

Comparative Seismic Analysis of High Rise Structural Steel Building with Seismic Dampers and Base Isolators

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ABSTRACT: Seismic loads are considered to be the most erratic loading when it comes to lateral loads. Region which are high prominent to earthquakes must be designed to resist the earthquake and also be designed to dissipate the excitation energy it undergoes. Recent advancements in seismology has introduced structures with special devices which gets integrated to structural building system and thereby making the structure to be stable. There are various advanced damping devices which are used for dissipating the energy of seismic loads. This paper deals with analysis of high rise structural steel building system with and without passive energy control system and comparing the modal results of the structural model with viscous damper with natural time period of 1.97 secs and structural model with lead rubber bearing have natural time period 3.7 secs. Base shear for structural model with viscous dampers (M-FVD) experienced a maximum base shear of 7517 kN and model with lead rubber bearing (M-LRB) bearing experienced a maximum base shear of 3890 kN.

KEYWORDS: Storey Displacement, Storey base shear, Natural period, M-FVD, M-LRB.

I. INTRODUCTION

When it comes to history of earthquake across India the most devastating earthquake is the Bhuj Earthquake which occurred in Gujarat with a magnitude of 7.7 with an intensity of extreme. Thereby it was mandatory to design a building to resist the seismic loads based on seismic zone and importance factor of the building. Nowadays energy dissipation system have got integrated to the building systems by making the structure to respond to the excitation and undergo safe deformations.

The structural control systems are classified into three basic types as active, semi-active, passive energy dissipation control system. This paper details with analysis of high rise structural steel building with base passive control system such as base isolation system and viscous damping and understand the response for the building system and compare the results.

II. PASSIVE CONTROL SYSTEM

The passive control systems does not require an external power source and being utilizes the structural motion to dissipate seismic energy or isolates the vibrations so that response of structure can be controlled. The passive control devices includes.

1. Base Isolation.
2. Passive Energy Dissipation Devices.

Base Isolator System:-

Base Isolator is a passive damping system which is used to dissipate energy due to earthquake. It is process of decoupling the superstructure from the substructure thereby protecting the structure from earthquake excitation force. Isolation can be obtained by use of various techniques like rubber bearing, friction bearings, ball bearings and spring system. It makes the building overcome and survive a potential devastating seismic impact.

Viscous Damper

Viscous damper are passive energy control system which are added to the structure to increase the stiffness of new structure as well as retrofit an existing structure to enhance its performance for earthquake excitation force. The damper properties were adopted from Taylor Devices. The force of the damper can be represented by a formula.

$$F = CV^\alpha$$

Where,

C = Damping Coefficient

V= velocity of the piston.

α = velocity exponent.

Linear stiffness of the fluid viscous damper can be calculated by calculating the maximum storey stiffness by summing up the stiffness of column in a storey.

$$K = 595000 \text{ KN/m}$$

III. MODEL DETAILS

The structure is a high rise structural steel building system with composite floor systems. The structure is designed to be G+16 office building. The table shown below represents the model details

Table 1 Model Details

Model Details	
Length	45 m
Breadth	27 m
Height	75.2 m
No of floors	16
Storey Height	4.2 m
Grid line Spacing X	9 m
Grid line Spacing Y	9 m

