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Original Article

Influence of Various Arrangements of Viscous Dampers on RCC Framed Buildings

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ABSTRACT

In recent years, there has been an increase in high-magnitude earthquakes, which has led to a need for research on seismic protection and its importance in safeguarding structures such as buildings and bridges. Adding supplementary damping to the structure can help reduce dynamic responses and base shear demand. Energy dissipation devices such as fluid viscous dampers (FVDs) are often used to mitigate structural sway during seismic activity. The proposed thesis aims to study the effect of a viscous damper on the seismic performance of RCC-framed buildings. In this study, 3-D models of Four and Twelve story RCC frame building structures generated in the ETABs finite element package with and without diagonally placed viscous dampers in different configurations and placed in various locations throughout the structure will be subjected to earthquake loadings and the study will be carried out to investigate the influence of viscous damper configuration and location. The results obtained will also be used to identify optimal damper arrangement and placement for seismic mitigation. The results of the seismic performance of buildings with viscous dampers will be compared with the buildings without viscous dampers. The ETABs software will be used for modeling and analyzing various structures with and without viscous dampers and non-linear time history analysis methods will be adopted. The results obtained will be compared in the form of displacement, story drift, and Base shear. Also, the comparison of energy dissipation of dampers in different arrangements will be done in terms of link damper energy. One of the primary findings from the study underscores the crucial role of the damping system in enhancing the seismic resilience of the building. The research also confirms that integrating fluid viscous dampers into the structure leads to notable reductions in key structural metrics like displacement, drift, and shear. Moreover, the damping system substantially diminishes the building's susceptibility to seismic damage.

Keywords: Time History Analysis, Fluid Viscous Damper, Optimum Damper Arrangement, Peak Ground Acceleration (PGA) and Link Damper Energy

INTRODUCTION

In recent years, many existing buildings have been severely damaged due to strong ground motions around the world. Nepal is located in a highly seismic region due to its geographical position along the tectonic boundary of the Indian and Eurasian plates. The movement between the plates causes elastic deformation of the plates rather than inelastic deformation and thus strain energy has been accumulating for many years which could result in disastrous earthquakes of greater magnitude in the future. Given Nepal's location in a seismically active zone and its history of destructive earthquakes, predicting these events remains challenging despite advances in technology. This underscores the necessity for earthquake-resistant structures. When designing buildings, it's essential to meet two criteria: the limit state of collapse, where the structure must withstand earthquake loads without failure, and the limit state of serviceability, ensuring the building remains functional with deflection and vibration within acceptable bounds. Dampers are devices that are used to absorb or dissipate the vibration caused by the earthquake to the structure and to increase the damping and stiffness of the structure. Among various categories of dampers, fluid viscous dampers are of particular relevance, exceptionally reliable, and usually cost-effective (Kargahi & Ekwueme, 2004). Viscous fluid dampers consist of a hollow cylinder filled with fluid, the fluid typically being silicone based. The viscous dampers are passive energy dissipation device which is added to the structure to increase the effective stiffness of new and existing

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

buildings. The effectiveness of the devices is a function of where they are located in the structure and their arrangement. Viscous dampers are velocity dependent passive energy dissipation device. An approach to improving earthquake response performance is to introduce energy dissipation systems to the building structure. The primary reason for introducing energy dissipation systems into building frames is to reduce the displacement and damage in the structure. Displacement reduction is achieved by adding either stiffness and/or energy dissipation to the building structure. In these systems, viscous dampers are incorporated into the frame of the structure and absorb the energy from the earthquake reducing the drift as well effects on the critical components of the structure. These energy dissipating devices have been found to be quite promising and their applications form the focus of this study.

LITERATURE REVIEW:

(Mani Kant Sah, Radha Krishna Mallik & Gokarna Bahadur Motra, 2021): This research studied the effect of damper parameters for the design of nonlinear FVD on Reinforced concrete framed structure to enhance the seismic performance. A general finite element package of ETABs was used to generate three-dimensional model of four storey reinforced concrete building to undertake non-linear Time History analysis to capture the performance of building with and without damper for different damper parameters and different damper distribution. After analysis, the results showed that installing non-linear FVD with appropriate parameters reduced the responses of structure during seismic event. The lower the velocity exponent the more efficient the viscous damping for seismic energy dissipation. Diagonal corner damper distribution was found to be more effective than mid chevron (double diagonal) distribution of presented RC structure. (R. Gobirahavan & A.C. Wijeyewickrema, 2018): In this study, a non-iterative design procedure was proposed to determine the mechanical characteristics of additional linear viscous dampers that are needed, to achieve an enhanced seismic performance of existing RC buildings. The enhanced seismic performance of the buildings was based on the maximum Inter-story Drift Ratio (IDR) of the buildings. The viscous damper forces were calculated relative to the story shear forces in the unretrofitted buildings. The proposed design procedure was validated by considering 4-, 8-, and 12- story RC buildings, which were designed using IBC 2009, ASCE 7-05, and ACI 318-08. Seismic performance was enhanced according to the design level of IBC 2015. PERFORM -3D (CSI 2011) software was used for modeling and analysis of buildings. The effectiveness of the distribution of viscous damping constants proportional to story mass, story shear force, and IDR were investigated which suggested the buildings satisfied the target performance when the different methods were used to obtain the damping constants. (Felipe Saitua, 2017): This research paper discussed the optimal height-wise distribution of viscous damper in multistorey structures. The purposed framework was illustrated with the design of a supplemental viscous damping system for an actual Chilean 26-storey building, considering an excitation that was compatible with the regional seismic hazard. Results demonstrated that optimizing for cost resulted to substantial economic benefits and that dampers connected across multiple storeys contributed to considerable cost reduction. (John F. Hall, 2018): This research work investigated the performance of several viscous damping formulations in the inelastic seismic response of moment-frame buildings. The evaluation employed a detailed model of a 20-story steel structure. Damping schemes included in the study were Rayleigh, condensed Rayleigh, Wilson-Penzien, tangent Rayleigh, and one implementation of capped damping. Caughey damping was found not to be computationally viable. Performance of Rayleigh damping under vertical ground motion was discussed, including the effect of soil-structure interaction., (Enrico Tubaldi, Laura Ragni & Andrea Dall'Asta, 2014): This research paper evaluated the influence of the damper properties on the probabilistic seismic response of structural systems equipped with nonlinear viscous dampers. A linear single-degree-of-freedom system with an added linear or nonlinear viscous damper was considered, and the seismic response statistic were evaluated for a set of natural records describing the ground motion uncertainty. An extensive parametric study was carried out to estimate the influence of the damper properties on the statistics of maximum displacements, accelerations and damper forces for a wide range of values of the characteristic parameters. (Giuseppe Marcantonio Del Gobbo, Anthony Blakeborough & Martin S.

Williams, 2018): This research paper investigated the application of linear FVDs to improve total-building seismic performance considering repair costs. The energy-based method commonly used to calculate damper coefficients was modified to improve its accuracy. The optimal amount of damping with respect to repair costs (estimated using the FEMA P-58 procedure) was identified as 25-45%, based on structural parameters, that was frequently targeted. The FVD buildings significantly reduced both drift-sensitive and acceleration-sensitive damage. Structural damage was also negligible in the FVD buildings: a major step towards achieving building serviceability following an ultimate limit state level earthquake.

STATEMENTS OF PROBLEM:

The use of passive energy dissipation devices has become very popular in recent years. However, the vast majority of applications were realized within frame structures, while investigations on the use of damping devices with various configurations and different locations on RCC framed structures are still very limited. For this reason, the aim of this research is to investigate the behavior of multi-story RCC frame structures under earthquake loads with damping devices strategically located within various locations and with different configurations. Despite the potential benefits, the effect of viscous dampers on RCC framed structures remains an area of significant interest and concern. Addressing this research problem will contribute to a deeper understanding of the behavior of RCC framed structures equipped with viscous dampers under seismic loads. The findings of this research are expected to provide valuable insights for structural engineers and researchers to optimize the design and implementation of these damping systems, thereby leading to more earthquake-resistant and safer structures in seismic-prone regions.

OBJECTIVES OF STUDY:

The aim of this research is to study the seismic response of low-rise (4-storied) and mid-rise (12-storied) RCC framed buildings equipped with fluid viscous dampers in various configurations and placements in terms of structural displacements, base shears, inter-story drifts and link damper energies and compare the results to that of structures without using FVDs.

DIMENSIONS AND MODELS:

Reinforced concrete buildings of 4 and 12 story are considered in this research. The plan of the structure is symmetric having the plan dimensions of 16m X 16m. Each spacing of the gridline is 4m on both sides. The height of each story of the structure is 3m. There are four bays in each direction. Beam and column elements are modeled as rectangular framed elements with material properties and section properties shown in the description below. Slab section is considered as thin shell elements. The dampers are used in the structure in seven different cases, each with different arrangement of dampers, which is shown below. The number of dampers for a particular storied building is kept constant. The total number of dampers used in 4 story building is 32, whereas for 12 story building, the number of dampers used is 96. Only one type of damper is used for particular storied buildings having same capacity and properties. The dampers are only used on the exterior faces of the buildings. Structural loading details considered for the analysis will include dead load of 12KN/m exterior wall load, 6KN/m interior wall load, 2.5 KN/m parapet wall load, floor live load of 4 KN/m2, roof live load 2 KN/m2 and Floor Finish of 1.5 KN/m2. Seismic code considered is NBC 105:2020. The importance factor (I) considered for building models is 1. Soil type considered is Type II i.e. medium soil. Time History of Gorkha Earthquake (Kirtipur) is considered. Damping coefficient (ζ) is considered as 0.05.

Table 1. Collection of Data for Analysis of Buildings

	Height	Area	Each Storey Height	Column	Beam	Slab
4 Story (Low Rise Buildings) Model-1	12m	16mX16m	3m	C1(400mm×400mm)	MB1(300mm X 450mm)	125mm
12 Story (Mid Rise Buildings) Model-2	36m	16mX16m	3m	C2(800mm×800mm)	MB2(600mm X 900mm)	150mm

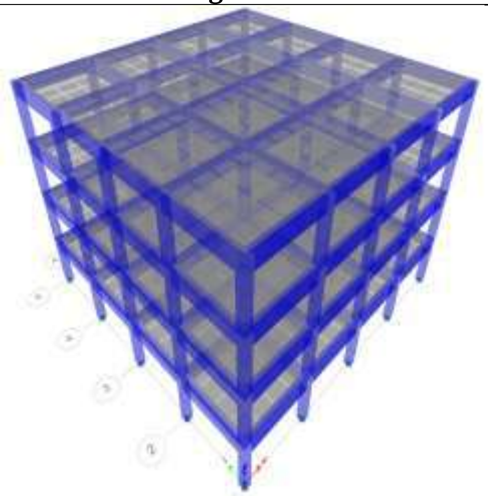
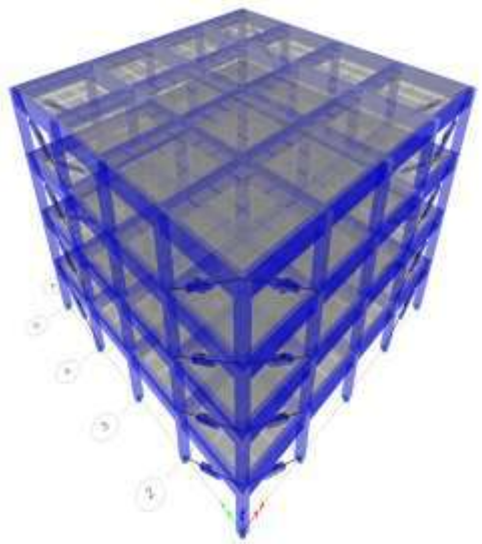
Table 2. Nonlinear Damper Parameters

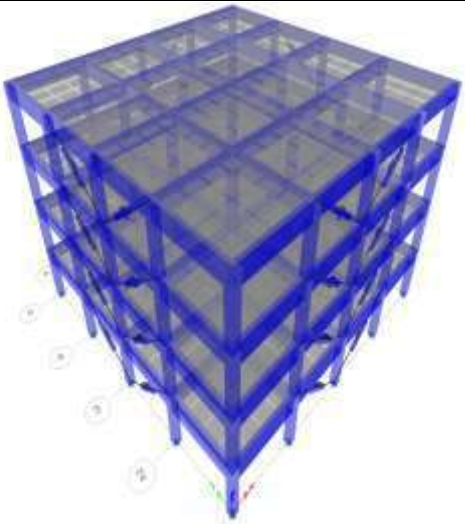
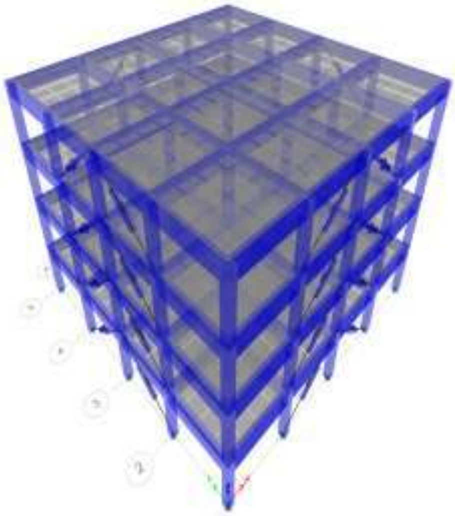
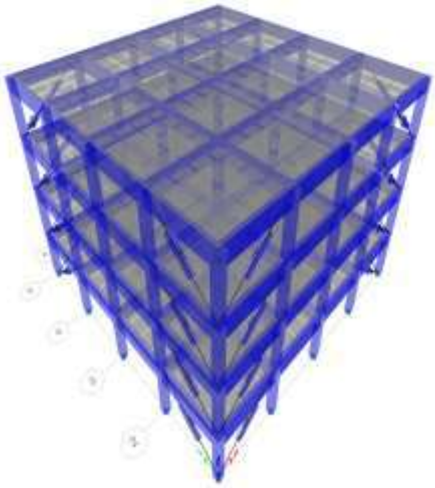
Model	C (KN*s/m)	Alpha	Stiffness (KN/mm)
M1 (4 Story)	350	0.3	400
M2 (12 Story)	700	0.3	400

