 2(c) is having 26.64% less time period than model 1(c), 0.15% less time period than model 3(c) and 18.58% less time period than model 4(c) in X direction and model 4(c) is having 27.65% less time period than model 1(c), 4.67% less time period than model 2(c) and 6.28% less time period than model 3(c) in Y direction.

4.3.4 Comparison of Time Period Results for Model 1(a), 1(b) & 1(c)

Comparison of Time Period Results for Model 1(a), 1(b) & 1(c) in X and Y directions are shown in Table 4.

Table 4 Comparison of Time Period Results for Model 1(a), 1(b) & 1(c)

Time Period	**X-Direction**	**Y-Direction**
Model 1(a)	5.14	5.14
Model 1(b)	7.30	4.49
Model 1(c)	8.55	3.87

From Table 4 showing the time periods of different models used for the comparative study it can be observed that the model 1(a) is having 34.73% less time period than model 1(b) and 49.82% less time period than model 1(c) in X direction and model 1(c) is having 28.19% less time period than model 1(a) and 14.83% less time period than model 1(b) in Y direction.

4.3.5 Comparison of Time Period Results for Model 2(a), 2(b) & 2(c)

Comparison of Time Period Results for Model 2(a), 2(b) & 2(c) in X and Y directions are shown in Table 5

Table 5 Comparison of Time Period Results for Model 2(a), 2(b) & 2(c)

Time Period	**X-Direction**	**Y-Direction**
Model 2(a)	4.17	4.17
Model 2(b)	5.79	4.89
Model 2(c)	6.54	3.07

From Table 5 showing the time periods of different models used for the comparative study it can be observed that the model 2(a) is having 32.53% less time period than model 2(b) and 44.26% less time period than model 2(c) in X direction and model 2(c) is having 30.39% less time period than model 2(a) and 45.73% less time period than model 2(b) in Y direction.

4.3.6 Comparison of Time Period Results for Model 3(a), 3(b) & 3(c)

Comparison of Time Period Results for Model 3(a), 3(b) & 3(c) in X and Y directions are shown in Table 6

Table 6 Comparison of Time Period Results for Model 3(a), 3(b) & 3(c)

Time Period	X-Direction	Y-Direction
Model 3(a)	4.14	4.14
Model 3(b)	5.95	3.25
Model 3(c)	6.55	3.12

From Table 6 showing the time periods of different models used for the comparative study it can be observed that the model 3(a) is having 35.88% less time period than model 3(b) and 45.1% less time period than model 3(c) in X direction and model 3(c) is having 28.1% less time period than model 3(a) and 4.08% less time period than model 3(b) in Y direction.

4.3.7 Comparison of Time Period Results for Model 4(a), 4(b) & 4(c)

Comparison of Time Period Results for Model 4(a), 4(b) & 4(c) in X and Y directions are shown in Table7

Table 7 Comparison of Time Period Results for Model 4(a), 4(b) & 4(c)

Time Period	X-Direction	Y-Direction
Model 4(a)	4.04	4.04
Model 4(b)	5.28	3.40
Model 4(c)	7.88	2.93

From Table 7 showing the time periods of different models used for the comparative study it can be observed that the model 4(a) is having 26.61% less time period than model 4(b) and 64.43% less time period than model 4(c) in X direction and model 4(c) is having 31.85% less time period than model 4(a) and 14.8 5% less time period than model 4(b) in Y direction.

4.4 STOREY DRIFT

It is the relative displacement between the floor or roof in the building considered, as per IS1893:2016 the Storey drift in any Storey should not exceed 0.004 times the Storey height. Higher the lateral stiffness lesser is the likely damage.

4.4.1 Comparison of Storey Drift Results for Model 1(a), 2(a), 3(a) & 4(a)

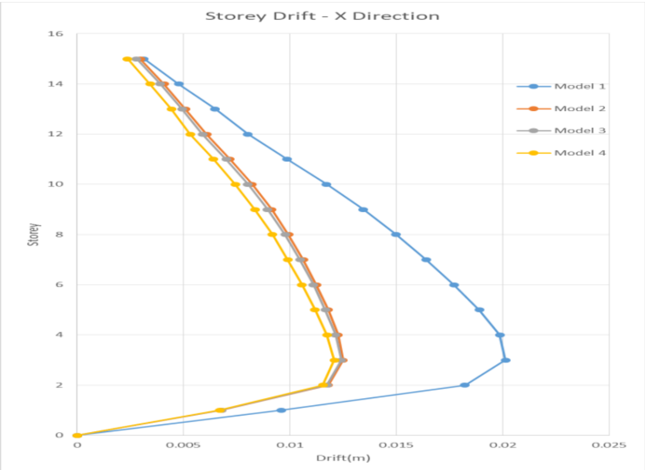

Fig 8(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 1(a), 2(a), 3(a) & 4(a)

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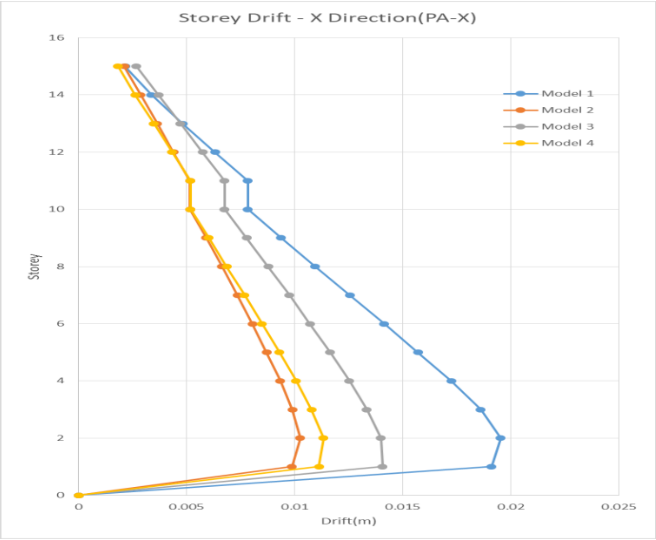

Fig 8(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 1(a), 2(a), 3(a) & 4(a)

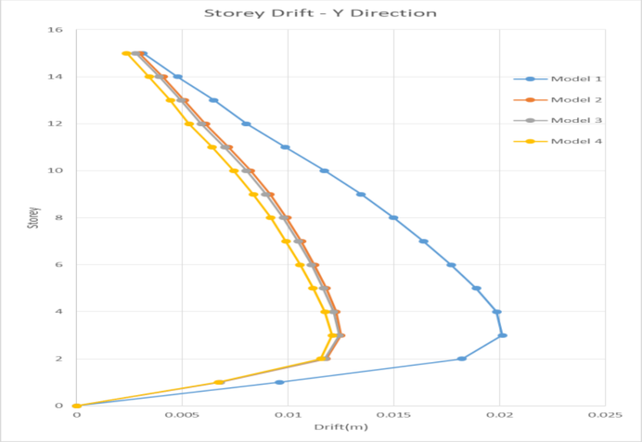

Fig 8(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 1(a), 2(a), 3(a) & 4(a)

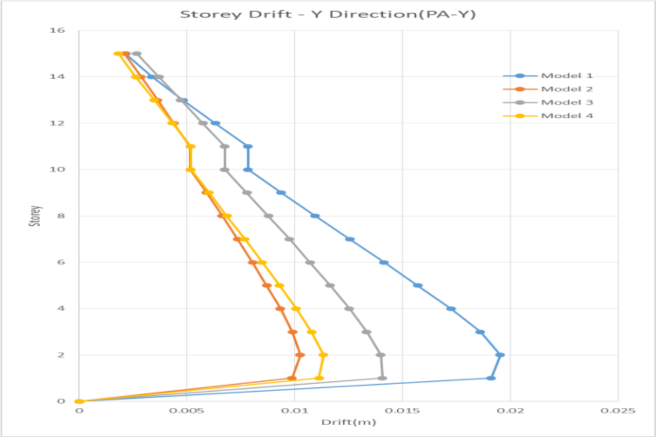

Fig 8(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 1(a), 2(a), 3(a) & 4(a)

Figures 8(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 4(a) is having 16.38% less storey drift than model 1(a), 14.6% less storey drift than model 2(a) and 37.86% less storey drift than model 3(a).

4.4.2 Comparison of Storey Drift Results for Model 1(b), 2(b), 3(b) & 4(b)

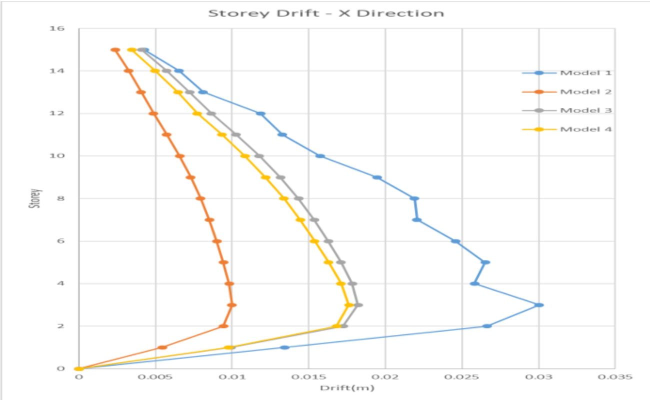

Fig 9(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 1(b), 2(b), 3(b) & 4(b)

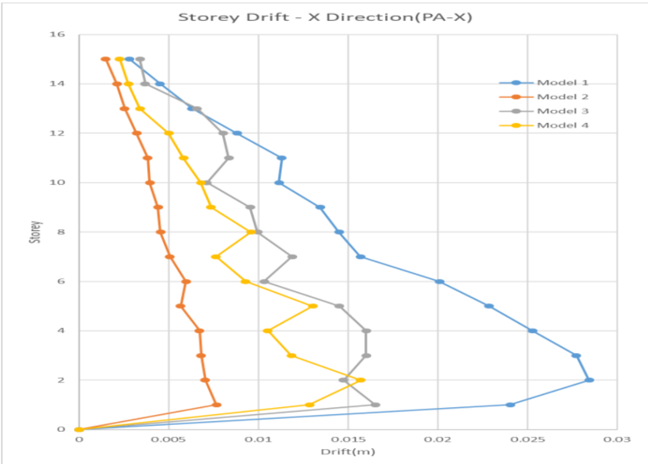

Fig 9(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 1(b), 2(b), 3(b) & 4(b)

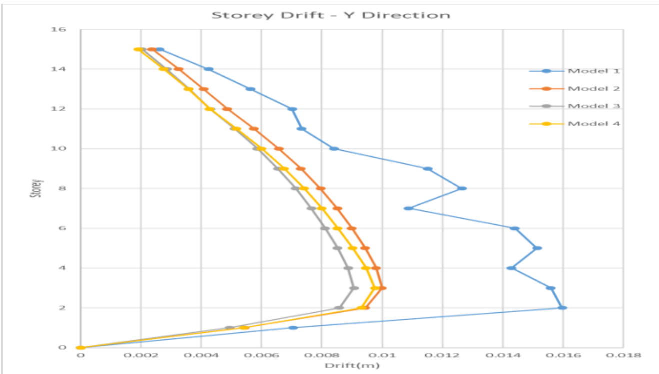

Fig 9(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 1(b), 2(b), 3(b) & 4(b)

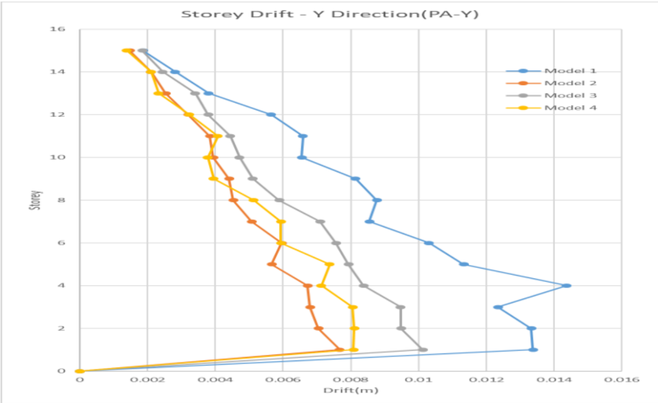

Fig 9(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 1(b), 2(b), 3(b) & 4(b)

Figures 9(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 2(b) is having 62.07% less storey drift than model 1(b), 78.41% less storey drift than model 3(b) and 41.63% less storey drift than model 4(b) in X direction and model 4(b) is having 28.75% less storey drift than model 1(b), 5.77% less storey drift than model 2(b) and 27.64% less storey drift than model 3(b) in Y direction.

4.4.3Comparison of Storey Drift Results for Model 1(c), 2(c), 3(c) & 4(c)

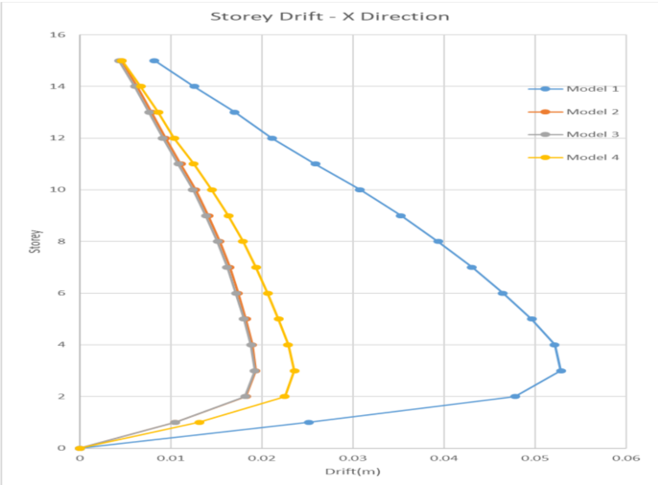

Fig 10(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 1(c), 2(c), 3(c) & 4(c)

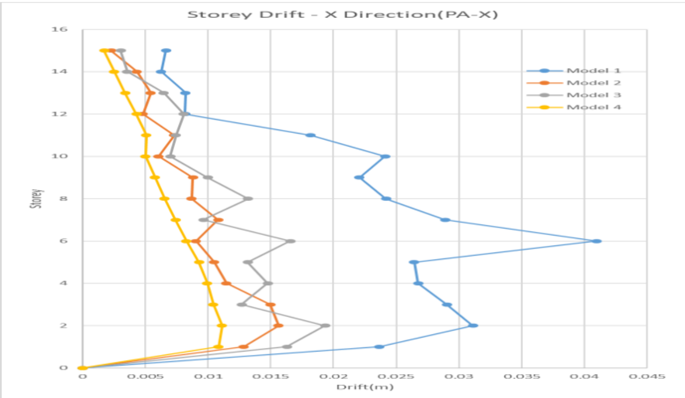

Fig 10(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 1(c), 2(c), 3(c) & 4(c)

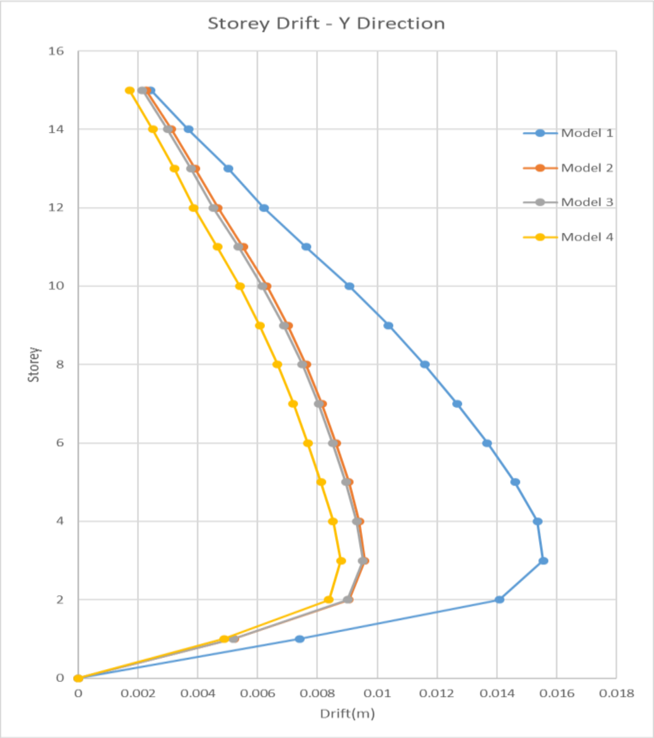

Fig 10(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 1(c), 2(c), 3(c) & 4(c)

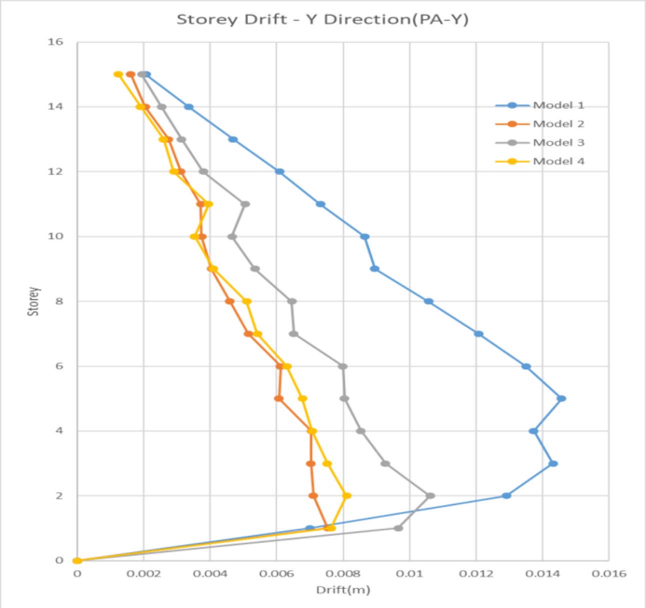

Fig 10(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 1(c), 2(c), 3(c) & 4(c)

Figures 10(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 4(c) is having 117.45% less storey drift than model 1(c), 27.19% less storey drift than model 2(c) and 54.94% less storey drift than model 3(c) in X direction and model 4(c) is having 49.62% less storey drift than model 1(c), 25.52% less storey drift than model 2(c) and 43.96% less storey drift than model 3(c) in Y direction.