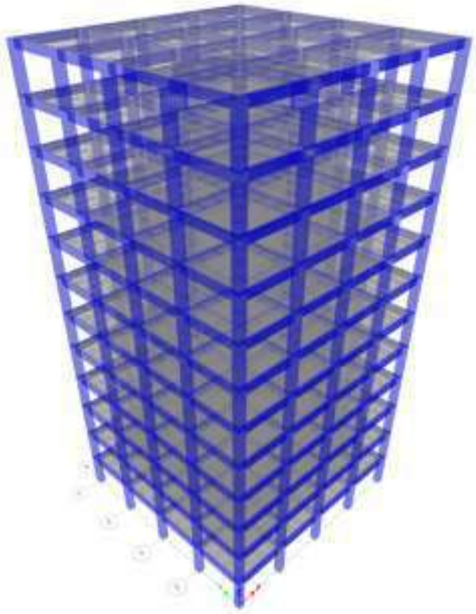
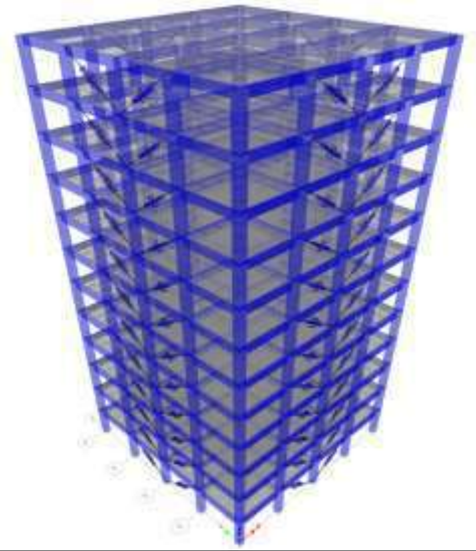
Table 3. Damper Properties

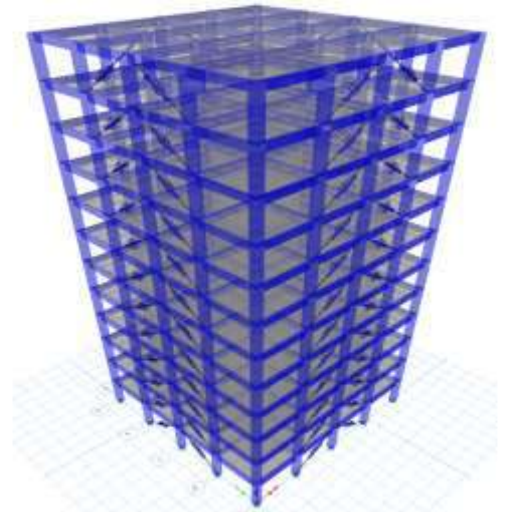
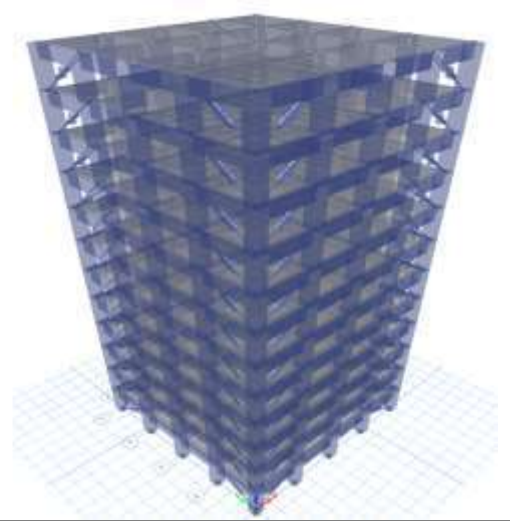
Buildings	4 Story (Fvd 250)	12 Story (Fvd 750)
Force (KN)	250	750
Taylor Devices Model Number	17120	17140
Spherical Bearing Bore Diameter (mm)	38.10	57.15
Mid-Stroke Length (mm)	787	1016
Stroke (mm)	± 75	± 100
Clevis Thickness (mm)	43	59
Maximum Clevis Width (mm)	100	155
Clevis Depth (mm)	83	129
Bearing Thickness (mm)	33	50
Maximum Diameter (mm)	114	184
Weight (Kg)	44	168

Table 4. Table of Models

S. N	ETABS Modeling	Name of Model	Notation	Remarks
1		Model-1: Four Story Without Dampers	M-1	
2		Model-1: Four Story with Damper Case 1	M-1 C-1	

3		Model-1: Four Story with Damper Case 2	M-1 C-2	
4		Model-1: Four Story with Damper Case 3	M-1 C-3	
5		Model-1: Four Story with Damper Case 4	M-1 C-4	

8		Model-2: Twelve Story Without Damper	M-2	
9		Model-2: Twelve Story with Damper Case 1	M-2 C-1	
10		Model-2: Twelve Story with Damper Case 2	M-2 C-2	

11		Model-2: Twelve Story with Damper Case 3	M-2 C-3	
12		Model-2: Twelve Story with Damper Case 4	M-2 C-4	

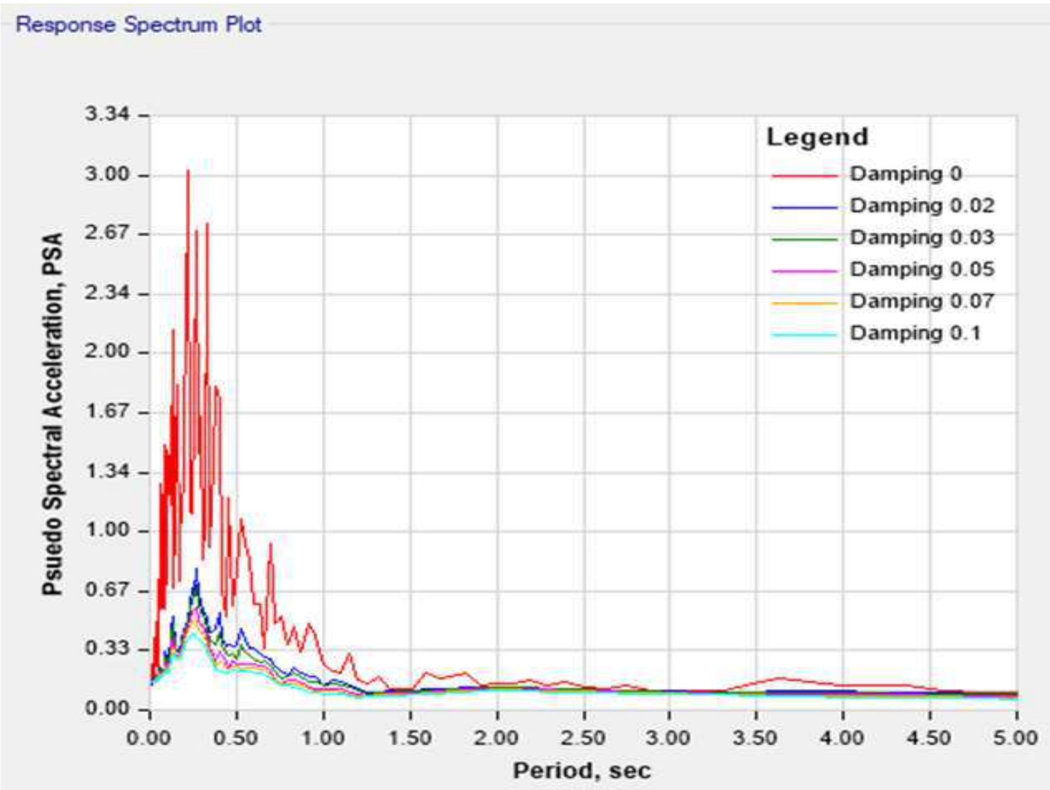


Figure 1: Response Spectrum for Specified Damping Ratios (NBC Type B)

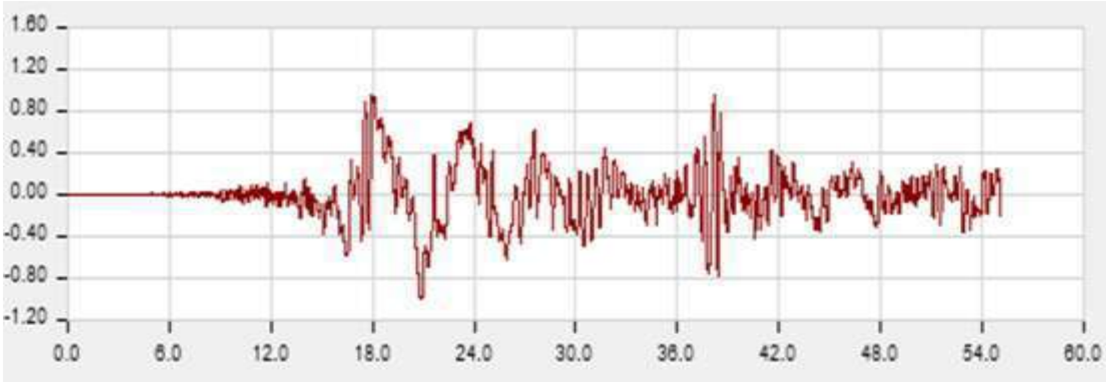


Figure 2: Time History Function Graph of Gorkha Earthquake EW – 1g PGA

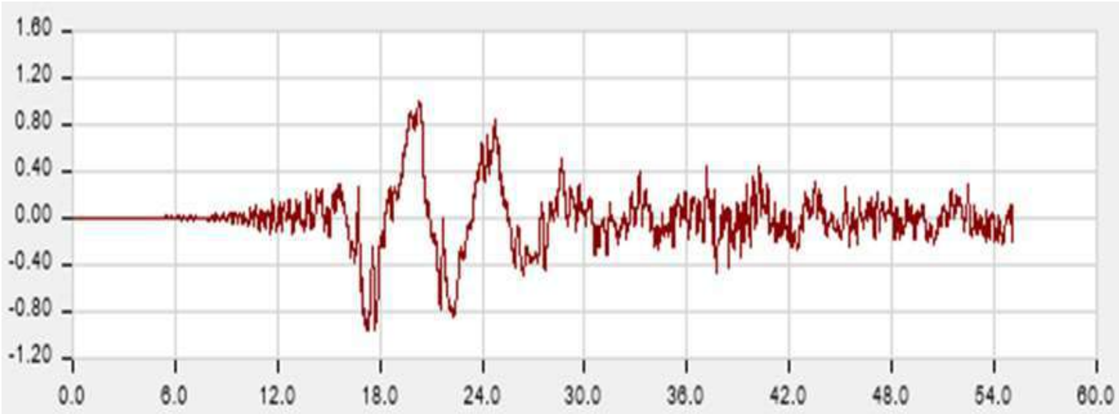


Figure 3: Time History Function Graph of Gorkha Earthquake NS – 1g PGA

RESEARCH METHODOLOGY:

To obtain the stated objective, the methodological procedure applied is as following:

1.Study of various literature reviews related to the work.

2.Identify of the problem and set the research question.

3.Selection of samples and modelling of building in ETABS.

4.Analysis of the models using Nonlinear Time History Analysis

5.Evaluation of Performance of Buildings without and with diagonally placed FVDs in different arrangements

6.Comparison of results, findings, give idea about the optimal position and arrangement of the FVDs and recommendation for further study.

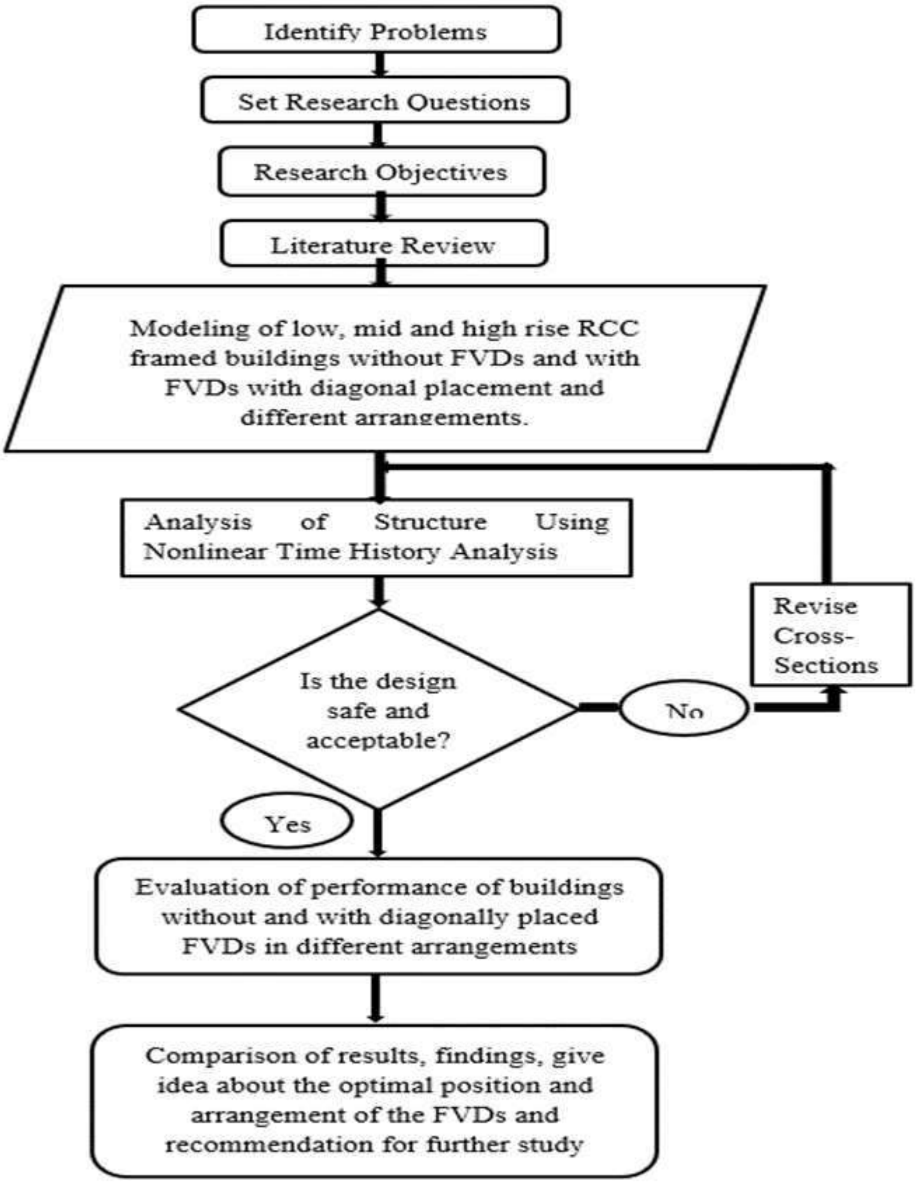


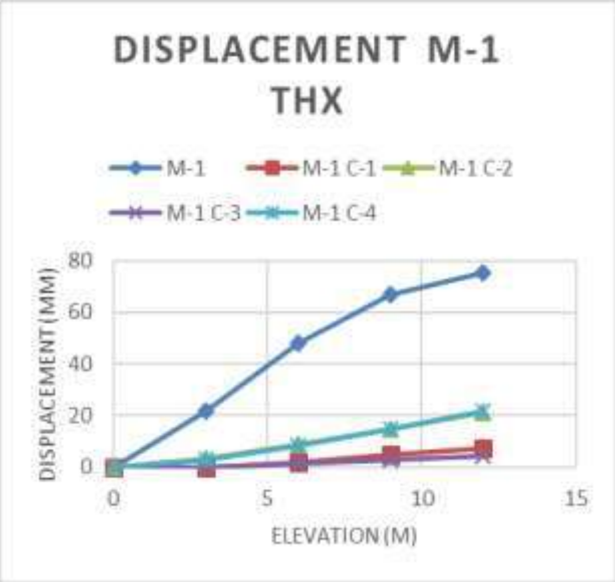
Figure 4: Flowchart of Methodological Framework