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4.4.4 Comparison of Storey Drift Results for Model 1(a), 1(b) & 1(c)

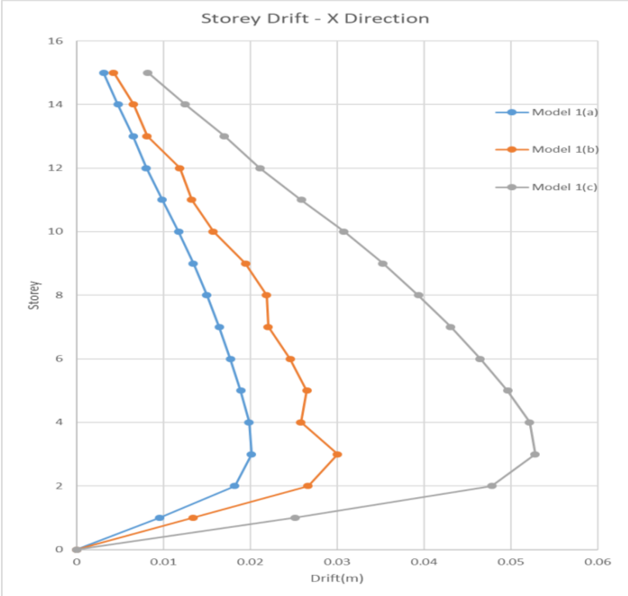

Fig 11(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 1(a), 1(b) & 1(c)

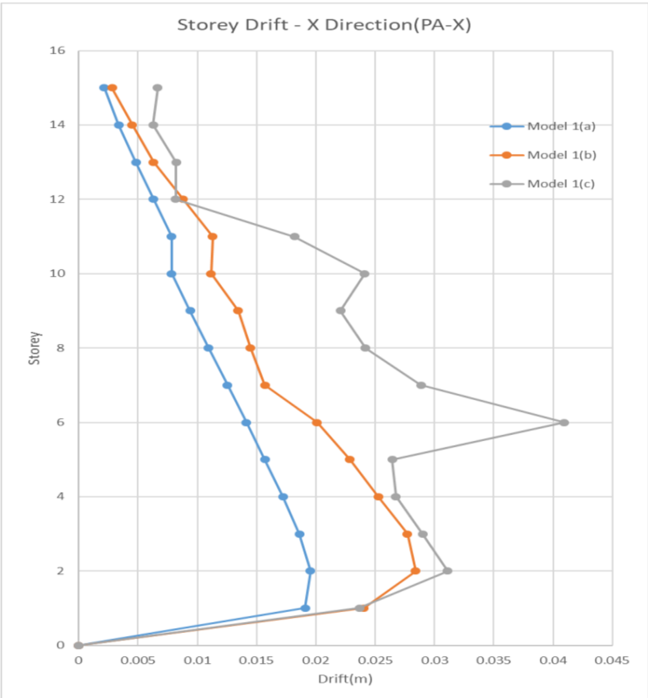

Fig 11(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 1(a), 1(b) & 1(c)

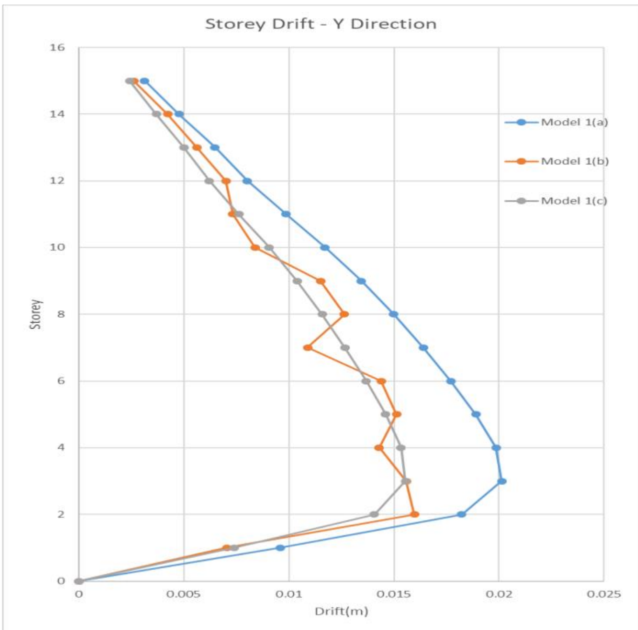

Fig 11(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 1(a), 1(b) & 1(c)

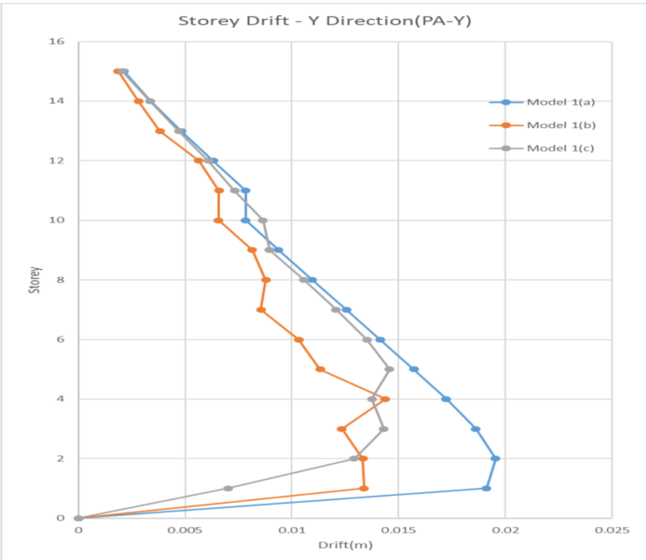

Fig 11(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 1(a), 1(b) & 1(c)

Figures 11(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 1(a) is having 26.82% less storey drift than model 1(b) and 102.50% less storey drift than model 1(c) in X direction and model 1(b) is having 13.99% less storey drift than model 1(a) and 10.13% less storey drift than model 1(c) in Y direction.

4.4.5 Comparison of Storey Drift Results for Model 2(a), 2(b) & 2(c)

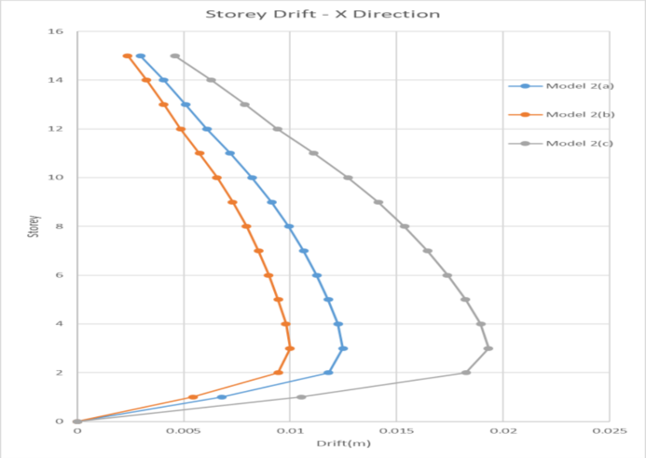

Fig 12(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 2(a), 2(b) & 2(c)

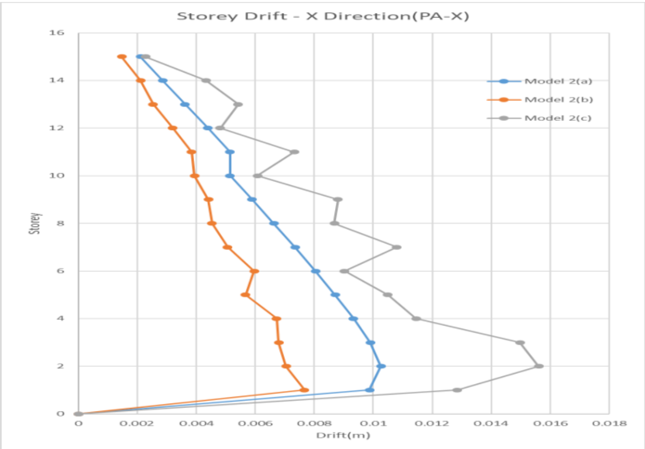

Fig 12(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 2(a), 2(b) & 2(c)