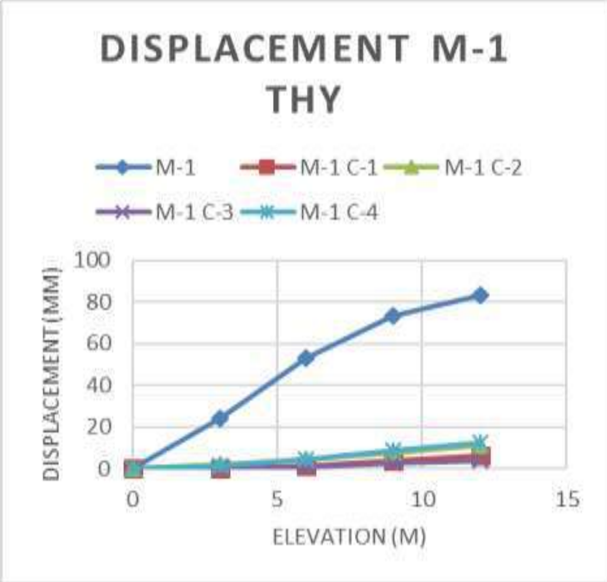
RESULTS:

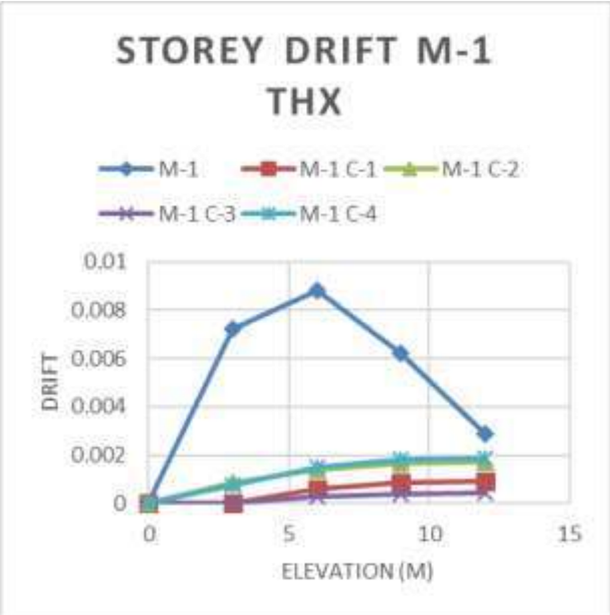
Following results in terms of displacement, drift and story shear were obtained for 4 and 12 story buildings without FVDs and with FVDs in six different cases of damper arrangements. Also, discussion and comparison are presented for the results obtained.

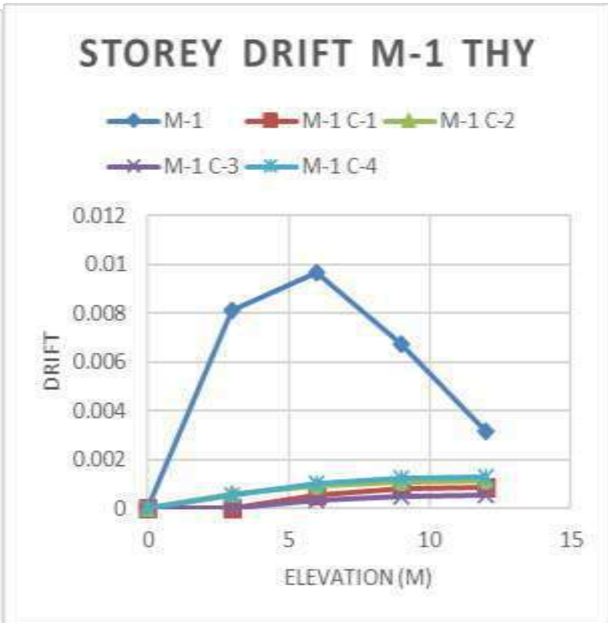
Results for 0.25g PGA Time History of Gorkha Earthquake (Kantipath)

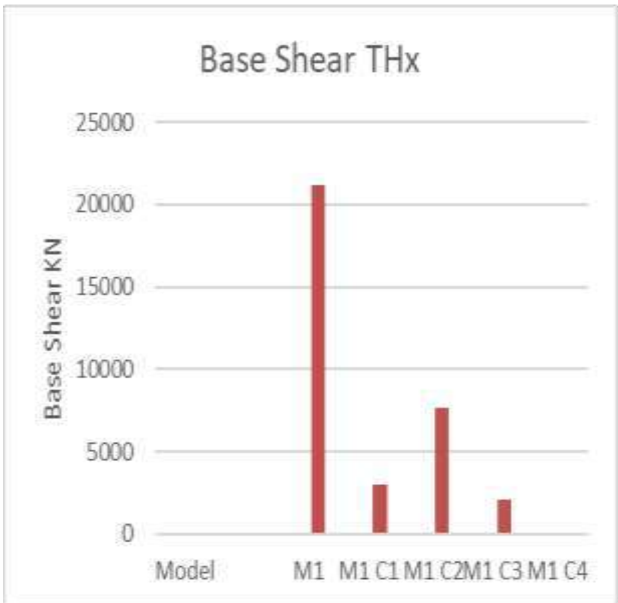
Model 1

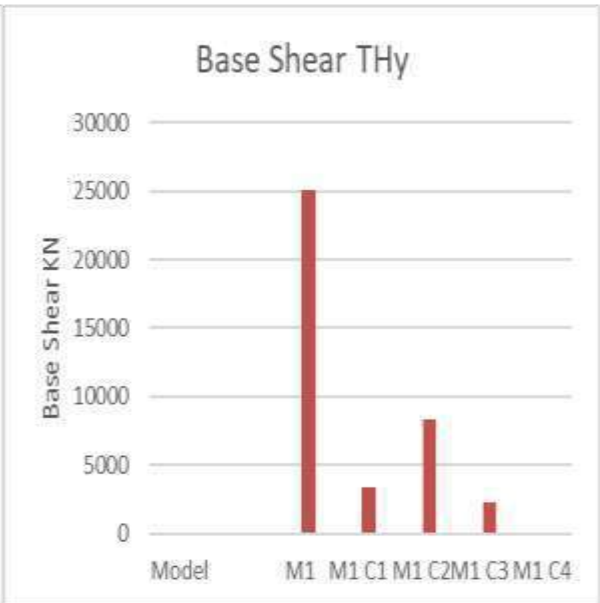

DISPLACEMENT M-1 THX
M-1
M-1 C-1
M-1 C-2
M-1 C-3
M-1 C-4
DISPLACEMENT (MM)
ELEVATION (M)

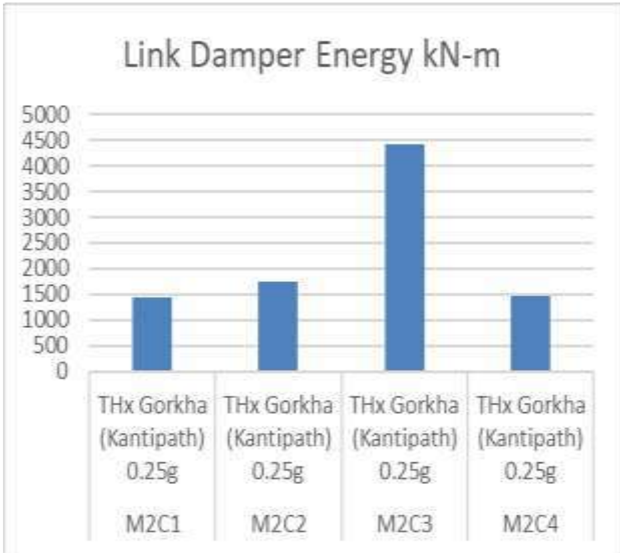

DISPLACEMENT M-1 THY
M-1
M-1 C-1
M-1 C-2
M-1 C-3
M-1 C-4
DISPLACEMENT (MM)
ELEVATION (M)

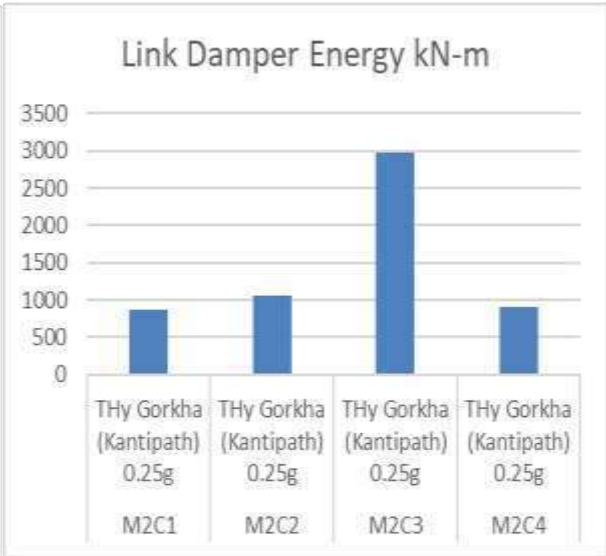

STOREY DRIFT M-1 THX
M-1
M-1 C-1
M-1 C-2
M-1 C-3
M-1 C-4
DRIFT
ELEVATION (M)


STOREY DRIFT M-1 THY
M-1
M-1 C-1
M-1 C-2
M-1 C-3
M-1 C-4
DRIFT
ELEVATION (M)

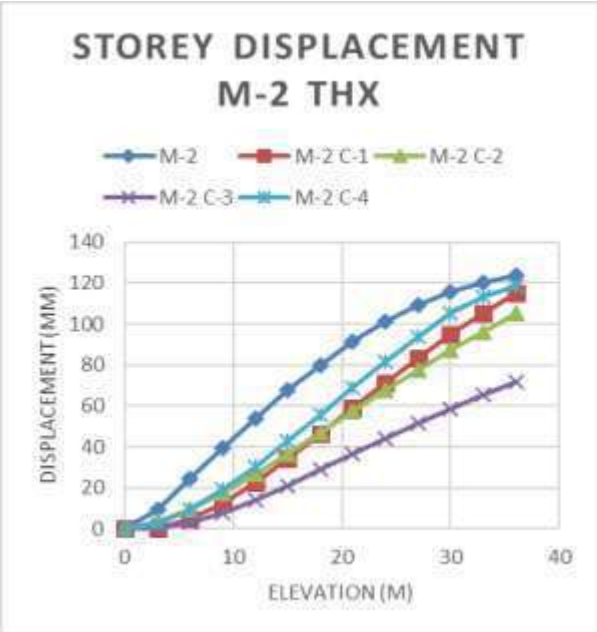

Base Shear THx
Base Shear KN
Model
M1
M1 C1
M1 C2
M1 C3
M1 C4

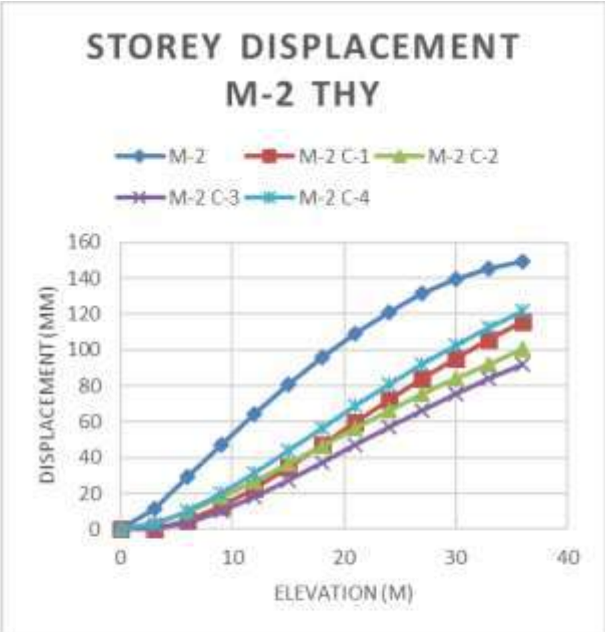

Base Shear THy
Base Shear KN
Model
M1
M1 C1
M1 C2
M1 C3
M1 C4

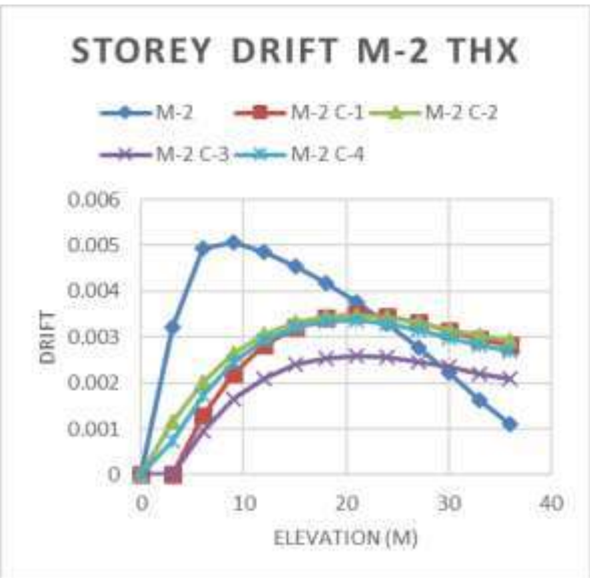

Link Damper Energy kN-m
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
THx Gorkha (Kantipath) 0.25g
M2C1
M2C2
M2C3
M2C4