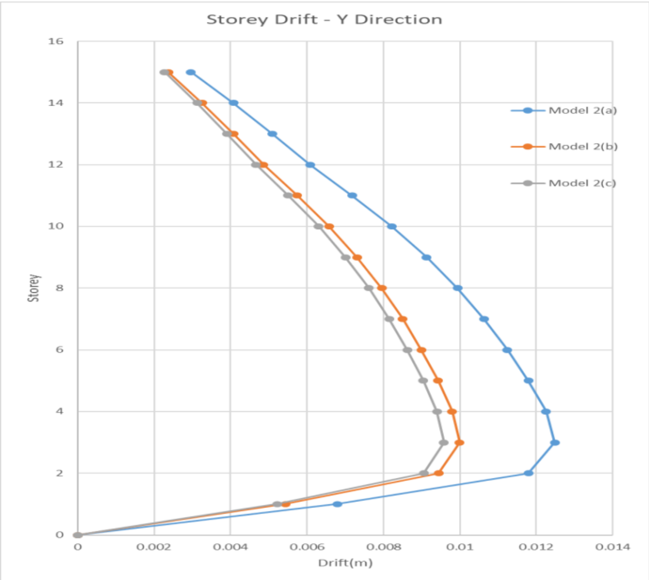

Fig 12(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 2(a), 2(b) & 2(c)

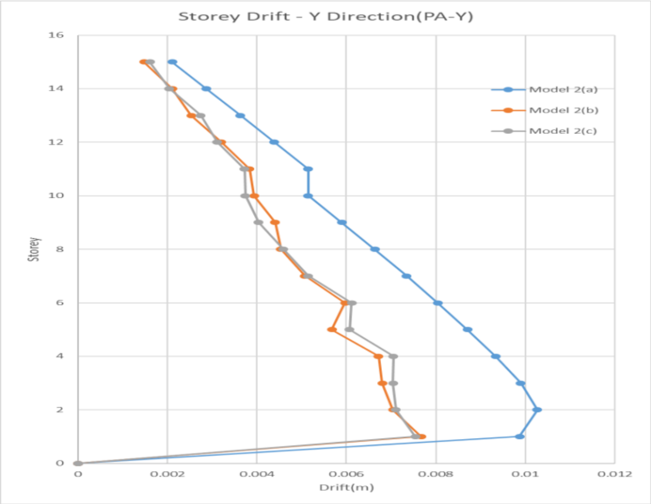

Fig 12(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 2(a), 2(b) & 2(c)

Figures 12(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 2(b) is having 35.06% less storey drift than model 2(a) and 42.42% less storey drift than model 2(c) in X direction and model 2(b) is having 35.06% less storey drift than model 2(a) and 8.28% less storey drift than model 2(c) in Y direction.

4.4.6 Comparison of Storey Drift Results for Model 3(a), 3(b) & 3(c)

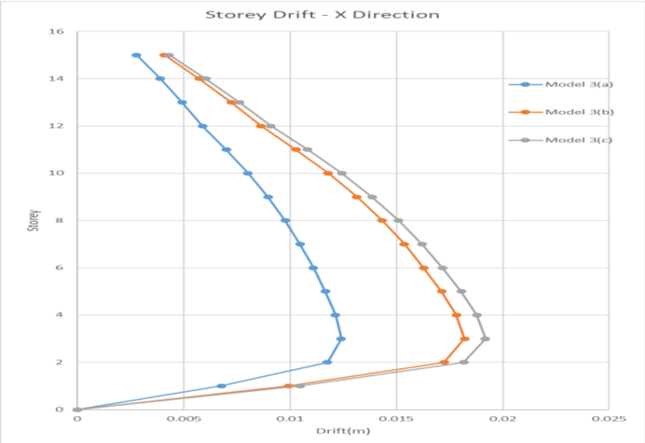

Fig 13(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 3(a), 3(b) & 3(c)

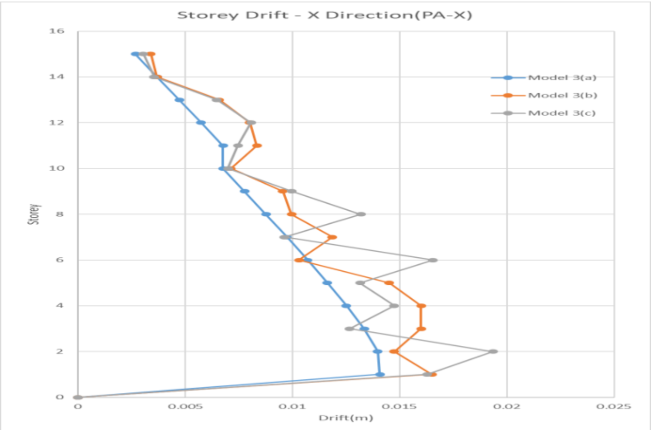

Fig 13(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 3(a), 3(b) & 3(c)

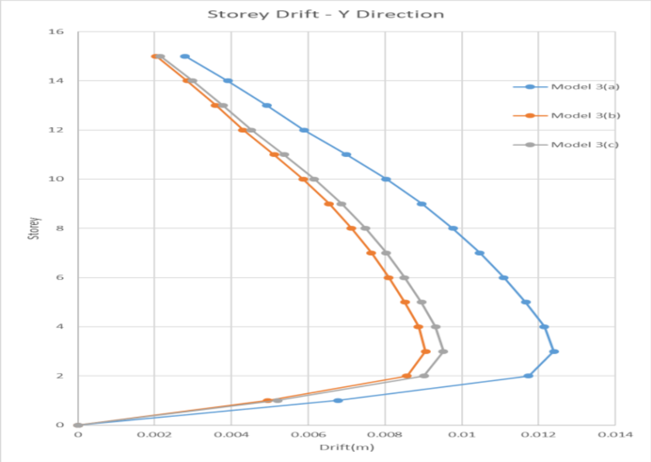

Fig 13(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 3(a), 3(b) & 3(c)

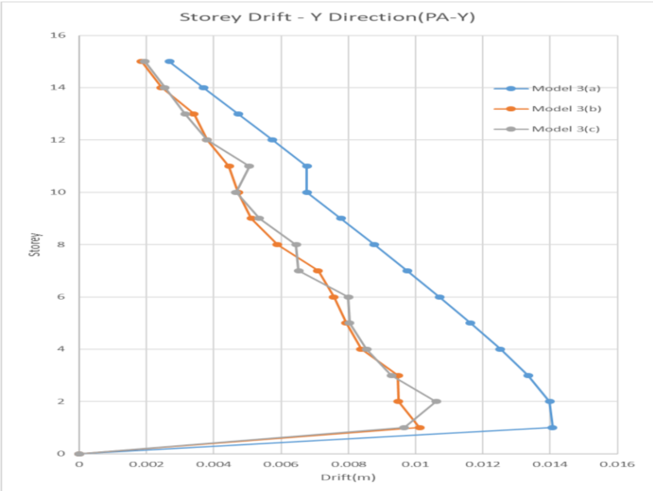

Fig 13(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 3(a), 3(b) & 3(c)

Figures 13(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 3(a) is having 23.61% less storey drift than model 3(b) and 12.98% less storey drift than model 3(c) in X direction and model 3(b) is having 36.64% less storey drift than model 3(a) and 5.28% less storey drift than model 3(c) in Y direction.

4.4.7 Comparison of Storey Drift Results for Model 4(a), 4(b) & 4(c)

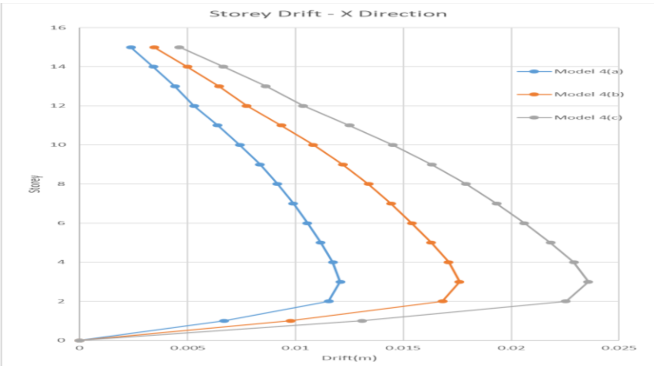

Fig 14(a) Graph showing Comparison of Storey Drift Results for EQ-X Loads for Model 4(a), 4(b) & 4(c)

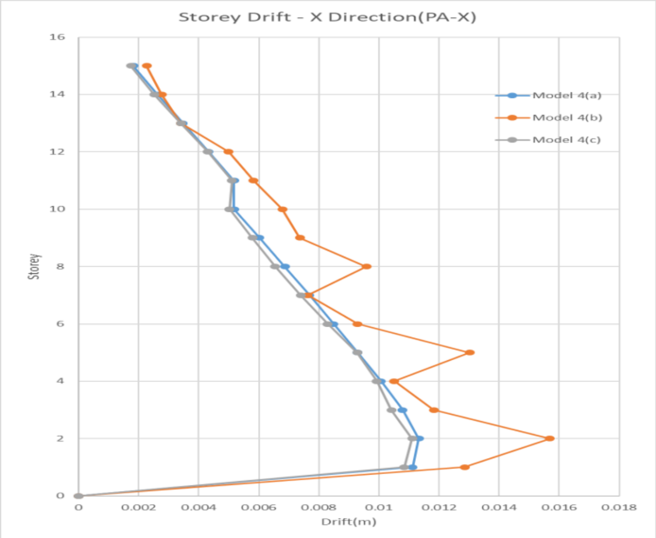

Fig 14(b) Graph showing Comparison of Storey Drift Results for PA-X Loads for Model 4(a), 4(b) & 4(c)