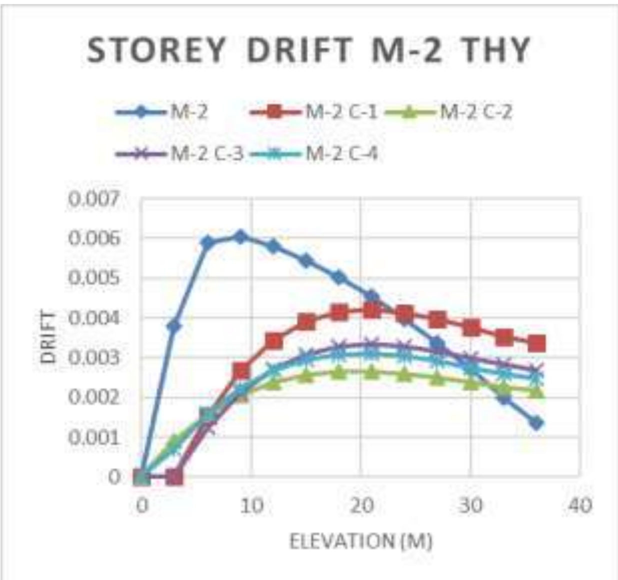

Link Damper Energy kN-m
3500
3000
2500
2000
1500
1000
500
0
THy Gorkha (Kantipath) 0.25g
M2C1
M2C2
M2C3
M2C4

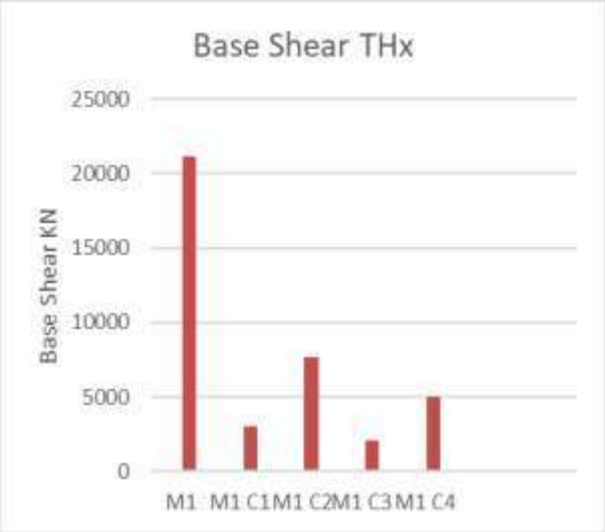
Model 2

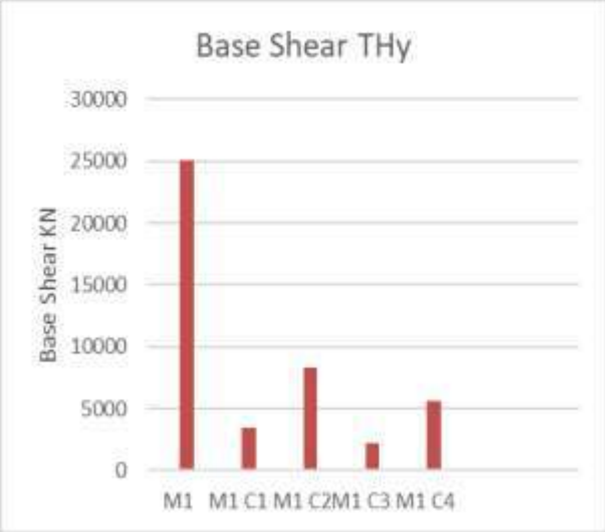

STOREY DISPLACEMENT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
ELEVATION (M)

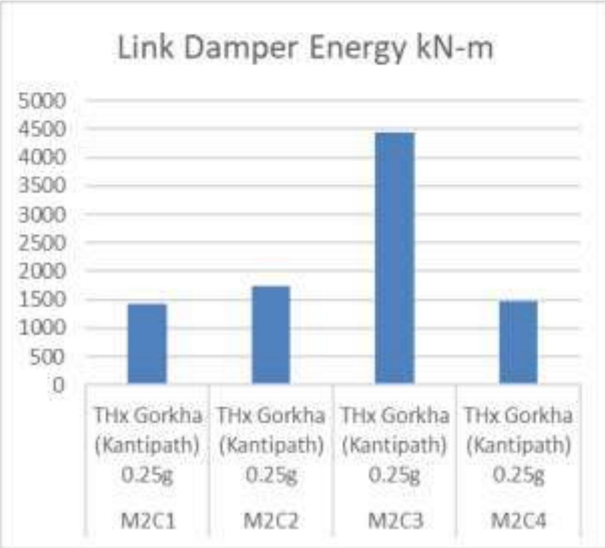

STOREY DISPLACEMENT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
ELEVATION (M)

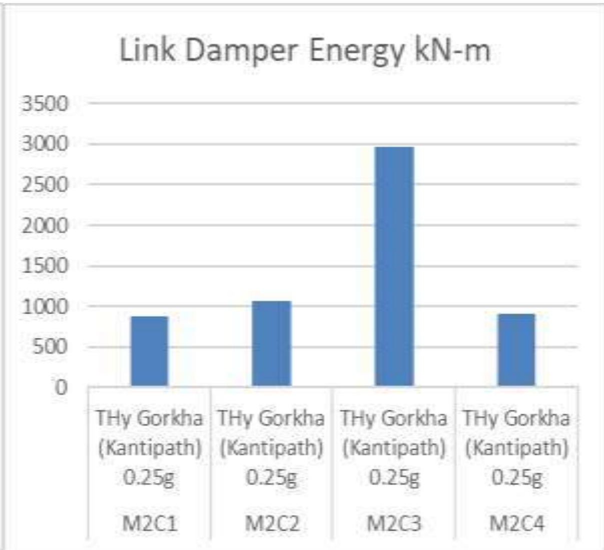

STOREY DRIFT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
ELEVATION (M)


STOREY DRIFT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
ELEVATION (M)



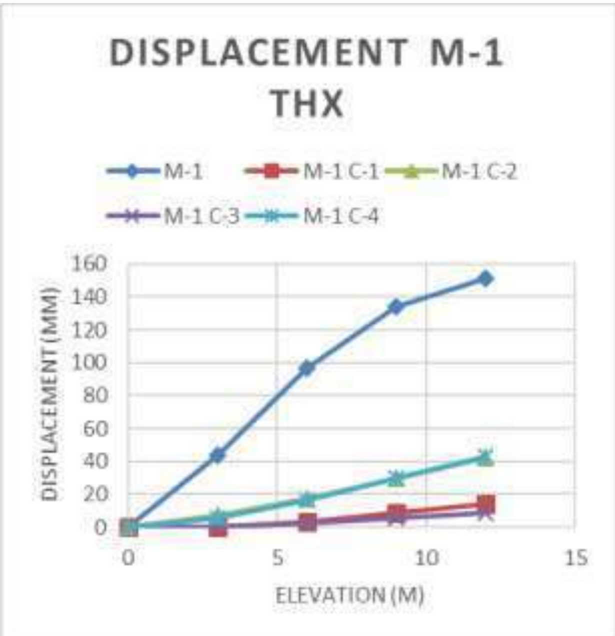


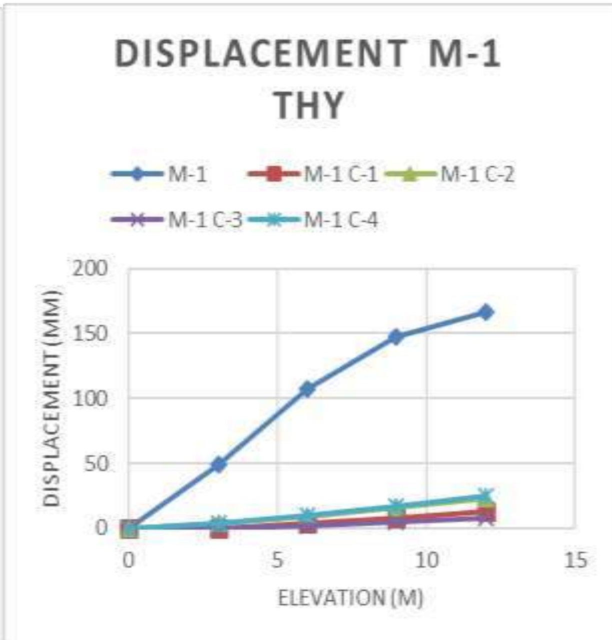


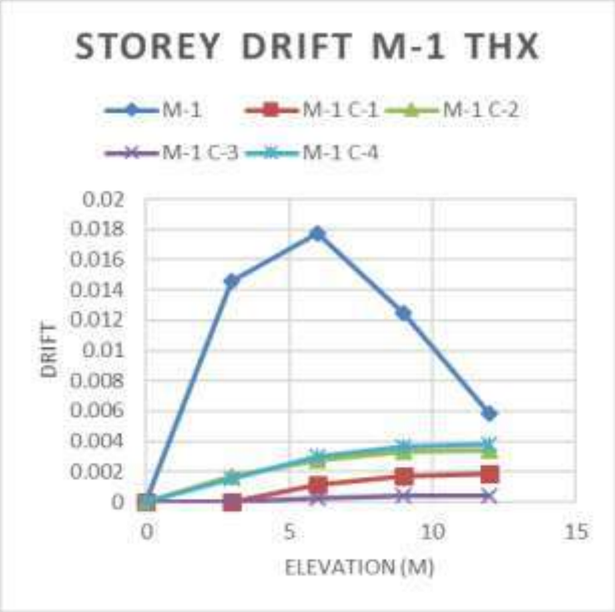


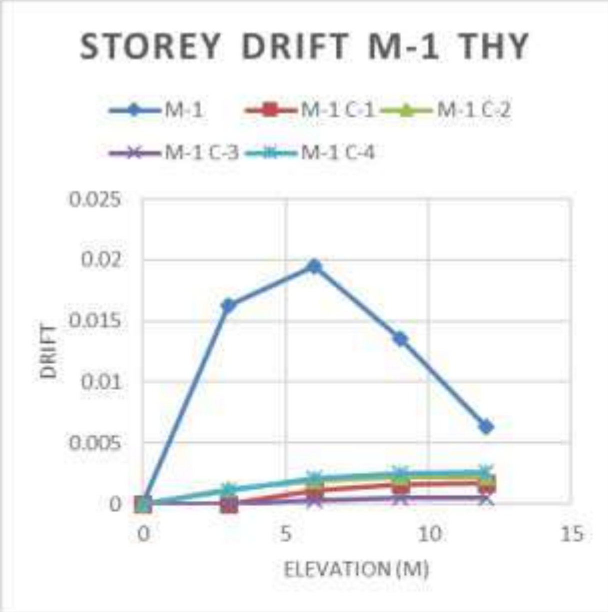
Results for 0.5g PGA Time History of Gorkha Earthquake (Kantipath)

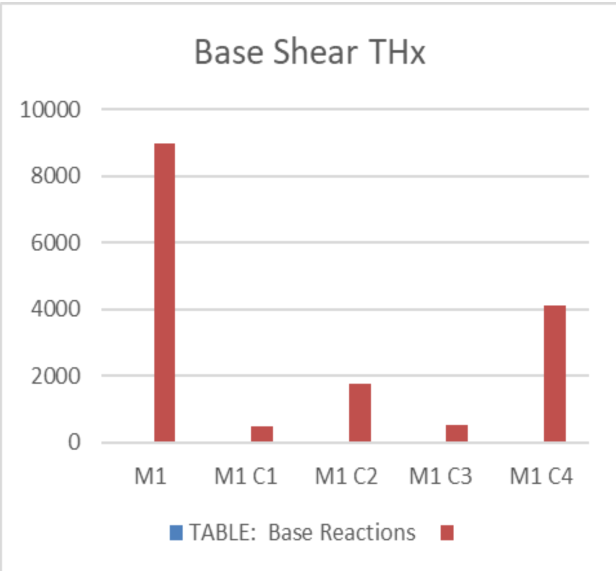
Model 1

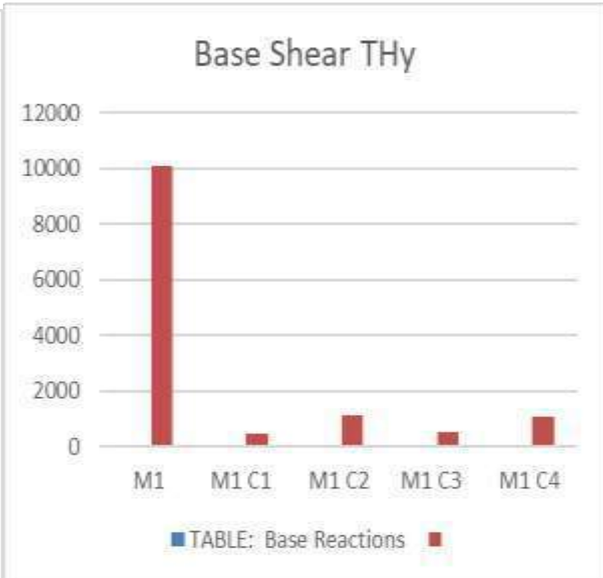


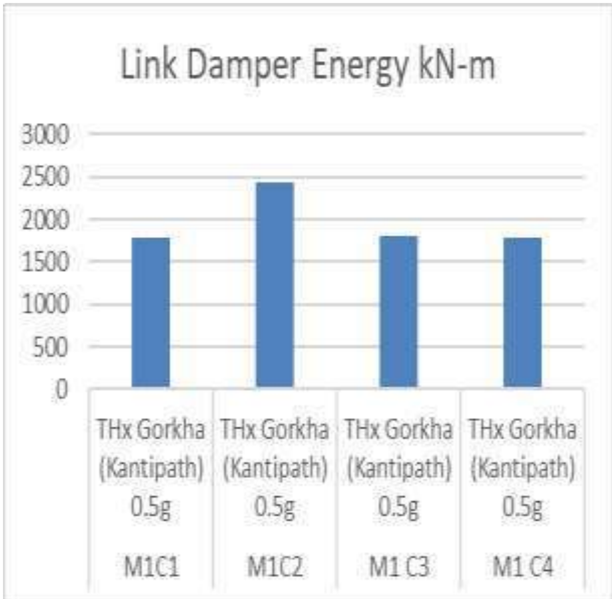


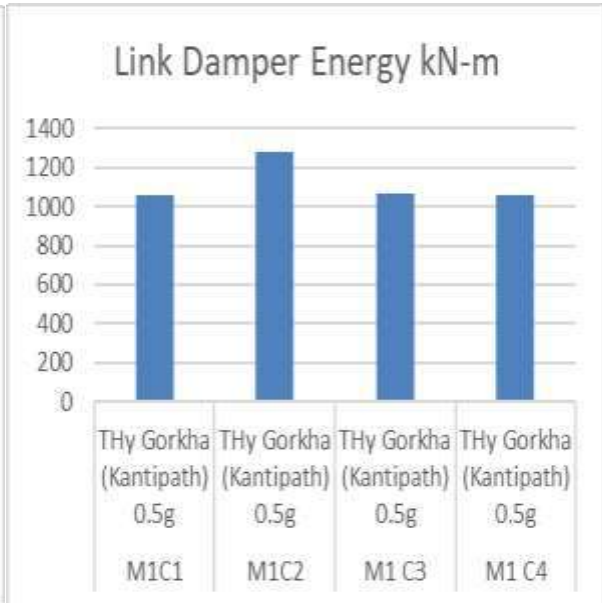

STOREY DRIFT M-1 THX
M-1
M-1 C-1
M-1 C-2
M-1 C-3
M-1 C-4
DRIFT
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
5
10
15
ELEVATION (M)


STOREY DRIFT M-1 THY
M-1
M-1 C-1
M-1 C-2
M-1 C-3
M-1 C-4
DRIFT
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
ELEVATION (M)

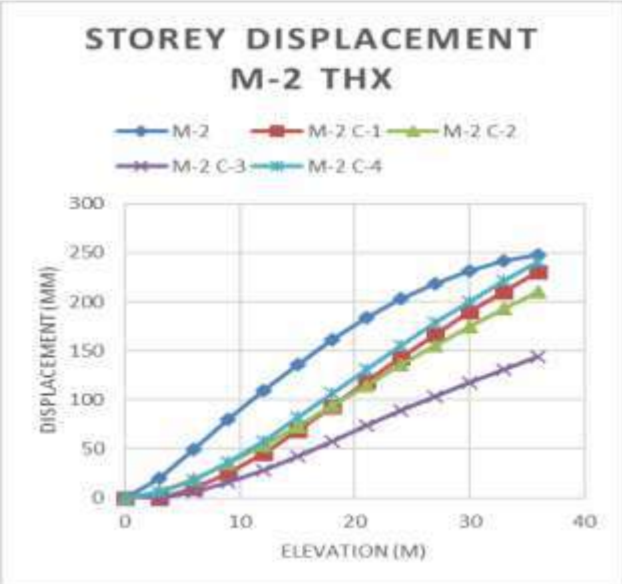

Base Shear THx
10000
8000
6000
4000
2000
0
M1
M1 C1
M1 C2
M1 C3
M1 C4
TABLE: Base Reactions

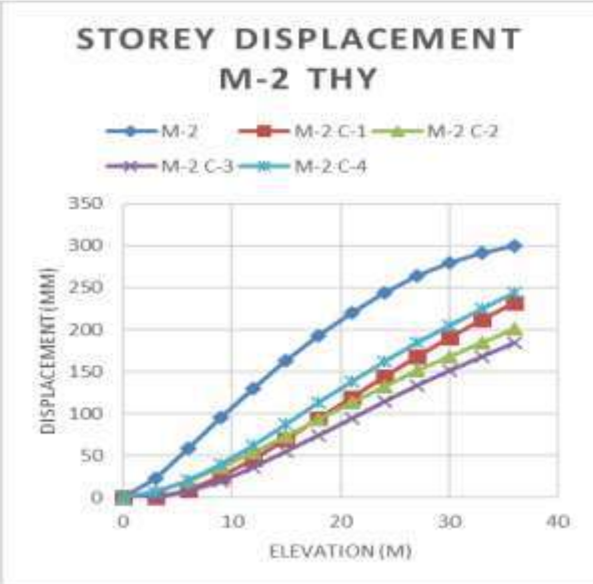

Base Shear THy
12000
10000
8000
6000
4000
2000
0
M1
M1 C1
M1 C2
M1 C3
M1 C4
TABLE: Base Reactions

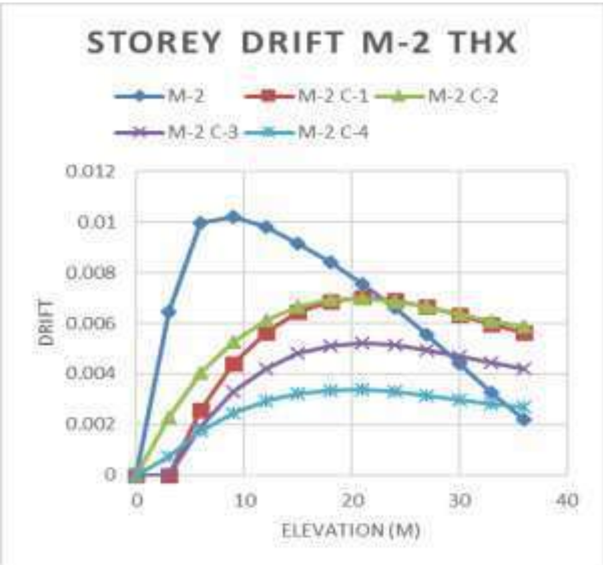

Link Damper Energy kN-m
3000
2500
2000
1500
1000
500
0
THx Gorkha (Kantipath) 0.5g
THx Gorkha (Kantipath) 0.5g
THx Gorkha (Kantipath) 0.5g
THx Gorkha (Kantipath) 0.5g
M1C1
M1C2
M1 C3
M1 C4

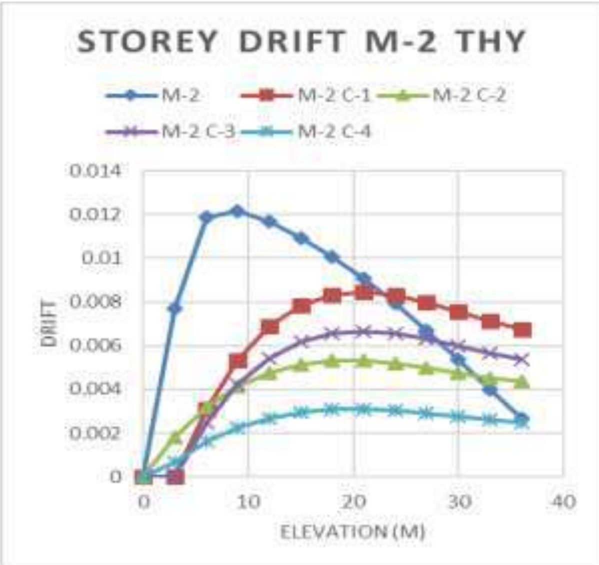

Link Damper Energy kN-m
1400
1200
1000
800
600
400
200
0
THy Gorkha (Kantipath) 0.5g
THy Gorkha (Kantipath) 0.5g
THy Gorkha (Kantipath) 0.5g
THy Gorkha (Kantipath) 0.5g
M1C1
M1C2
M1 C3
M1 C4

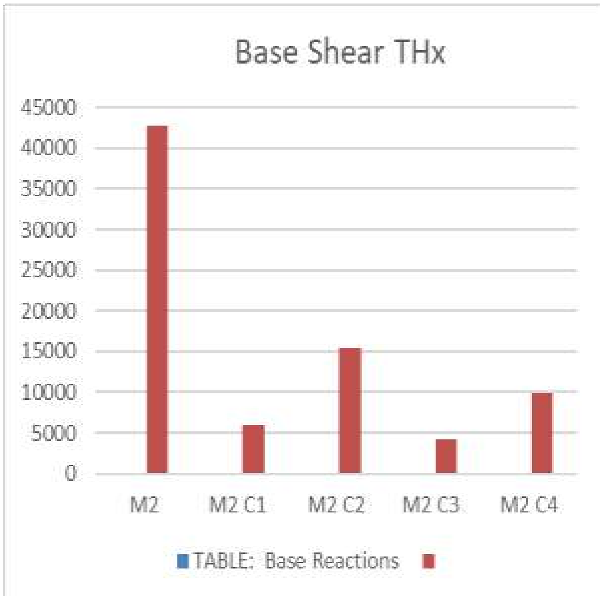
Model 2

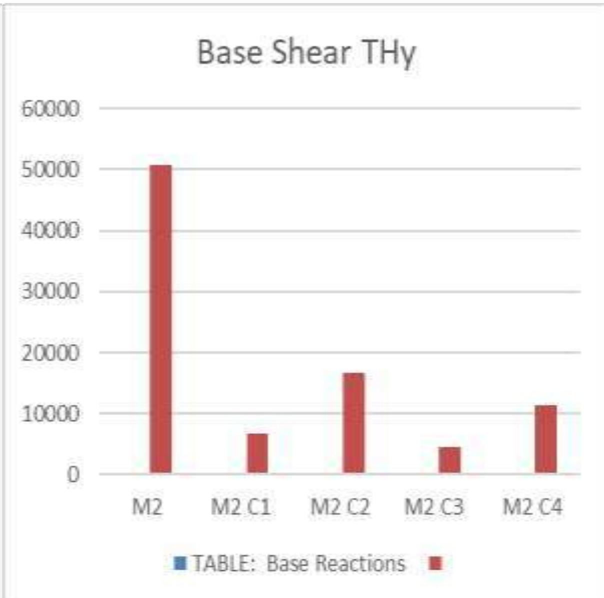

STOREY DISPLACEMENT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
0
50
100
150
200
250
300
0
10
20
30
40
ELEVATION (M)

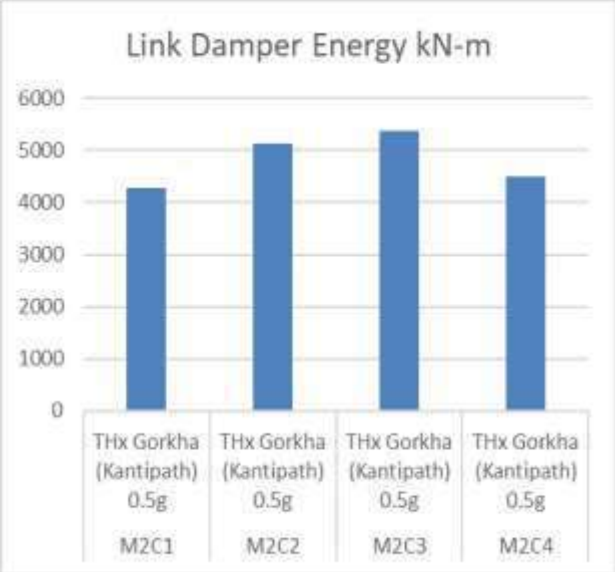

STOREY DISPLACEMENT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
0
50
100
150
200
250
300
350
0
10
20
30
40
ELEVATION (M)

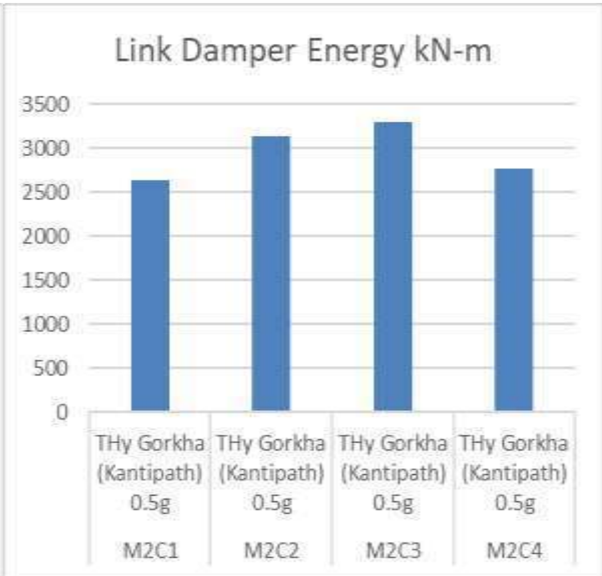

STOREY DRIFT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
0
0.002
0.004
0.006
0.008
0.01
0.012
0
10
20
30
40
ELEVATION (M)


STOREY DRIFT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0
10
20
30
40
ELEVATION (M)


Base Shear THx
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
M2
M2 C1
M2 C2
M2 C3
M2 C4
TABLE: Base Reactions

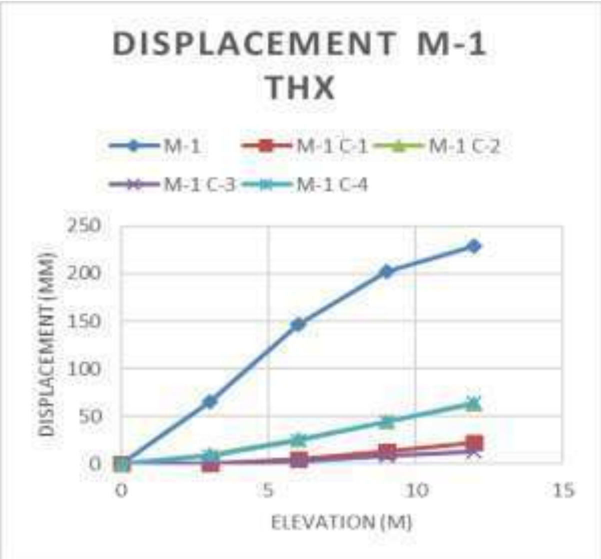

Base Shear THy
0
10000
20000
30000
40000
50000
60000
M2
M2 C1
M2 C2
M2 C3
M2 C4
TABLE: Base Reactions