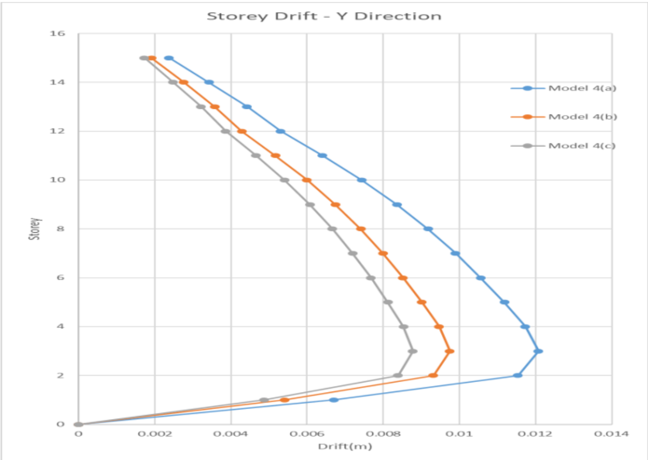

Fig 14(c) Graph showing Comparison of Storey Drift Results for EQ-Y Loads for Model 4(a), 4(b) & 4(c)

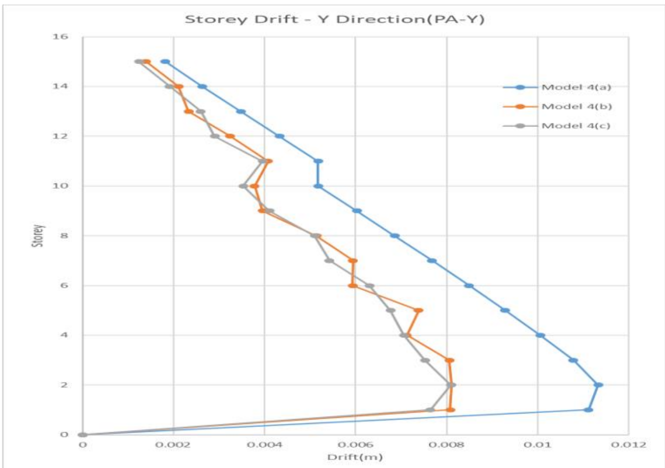

Fig 14(d) Graph showing Comparison of Storey Drift Results for PA-Y Loads for Model 4(a), 4(b) & 4(c)

Figures 14(a, b, c & d) showing the storey drift of different models used for the comparative study it can be observed that the model 4(c) is having 5.05% less storey drift than model 4(a) and 26.36% less storey drift than model 4(b) in X direction and model 4(c) is having 37.74% less storey drift than model 4(a) and 11.61% less storey drift than model 4(b) in Y direction.

4.5 STOREY SHEAR

The design seismic force to be applied at each floor level is called storey shear.

4.5.1 Comparison of Storey Shear Results for Model 1(a), 2(a), 3(a) & 4(a)

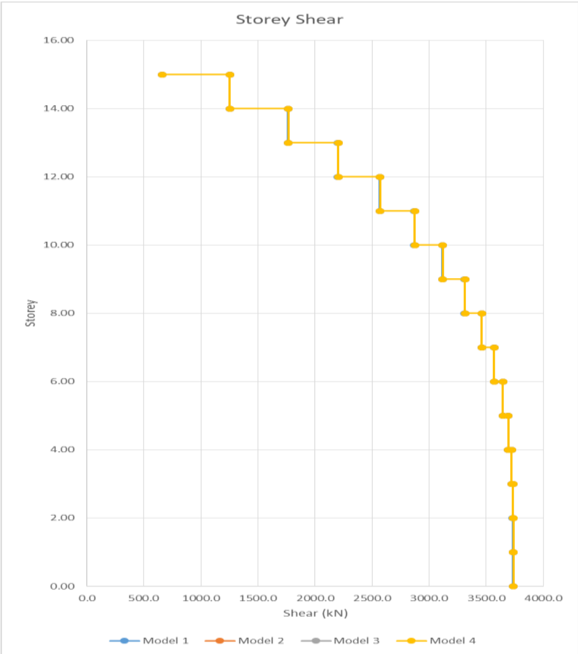

Fig 15 showing the storey shear of different models used for the comparative study it can be observed to be equal for Model 2(a), 3(a) and 4(a) while for Model 1(a), it is slightly less.

4.5.2 Comparison of Storey Shear Results for Model 1(b), 2(b), 3(b) & 4(b)

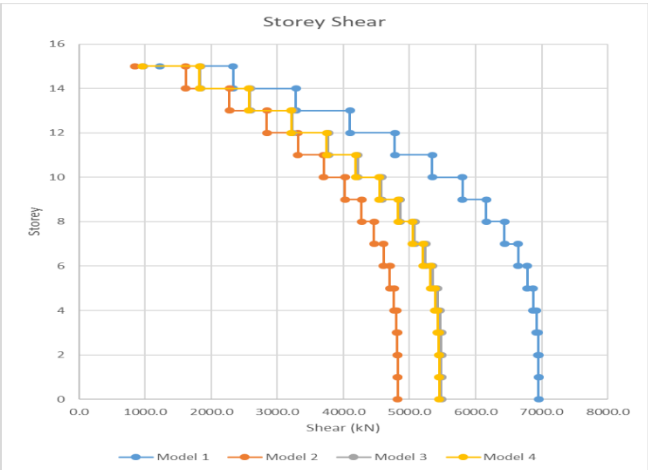

Fig 16 Graph showing Comparison of Storey Shear Results for Model 1(b), 2(b), 3(b) & 4(b)

Fig 16 showing the storey shear of different models used for the comparative study it can be observed that model 2(b) is having 36.21% less storey shear than model 1(b), 12.88% less storey shear than model 3(b) and 12.23% less storey shear than model 4(b).

4.5.3 Comparison of Storey Shear Results for Model 1(c), 2(c), 3(c) & 4(c)

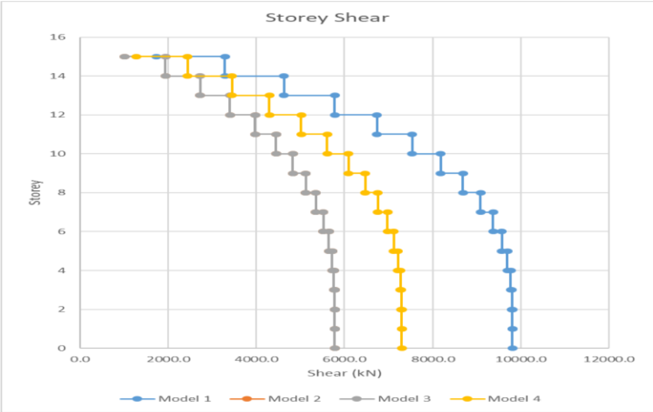

Fig 17 Graph showing Comparison of Storey Shear Results for Model 1(c), 2(c), 3(c) & 4(c)

Fig 17 showing the storey shear of different models used for the comparative study it can be observed that model 2(c) and 3(c) are having equal storey shear which is 51.62% less storey shear than model 1(c) and 23.16% less storey shear than model 4(c).

4.5.4 Comparison of Storey Shear Results for Model 1(a), 1(b) & 1(c)

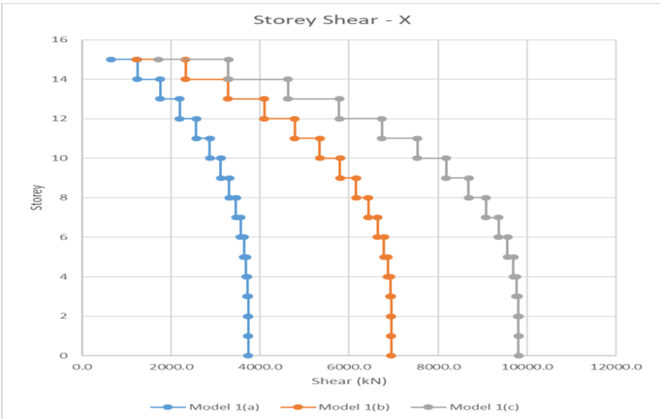

Fig 18 Graph showing Comparison of Storey Shear Results for Model 1(a), 1(b) & 1(c)

Fig 18 showing the storey shear of different models used for the comparative study it can be observed that model 1(a) is having 60.18% less storey shear than model 1(b) and 89.62% less storey shear than model 1(c).