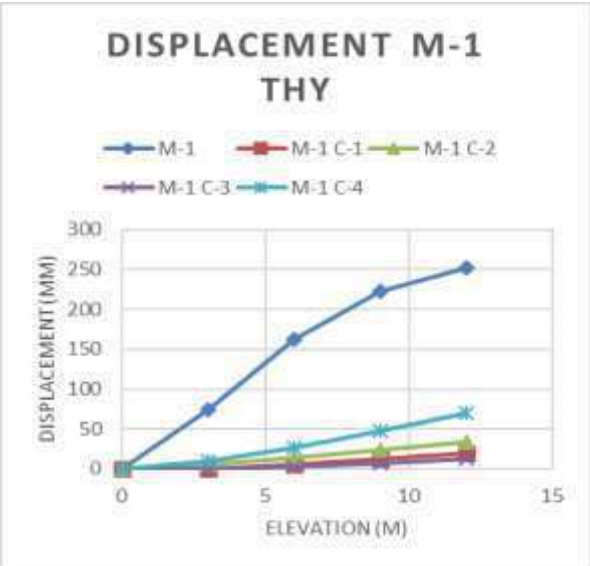


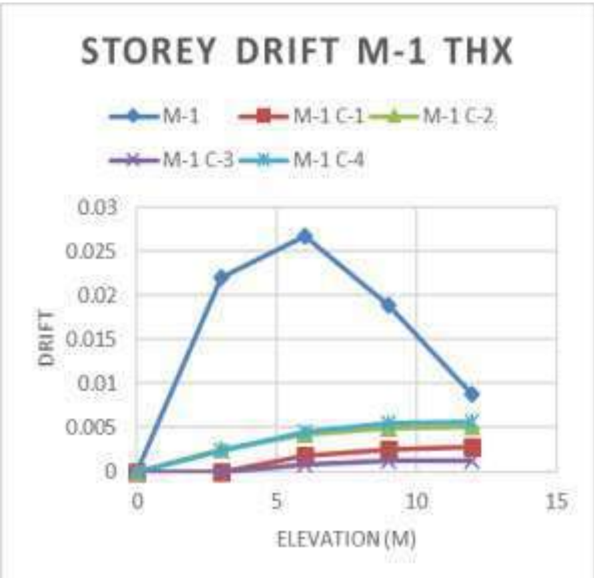


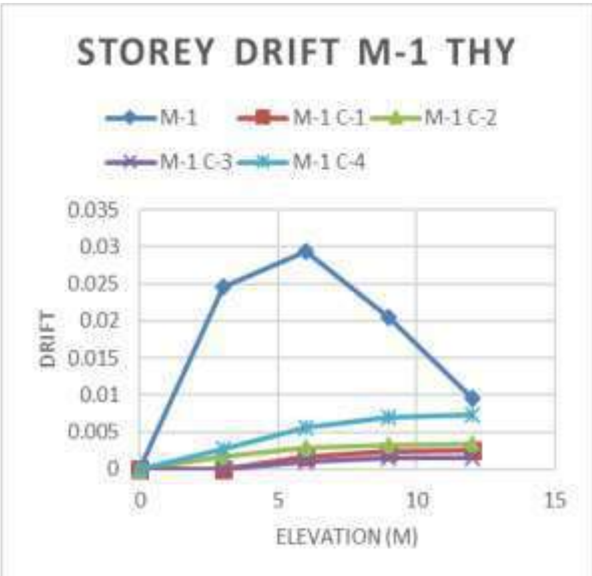
Results for 0.75g PGA Time History of Gorkha Earthquake (Kantipath)

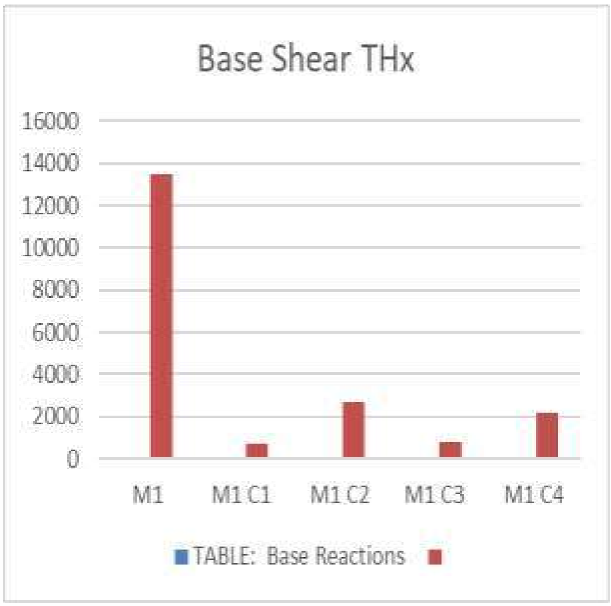
Model 1

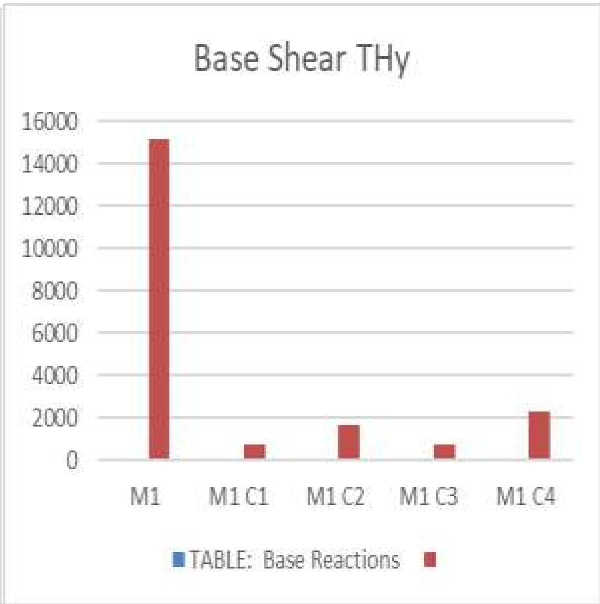


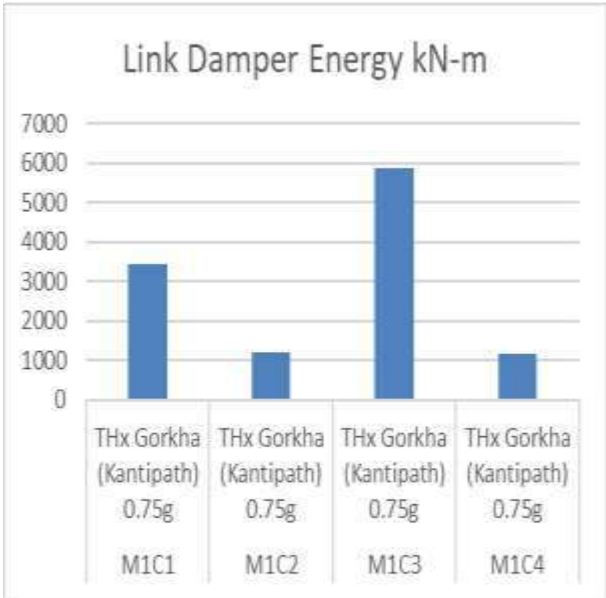


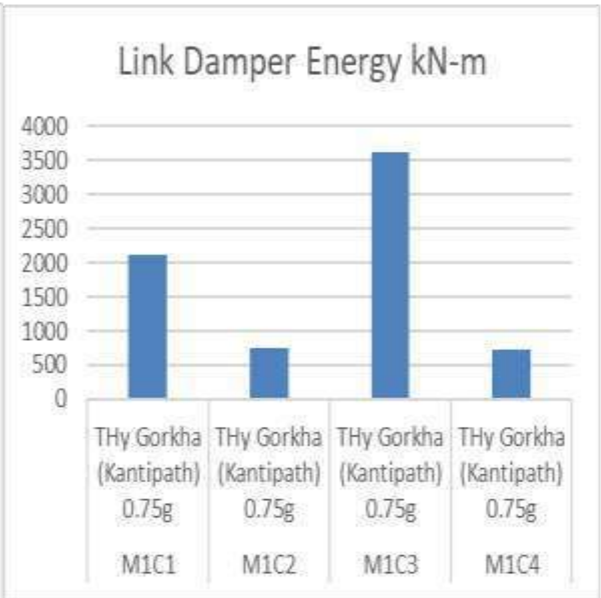




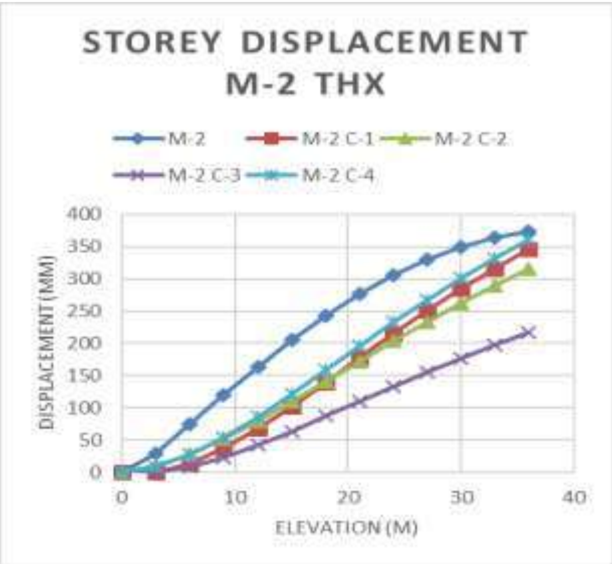

Base Shear THx
16000
14000
12000
10000
8000
6000
4000
2000
0
M1
M1 C1
M1 C2
M1 C3
M1 C4
TABLE: Base Reactions

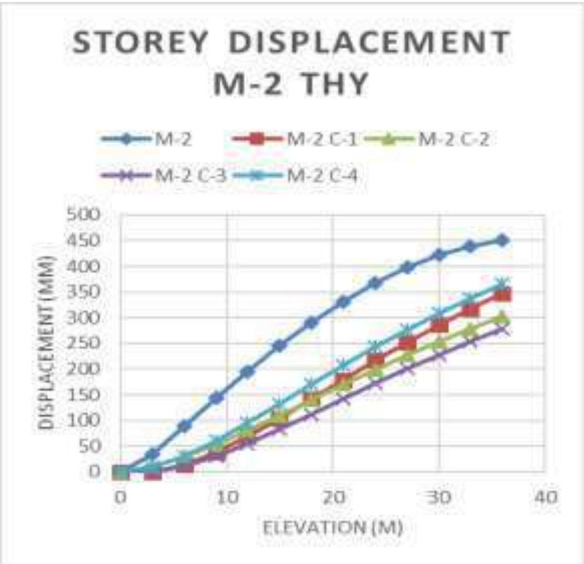

Base Shear THy
16000
14000
12000
10000
8000
6000
4000
2000
0
M1
M1 C1
M1 C2
M1 C3
M1 C4
TABLE: Base Reactions

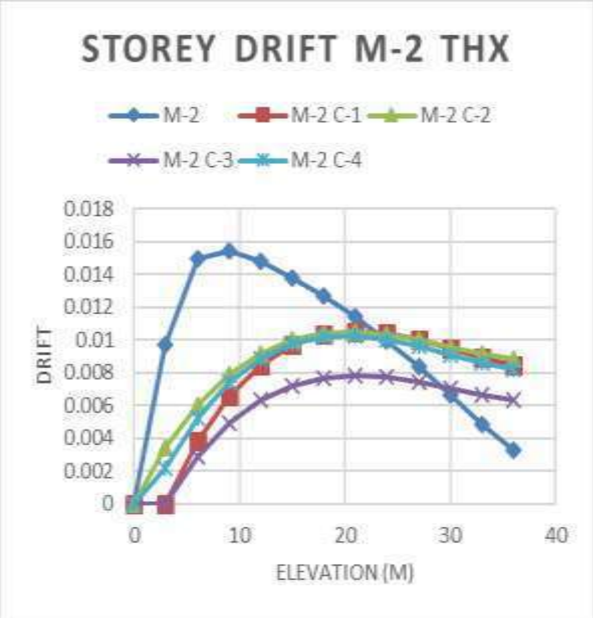

Link Damper Energy kN-m
7000
6000
5000
4000
3000
2000
1000
0
THx Gorkha (Kantipath) 0.75g
M1C1
M1C2
M1C3
M1C4

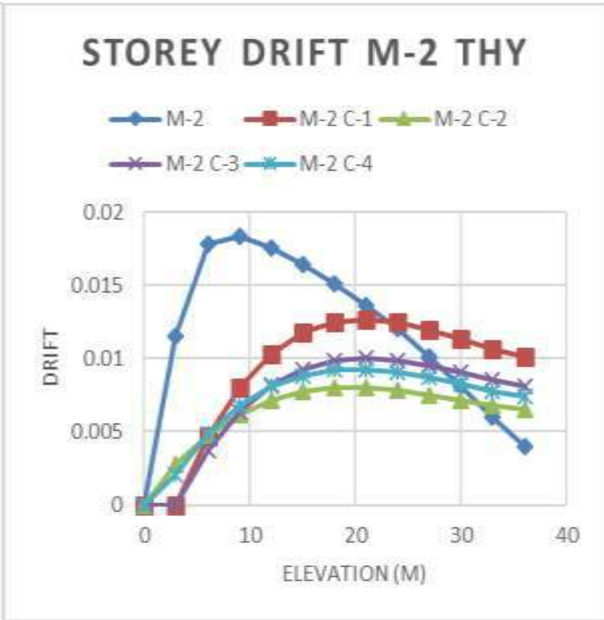

Link Damper Energy kN-m
4000
3500
3000
2500
2000
1500
1000
500
0
THy Gorkha (Kantipath) 0.75g
M1C1
M1C2
M1C3
M1C4

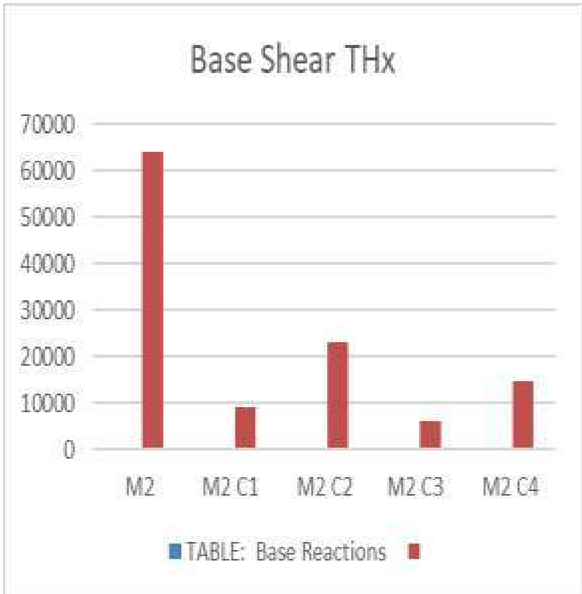
Model 2

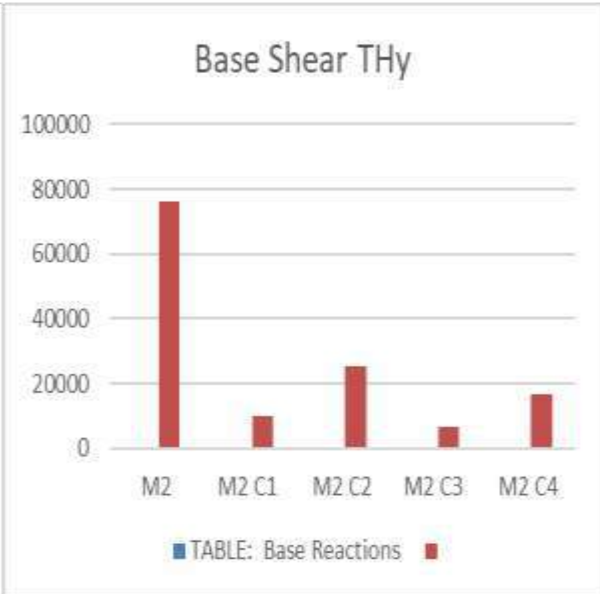

STOREY DISPLACEMENT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
ELEVATION (M)

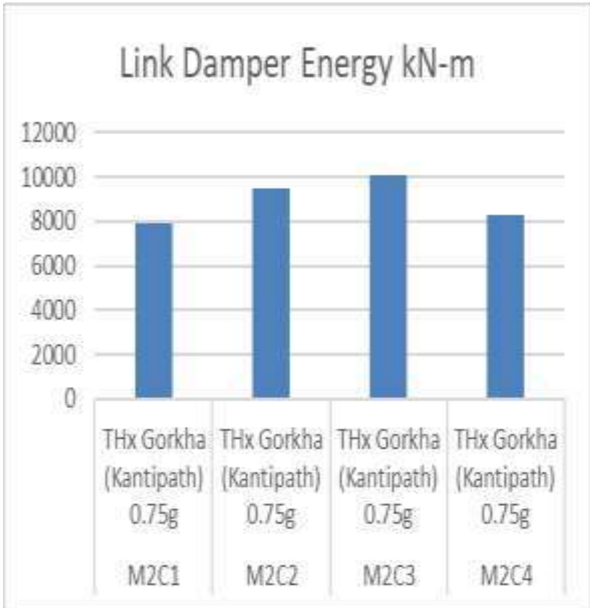

STOREY DISPLACEMENT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
ELEVATION (M)

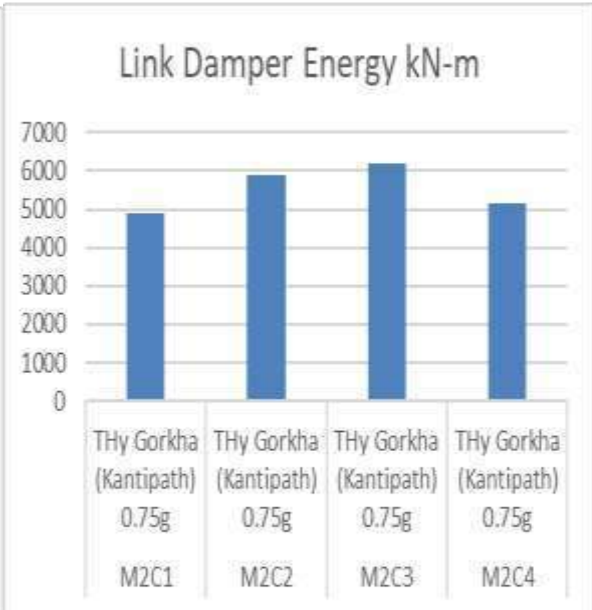

STOREY DRIFT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
ELEVATION (M)


STOREY DRIFT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
ELEVATION (M)


Base Shear THx
M2
M2 C1
M2 C2
M2 C3
M2 C4
TABLE: Base Reactions

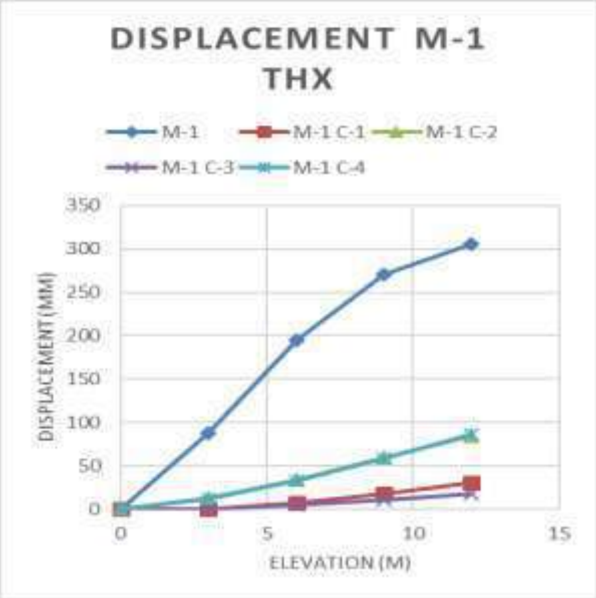

Base Shear THy
M2
M2 C1
M2 C2
M2 C3
M2 C4
TABLE: Base Reactions

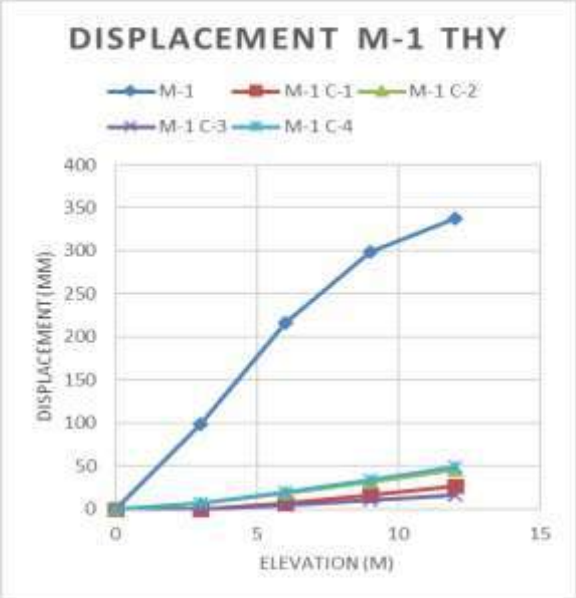

Link Damper Energy kN-m
THx Gorkha (Kantipath) 0.75g
M2C1
M2C2
M2C3
M2C4

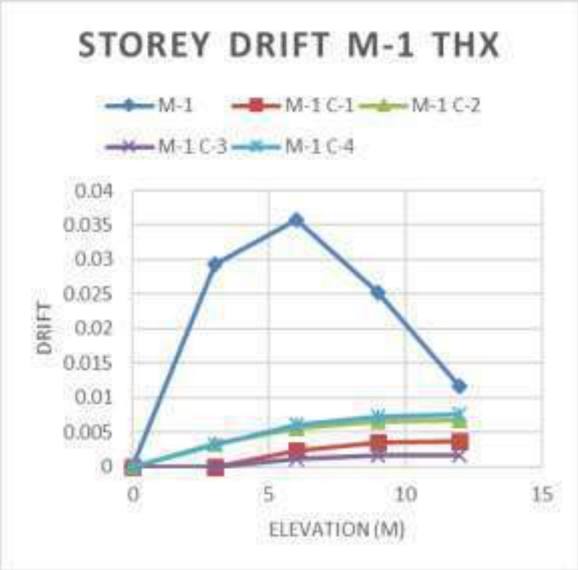

Link Damper Energy kN-m
THy Gorkha (Kantipath) 0.75g
M2C1
M2C2
M2C3
M2C4

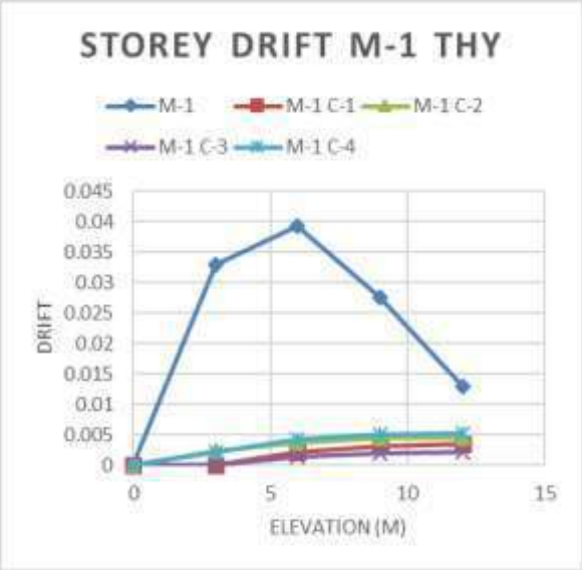
Results for 1g PGA Time History of Gorkha Earthquake (Kantipath)

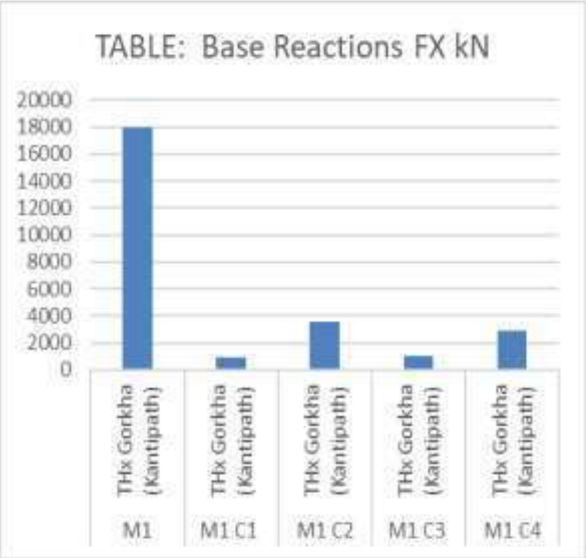
Model 1

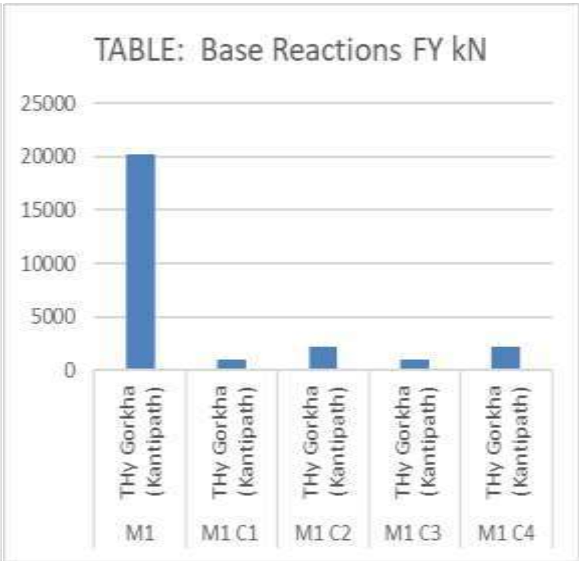




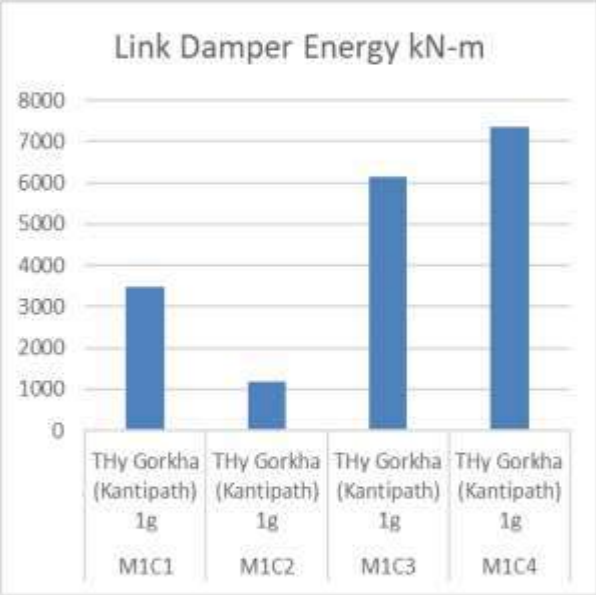




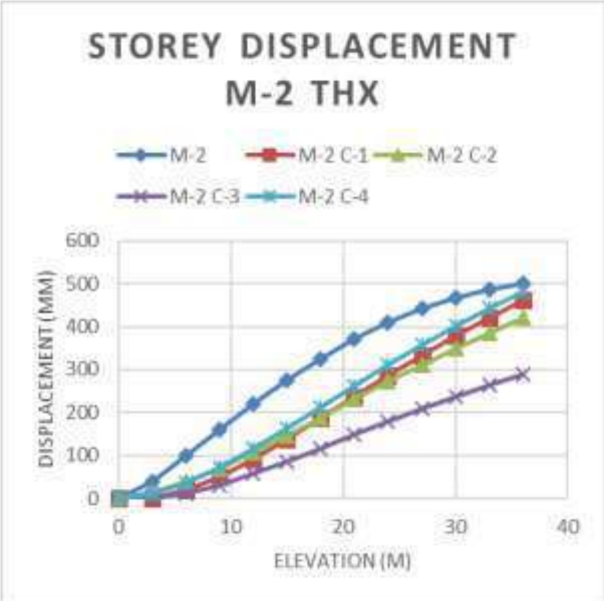


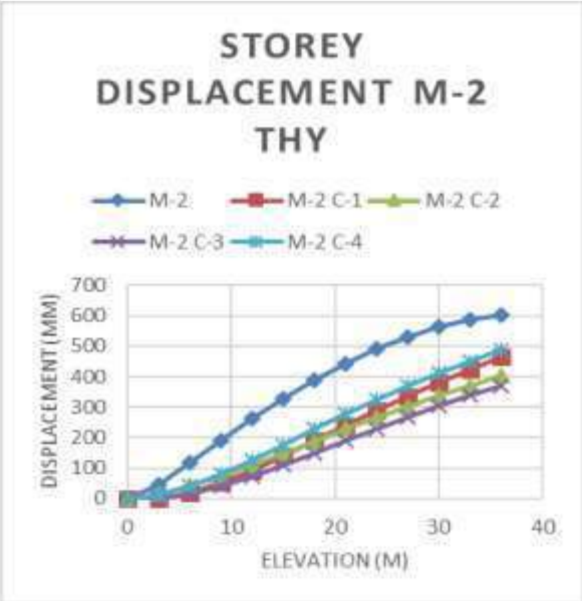


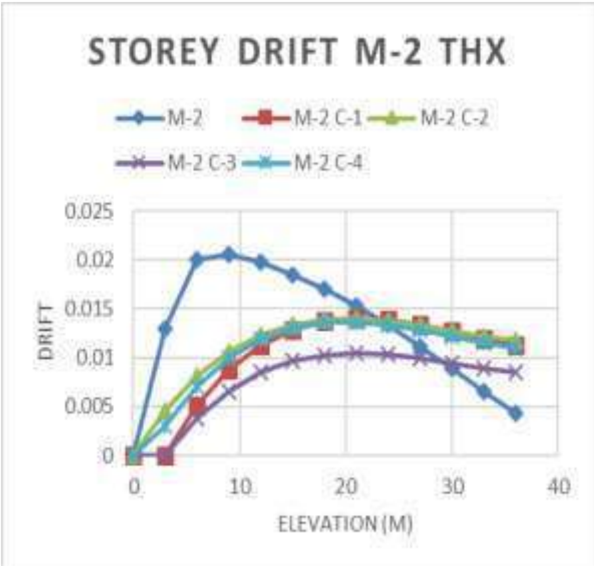

Link Damper Energy kN-m
14000
12000
10000
8000
6000
4000
2000
0
THx Gorkha (Kantipath) 1g
M1C1
M1C2
M1C3
M1C4