4.5.5 Comparison of Storey Shear Results for Model 2(a), 2(b) & 2(c)

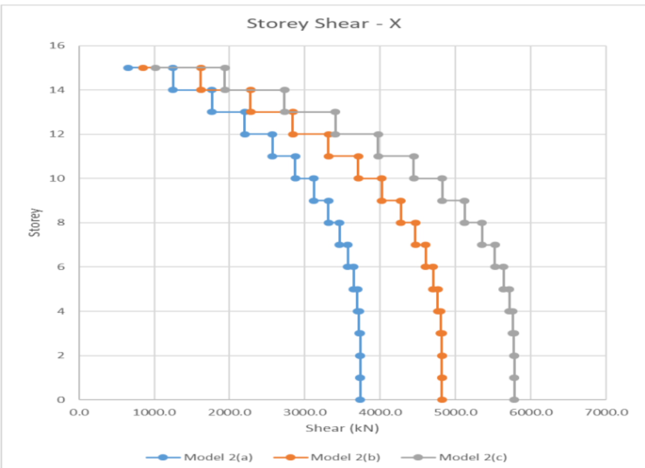

Fig 19 Graph showing Comparison of Storey Shear Results for Model 2(a), 2(b) & 2(c)

Fig 19 showing the storey shear of different models used for the comparative study it can be observed that model 2(a) is having 25.34% less storey shear than model 2(b) and 42.95% less storey shear than model 2(c).

4.5.6 Comparison of Storey Shear Results for Model 3(a), 3(b) & 3(c)

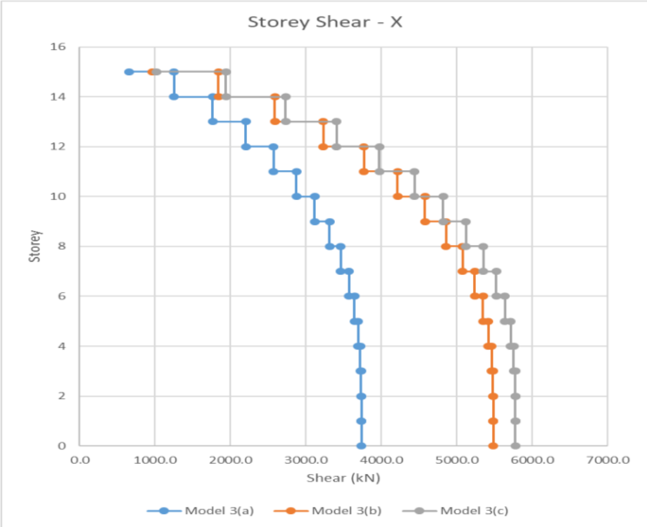

Fig 20 Graph showing Comparison of Storey Shear Results for Model 3(a), 3(b) & 3(c)

Fig 20 showing the storey shear of different models used for the comparative study it can be observed that model 3(a) is having 37.91% less storey shear than model 3(b) and 42.95% less storey shear than model 3(c).

4.5.7 Comparison of Storey Shear Results for Model 4(a), 4(b) & 4(c)

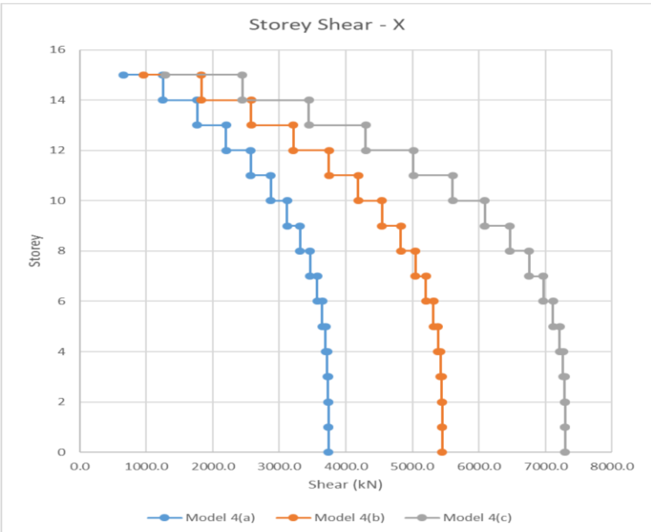

Fig 21 Graph showing Comparison of Storey Shear Results for Model 4(a), 4(b) & 4(c)

Fig 21 showing the storey shear of different models used for the comparative study it can be observed that model 4(a) is having 37.31% less storey shear than model 4(b) and 64.50% less storey shear than model 4(c).

4.6 STORY STIFFNESS

The lateral stiffness of the storey is the ratio of storey shear to storey drift, basically when the structure is loaded laterally it tends to deform. To resist the failure the structures should have adequate lateral stiffness for the structural stability, to avoid soft storey effect in the structure the lower level storey should have more stiffness then storey's above.

4.6.1 Comparison of Storey Stiffness Results for Model 1(a), 2(a), 3(a) & 4(a)

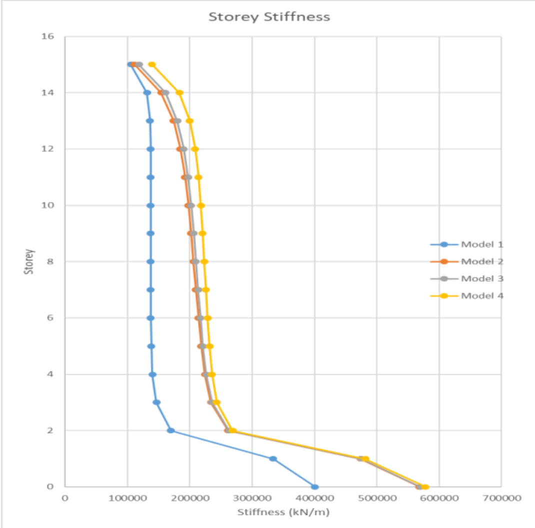

Fig 22 Graph showing Comparison of Storey Stiffness Results for Model 1(a), 2(a), 3(a) & 4(a)

Fig 22 showing the storey stiffness of different models used for the comparative study it can be observed that the model 4(a) is having 27.60% more storey stiffness than model 1(a), 22.30% more storey stiffness than model 2(a) and 16.35% more storey stiffness than model 3(a).

4.6.2 Comparison of Storey Stiffness Results for Model 1(b), 2(b), 3(b) & 4(b)

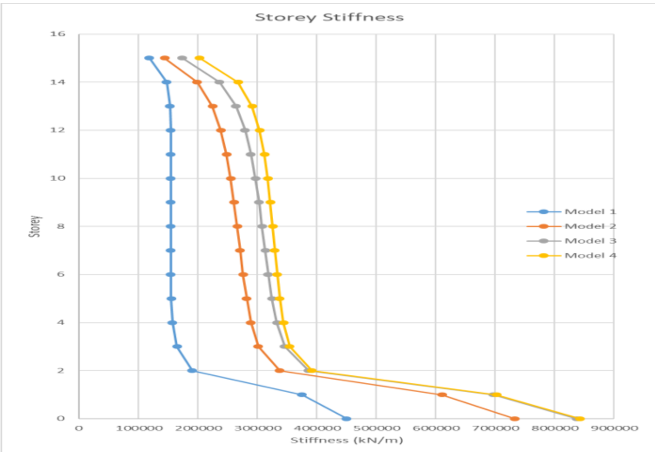

Fig 23 Graph showing Comparison of Storey Stiffness Results for Model 1(b), 2(b), 3(b) & 4(b)

Fig 23 showing the storey stiffness of different models used for the comparative study it can be observed that the model 4(b) is having 52.62% more storey stiffness than model 1(a), 34.28% more storey stiffness than model 2(b) and 15.70% more storey stiffness than model 3(b).

4.6.3 Comparison of Storey Stiffness Results for Model 1(c), 2(c), 3(c) & 4(c)

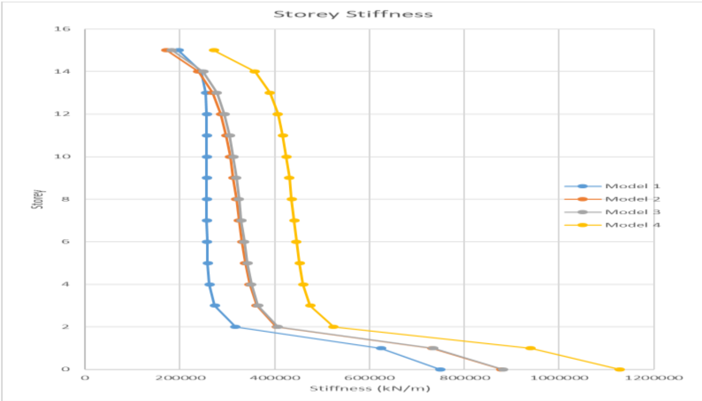

Fig 24 Graph showing Comparison of Storey Stiffness Results for Model 1(c), 2(c), 3(c) & 4(c)

Fig 24 showing the storey stiffness of different models used for the comparative study it can be observed that the model 4(c) is having 31.80% more storey stiffness than model 1(c), 44.88% more storey stiffness than model 2(c) and 39.14% more storey stiffness than model 3(c).

4.6.4 Comparison of Storey Stiffness Results for Model 1(a), 1(b) & 1(c)

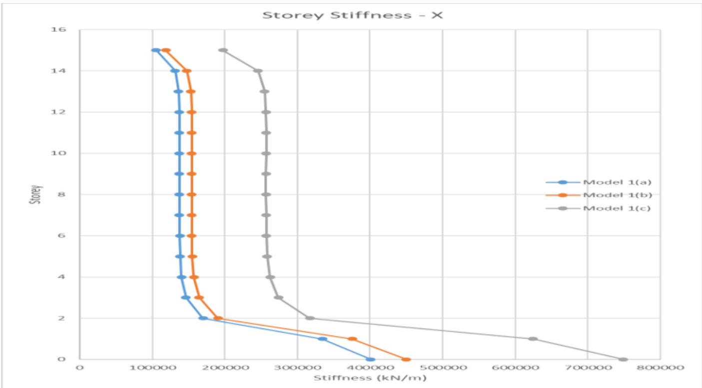

Fig 25 Graph showing Comparison of Storey Stiffness Results for Model 1(a), 1(b) & 1(c)

Fig 25 showing the storey stiffness of different models used for the comparative study it can be observed that the model 1(c) is having 60.63% more storey stiffness than model 1(a) and 49.92% more storey stiffness than model 1(b).

4.6.5 Comparison of Storey Stiffness Results for Model 2(a), 2(b) & 2(c)

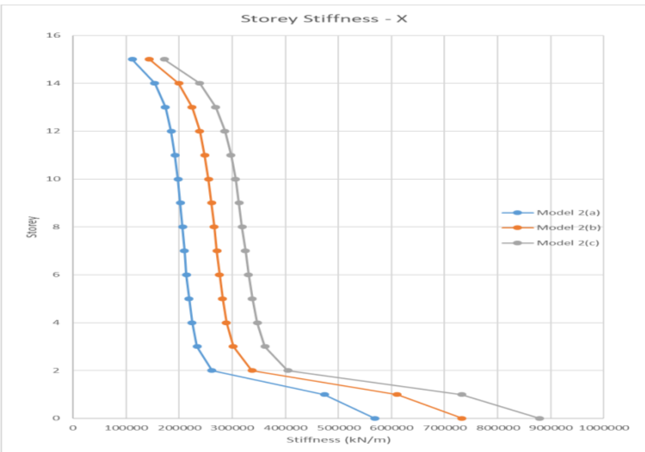

Fig 26 Graph showing Comparison of Storey Stiffness Results for Model 2(a), 2(b) & 2(c)

Fig 26 showing the storey stiffness of different models used for the comparative study it can be observed that the model 2(c) is having 42.95% more storey stiffness than model 2(a) and 18.11% more storey stiffness than model 2(b).

4.6.6 Comparison of Storey Stiffness Results for Model 3(a), 3(b) & 3(c)

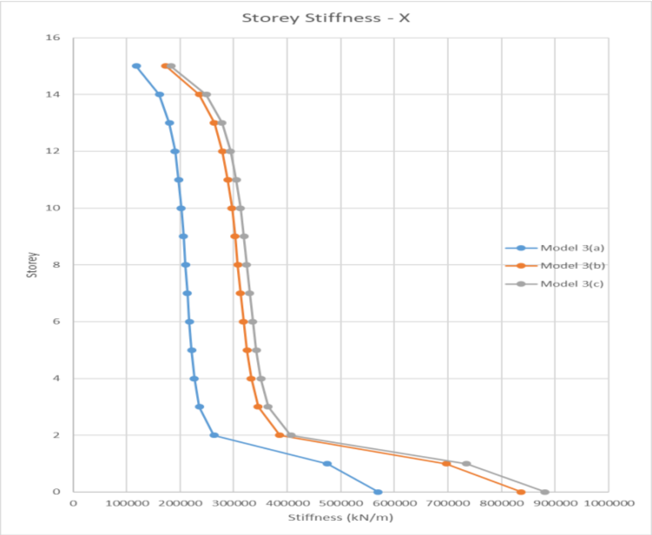

Fig 27 Graph showing Comparison of Storey Stiffness Results for Model 3(a), 3(b) & 3(c)

Fig 27 showing the storey stiffness of different models used for the comparative study it can be observed that the model 3(c) is having 42.95% more storey stiffness than model 3(a) and 5.25% more storey stiffness than model 3(b).

4.6.7 Comparison of Storey Stiffness Results for Model 4(a), 4(b) & 4(c)

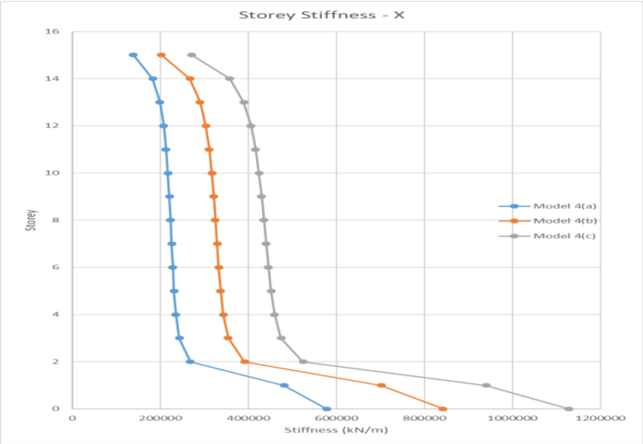

Fig 28 Graph showing Comparison of Storey Stiffness Results for Model 4(a), 4(b) & 4(c)

Fig 28 showing the storey stiffness of different models used for the comparative study it can be observed that the model 4(c) is having 64.50% more storey stiffness than model 4(a) and 28.97% more storey stiffness than model 4(b).

V. CONCLUSIONS

5.1 Conclusions

The following conclusions may be drawn from this investigation's observations and findings:

BASE SHEAR

- On comparing models 1(a), 2(a), 3(a) & 4(a) it can be observed that Model 2(a) is having 11.25% less base shear than model 1(a), 28.83% less base shear than model 3(a) and 12.5% less base shear than model 4(a).

- On comparing models 1(b), 2(b), 3(b) & 4(b) it can be observed that Model 2(b) is having 34.05% less base shear than model 1(b), 42.37% less base shear than model 3(b) and 0.55% less base shear than model 4(b) in x direction and 30.01% less base shear than model 1(b), 43.93% less base shear than model 3(b) and 24.85% less base shear than model 4(b) in y direction.
- On comparing models 1(c), 2(c), 3(c) & 4(c) it can be observed that Model 2(c) is having 75.67% less base shear than model 1(c), 85.98% less base shear than model 3(c) and 35% less base shear than model 4(c) in x direction and 25.14% less base shear than model 1(c), 31.49% less base shear than model 3(c) and 10.88% less base shear than model 4(c) in y direction.
- On comparing models 1(a), 1(b) & 1(c) it can be observed that Model 1(a) is having 46.34% less base shear than model 1(b) and 85.38% less base shear than model 1(c) in x direction and model 1(c) is having 26.93% less base shear than model 1(a) and 6.47% less base shear than model 1(b) in y direction.
- On comparing models 2(a), 2(b) & 2(c) it can be observed that Model 2(a) is having 23.95% less base shear than model 2(b) and 22.76% less base shear than model 2(c) in x direction and model 2(c) is having 40.54% less base shear than model 2(a) and 1.52% less base shear than model 2(b) in y direction.
- On comparing models 3(a), 3(b) & 3(c) it can be observed that Model 3(a) is having 37.6% less base shear than model 3(b) and 80.88% less base shear than model 3(c) in x direction and model 3(c) is having 37.93% less base shear than model 3(a) and 14.4% less base shear than model 3(b) in y direction.
- On comparing models 4(a), 4(b) & 4(c) it can be observed that Model 4(a) is having 12.06% less base shear than model 4(b) and 44.91% less base shear than model 4(c) in x direction and model 4(c) is having 42.12% less base shear than model 4(a) and 15.57% less base shear than model 4(b) in y direction.