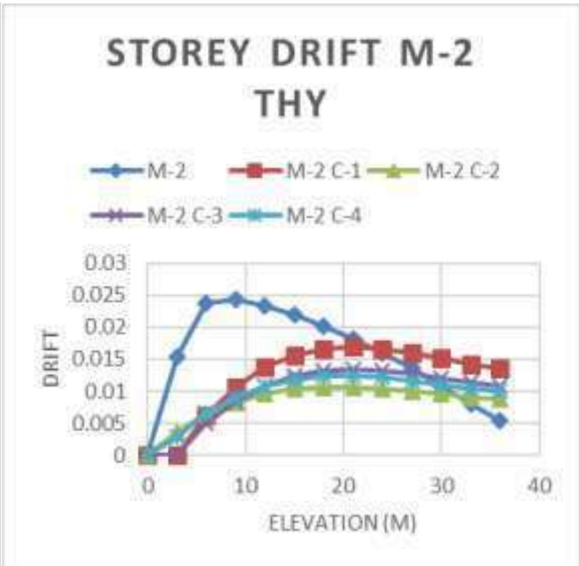

Link Damper Energy kN-m
8000
7000
6000
5000
4000
3000
2000
1000
0
THy Gorkha (Kantipath) 1g
M1C1
M1C2
M1C3
M1C4

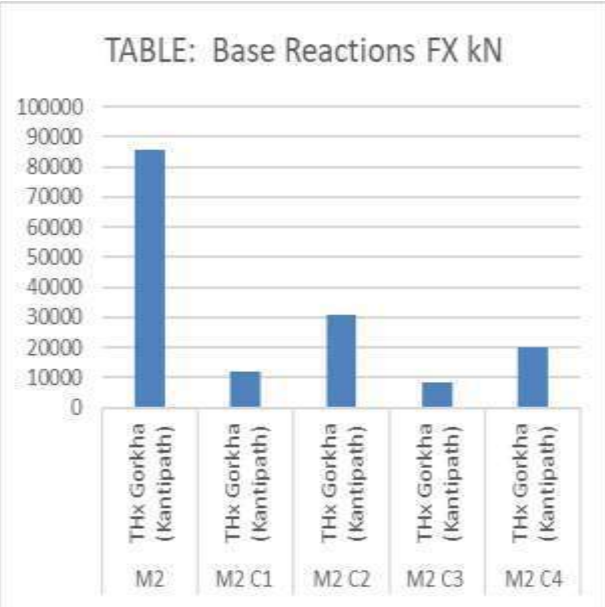
Model 2

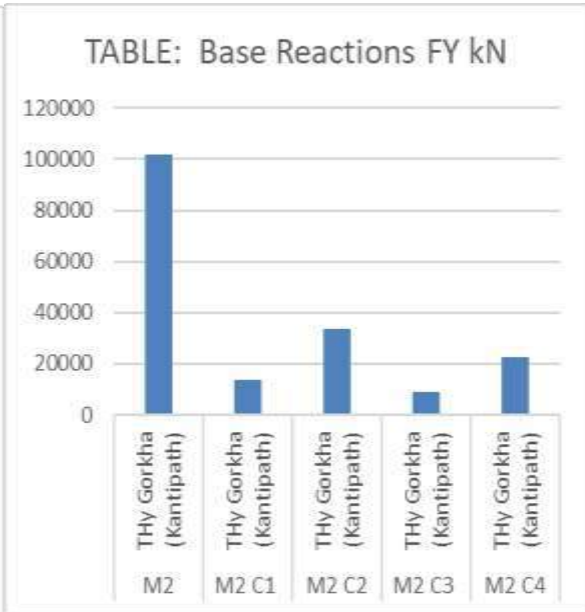

STOREY DISPLACEMENT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
ELEVATION (M)


STOREY DISPLACEMENT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DISPLACEMENT (MM)
ELEVATION (M)

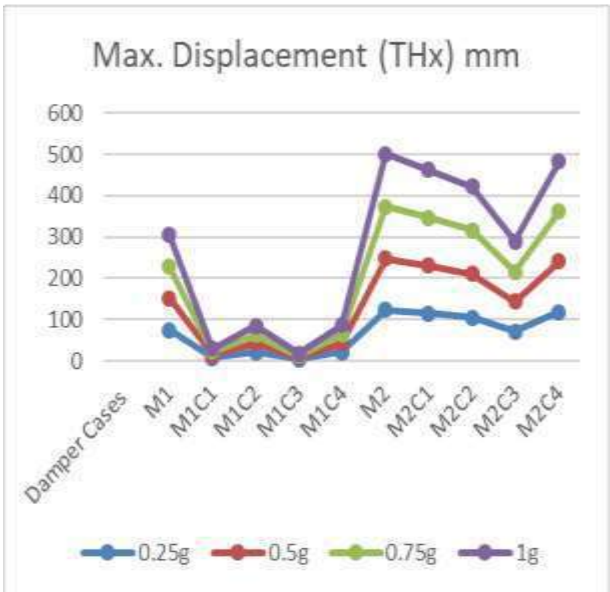

STOREY DRIFT M-2 THX
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
ELEVATION (M)

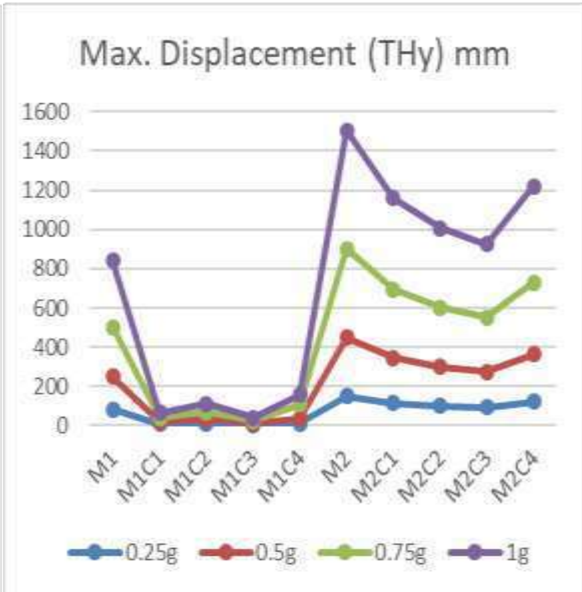

STOREY DRIFT M-2 THY
M-2
M-2 C-1
M-2 C-2
M-2 C-3
M-2 C-4
DRIFT
ELEVATION (M)



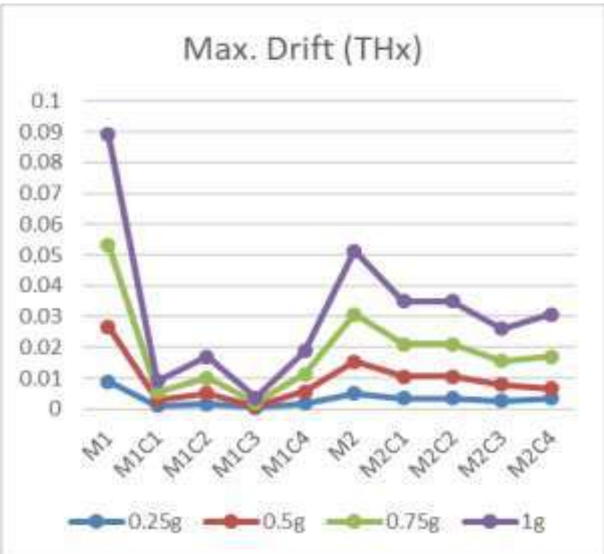


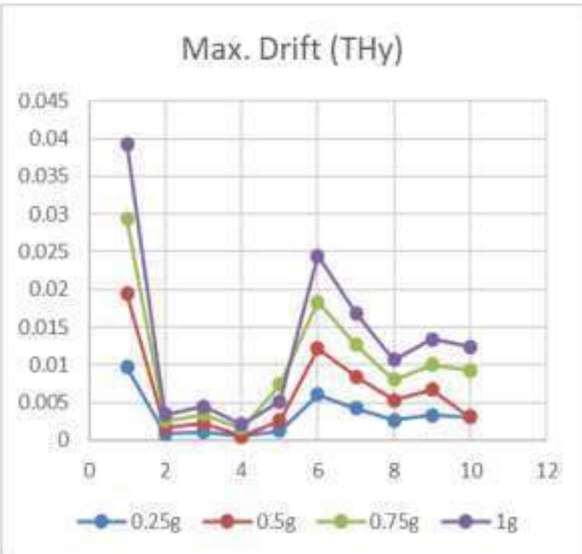
Maximum Displacement for different cases of damper arrangement at different PGA



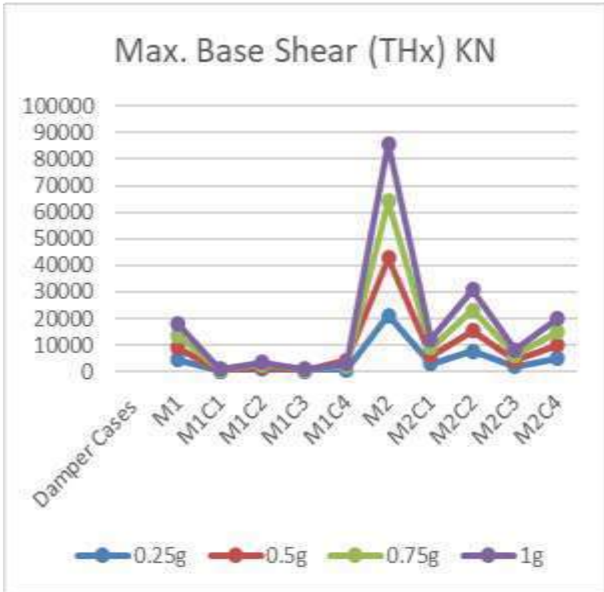


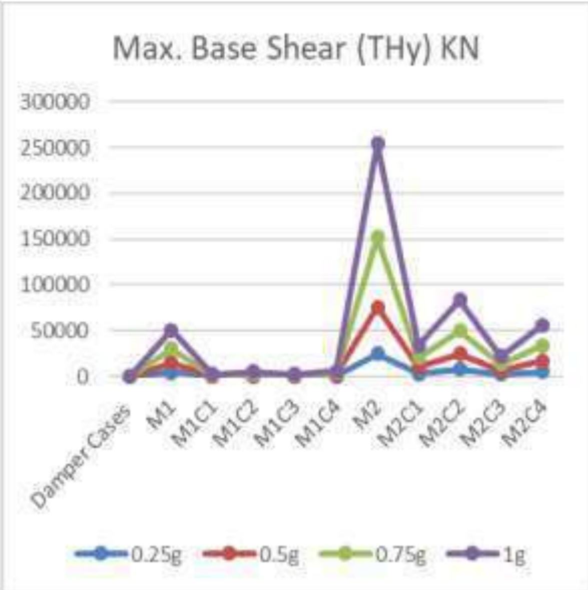
Maximum Drift for different cases of damper arrangement at different PGA



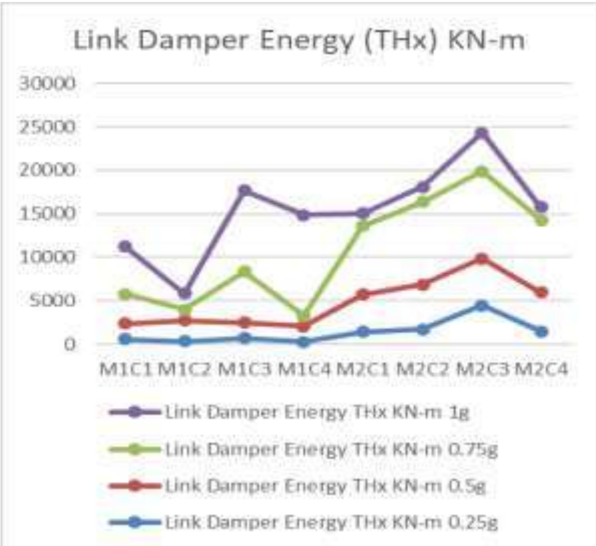


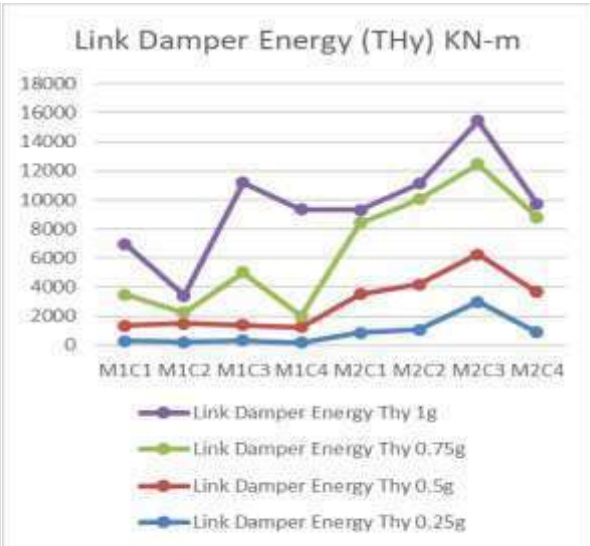
Maximum Base Shear for different cases of damper arrangement at different PGA





Link Damper Energy Comparison for different cases at different PGA





CONCLUSION:

From the result obtained from the analysis, following conclusion can be made:

i. Lateral displacement, drift and base shear of the structure decreases after the use of FVDs in the structure which is justified from above results.

ii. For Four Storied Building, it is found that the maximum reduction of maximum storey displacement is upto 94.599 %, the maximum reduction of maximum storey drift is upto 95.330 % and the maximum reduction of base shear is upto 94.959 %. For Twelve Storied Building, it is found that the maximum reduction of maximum storey displacement is upto 42.041 %, the maximum reduction of maximum storey drift is upto 48.8867 % and the maximum reduction of maximum base shear is upto 91.114 %.

iii. From the obtained results, among the four different cases of damper arrangement, Case 3 is found to be the optimum damper arrangement for which there was maximum reduction in the structure response parameters i.e. storey displacement, storey drift and base shear and link damper energy was maximum among all cases. Also, among these cases, Case 4 is found to be least effective in reducing these structure response parameters and link damper energy was minimum among all cases.

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