TIME PERIOD

- On comparing models 1(a), 2(a), 3(a) & 4(a) it can be observed that Model 4(a) is having 23.96% less time period than model 1(a), 3.12% less time period than model 2(a) and 2.45% less time period than model 3(a).
- On comparing models 1(b), 2(b), 3(b) & 4(b) it can be observed that Model 4(b) is having 32.11% less time period than model 1(b), 9.21% less time period than model 2(b) and 11.93% less time period than model 3(b) in x direction and model 3(b) is having 32.04% less time period than model 1(b), 40.29% less time period than model 2(b) and 4.51% less time period than model 4(b) in y direction.
- On comparing models 1(c), 2(c), 3(c) & 4(c) it can be observed that Model 2(c) is having 26.64% less time period than model 1(c), 0.15% less time period than model 3(c) and 18.58% less time period than model 4(c) in x direction and model 4(c) is having 27.65% less time period than model 1(c), 4.67% less time period than model 2(c) and 6.28% less time period than model 3(c) in y direction.
- On comparing models 1(a), 1(b) & 1(c) it can be observed that Model 1(a) is having 34.73% less time period than model 1(b) and 49.82% less time period than model 1(c) in x direction and model 1(c) is having 28.19% less time period than model 1(a) and 14.83% less time period than model 1(b) in y direction.
- On comparing models 2(a), 2(b) & 2(c) it can be observed that Model 2(a) is having 32.53% less time period than model 2(b) and 44.26% less time period than model 2(c) in x direction and model 2(c) is having 30.39% less time period than model 2(a) and 45.73% less time period than model 2(b) in y direction.
- On comparing models 3(a), 3(b) & 3(c) it can be observed that Model 3(a) is having 35.88% less time period than model 3(b) and 45.1% less time period than model 3(c) in x direction and model 3(c) is having 28.1% less time period than model 3(a) and 4.08% less time period than model 3(b) in y direction.
- On comparing models 4(a), 4(b) & 4(c) it can be observed that Model 4(a) is having 26.61% less time period than model 4(b) and 64.43% less time period than model 4(c) in x direction and model 4(c) is having 31.85% less time period than model 4(a) and 14.8 5% less time period than model 4(b) in y direction.

STOREY DRIFT

- On comparing models 1(a), 2(a), 3(a) & 4(a) it can be observed that Model 4(a) is having 16.38% less storey drift than model 1(a), 14.6% less storey drift than model 2(a) and 37.86% less storey drift than model 3(a).
- On comparing models 1(b), 2(b), 3(b) & 4(b) it can be observed that Model 2(b) is having 62.07% less storey drift than model 1(b), 78.41% less storey drift than model 3(b) and 41.63% less storey drift than model 4(b) in x direction and model 4(b) is having 28.75% less storey drift than model 1(b), 5.77% less storey drift than model 2(b) and 27.64% less storey drift than model 3(b) in y direction.
- On comparing models 1(c), 2(c), 3(c) & 4(c) it can be observed that Model 4(c) is having 117.45% less storey drift than model 1(c), 27.19% less storey drift than model 2(c) and 54.94% less storey drift than model 3(c) in x direction and model 4(c) is having 49.62% less storey drift than model 1(c), 25.52% less storey drift than model 2(c) and 43.96% less storey drift than model 3(c) in y direction.

- On comparing models 1(a), 1(b) & 1(c) it can be observed that Model 1(a) is having 26.82% less storey drift than model 1(b) and 102.50% less storey drift than model 1(c) in x direction and model 1(b) is having 13.99% less storey drift than model 1(a) and 10.13% less storey drift than model 1(c) in y direction.
- On comparing models 2(a), 2(b) & 2(c) it can be observed that Model 2(b) is having 35.06% less storey drift than model 2(a) and 42.42% less storey drift than model 2(c) in x direction and model 2(b) is having 35.06% less storey drift than model 2(a) and 8.28% less storey drift than model 2(c) in y direction.
- On comparing models 3(a), 3(b) & 3(c) it can be observed that Model 3(a) is having 23.61% less storey drift than model 3(b) and 12.98% less storey drift than model 3(c) in x direction and model 3(b) is having 36.64% less storey drift than model 3(a) and 5.28% less storey drift than model 3(c) in y direction.
- On comparing models 4(a), 4(b) & 4(c) it can be observed that Model 4(c) is having 5.05% less storey drift than model 4(a) and 26.36% less storey drift than model 4(b) in x direction and model 4(c) is having 37.74% less storey drift than model 4(a) and 11.61% less storey drift than model 4(b) in y direction.

STOREY SHEAR

- On comparing models 1(a), 2(a), 3(a) & 4(a) it can be observed to be equal for model 2(a), 3(a) and 4(a) while for model 1(a), it is slightly less.
- On comparing models 1(b), 2(b), 3(b) & 4(b) it can be observed that Model 2(b) is having 36.21% less storey shear than model 1(b), 12.88% less storey shear than model 3(b) and 12.23% less storey shear than model 4(b).
- On comparing models 1(c), 2(c), 3(c) & 4(c) it can be observed that Model 2(c) and 3(c) are having equal storey shear which is 51.62% less storey shear than model 1(c) and 23.16% less storey shear than model 4(c).
- On comparing models 1(a), 1(b) & 1(c) it can be observed that Model 1(a) is having 60.18% less storey shear than model 1(b) and 89.62% less storey shear than model 1(c).
- On comparing models 2(a), 2(b) & 2(c) it can be observed that Model 2(a) is having 25.34% less storey shear than model 2(b) and 42.95% less storey shear than model 2(c).
- On comparing models 3(a), 3(b) & 3(c) it can be observed that Model 3(a) is having 37.91% less storey shear than model 3(b) and 42.95% less storey shear than model 3(c).
- On comparing models 4(a), 4(b) & 4(c) it can be observed that Model 4(a) is having 37.31% less storey shear than model 4(b) and 64.50% less storey shear than model 4(c).

STORY STIFFNESS

- On comparing models 1(a), 2(a), 3(a) & 4(a) it can be observed that Model 4(a) is having 27.60% more storey stiffness than model 1(a), 22.30% more storey stiffness than model 2(a) and 16.35% more storey stiffness than model 3(a).
- On comparing models 1(b), 2(b), 3(b) & 4(b) it can be observed that Model 4(b) is having 52.62% more storey stiffness than model 1(a), 34.28% more storey stiffness than model 2(b) and 15.70% more storey stiffness than model 3(b).
- On comparing models 1(c), 2(c), 3(c) & 4(c) it can be observed that Model 4(c) is having 31.80% more storey stiffness than model 1(c), 44.88% more storey stiffness than model 2(c) and 39.14% more storey stiffness than model 3(c).
- On comparing models 1(a), 1(b) & 1(c) it can be observed that Model 1(c) is having 60.63% more storey stiffness than model 1(a) and 49.92% more storey stiffness than model 1(b).
- On comparing models 2(a), 2(b) & 2(c) it can be observed that Model 2(c) is having 42.95% more storey stiffness than model 2(a) and 18.11% more storey stiffness than model 2(b).
- On comparing models 3(a), 3(b) & 3(c) it can be observed that Model 3(c) is having 42.95% more storey stiffness than model 3(a) and 5.25% more storey stiffness than model 3(b).
- On comparing models 4(a), 4(b) & 4(c) it can be observed that Model 4(c) is having 64.50% more storey stiffness than model 4(a) and 28.97% more storey stiffness than model 4(b).

5.2 Overall Conclusion

- On comparing models 1(a), 2(a), 3(a) & 4(a) it can be observed that model 4(a) performs better in terms of time period, story drift and story stiffness whereas model 2(a) performs better in terms of base shear.
- On comparing models 1(b), 2(b), 3(b) & 4(b) it can be observed that model 2(b) performs better in terms of base shear, story drift and story shear whereas model 4(b) performs better in terms of time period and story stiffness.

- On comparing models 1(c), 2(c), 3(c) & 4(c) it can be observed that model 2(c) performs better in terms of base shear, time period and story shear whereas model 4(c) performs better in terms of story drift and story stiffness.
- On comparing models 1(a), 1(b) & 1(c) it can be observed that model 1(a) performs better in terms of base shear, time period and storey drift in x direction and storey shear in both x and y directions whereas model 1(c) performs better in terms of base shear and time period in y direction and storey stiffness in both x and y directions.
- On comparing models 2(a), 2(b) & 2(c) it can be observed that model 2(a) performs better in terms of base shear and time period in x direction and storey shear and storey drift in both x and y directions whereas model 2(c) performs better in terms of base shear and time period in y direction and storey stiffness in both x and y directions.
- On comparing models 3(a), 3(b) & 3(c) it can be observed that model 3(a) performs better in terms of base shear, time period and storey drift in x direction and storey shear in both x and y directions whereas model 3(c) performs better in terms of base shear and time period in y direction and storey stiffness in both x and y directions.
- On comparing models 4(a), 4(b) & 4(c) it can be observed that model 4(a) performs better in terms of base shear and time period in x direction and storey shear in both x and y directions whereas model 4(c) performs better in terms of base shear and time period in y direction and storey drift and storey stiffness in both x and y directions.

5.3 Scope for further studies

- Further research can be carried out considering different types of dampers.
- To study the wind effects on structures incorporating dampers.

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