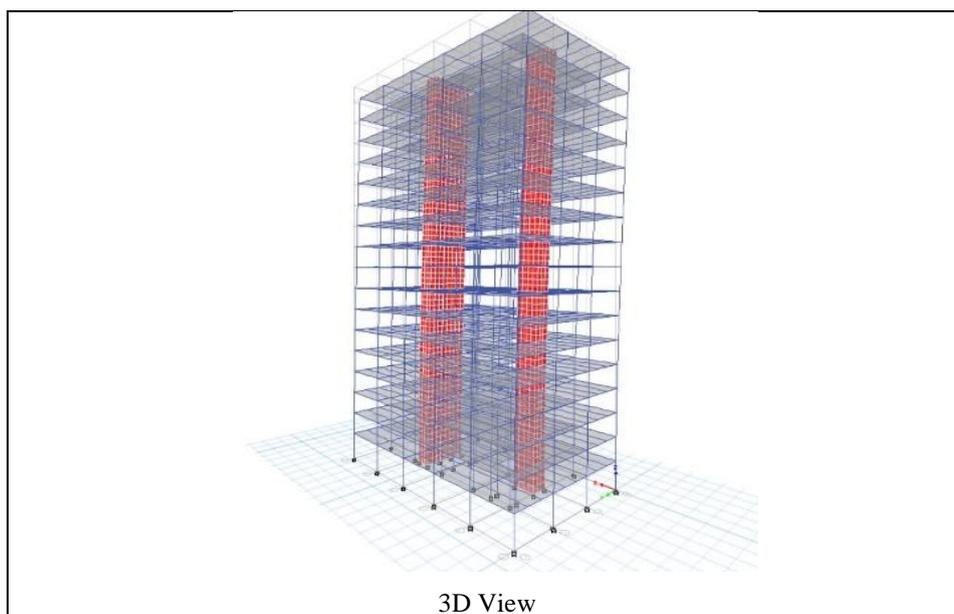


Fig 1 3D view & PLAN view

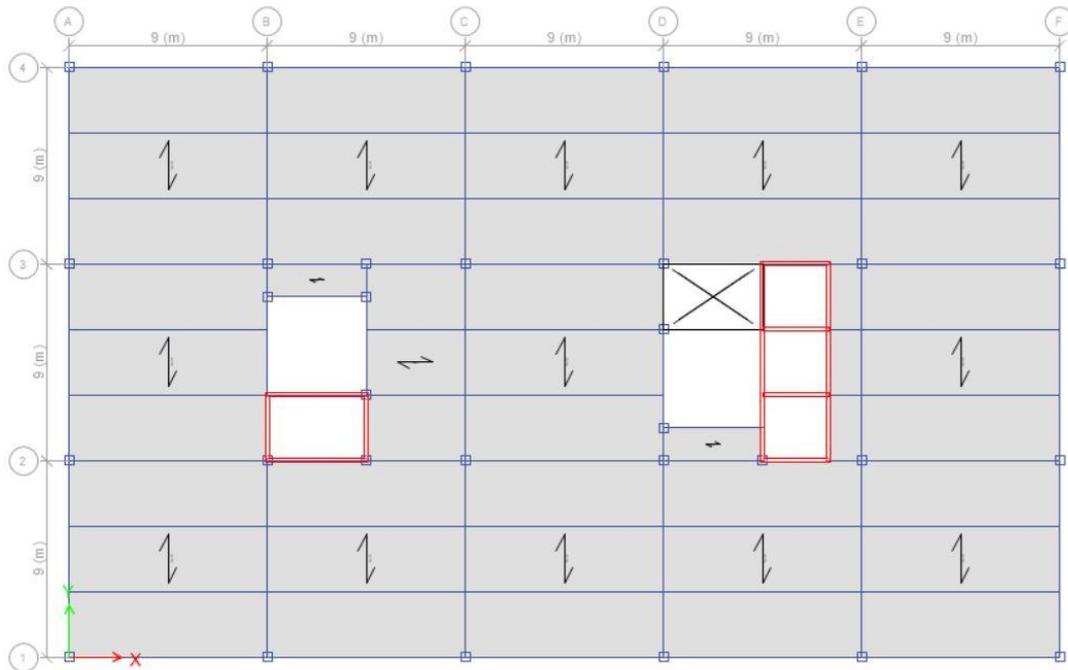


Fig 2 Grid System

Model Description

M-FVD – structural model with fixed base with fluid viscous energy control system.

M-LRB – structural model with base isolation energy control system

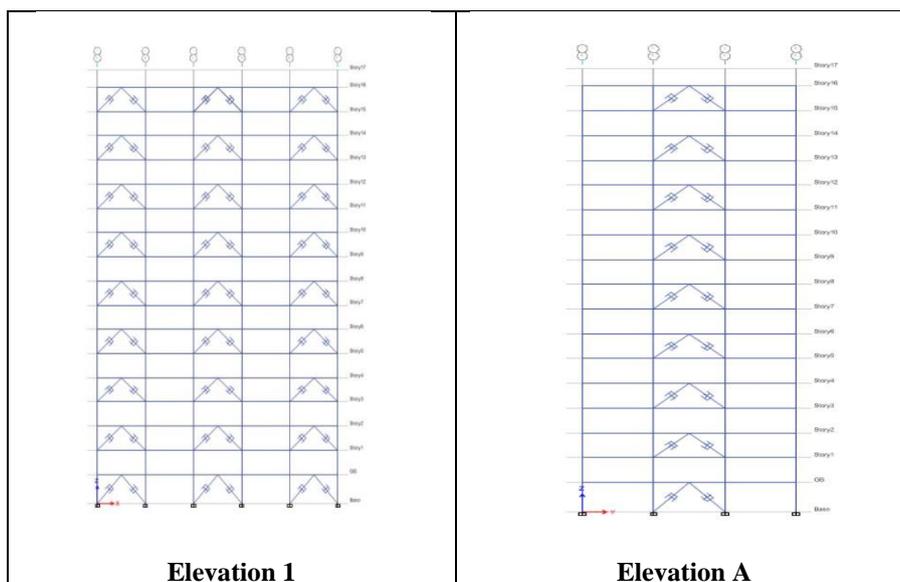


Fig 2 Alignment of Viscous Damper

Viscous dampers were assigned as chevron brace along the periphery frame of the structural model along elevation 1 & 4 and on elevation A & F. Fig 2 represents the



Viscous Damper properties

Structural model with fluid viscous damper (M-FVD) were assigned with links of Damper Exponential type in order to regain its original position. Table 2 represents the link properties

Table 2 Link Properties

Link Name	FVD
Line Type	Damper Exponential
Effective Stiffness	595238 kN/m

Base Isolation Properties

Structural model with lead rubber bearing (M-LRB) were assigned with spring at their base thereby separating the substructure from superstructure. Table 3 represents the spring properties.

Table 3 Spring Properties

Spring Name	LRB
Link Type	Rubber Isolator
Linear Effective Stiffness	7767260 kN/m

Load Details

The various gravity loads shown in table 3 represents the total load due to dead load with self-weight multiplier of 1, live load ranging 3-4 kN/m² and with super imposed dead load of intensity 3.5 kN/m². Mass source were assigned to the structure with dead load has multiplier of unity and for live load intensity with 3 and less than three with a multiplication factor of 0.25 (25% of the live load for calculating seismic weight) and for live load intensity greater than 3 kN/m² with a multiplication factor of 0.5 (50% of live load for calculating seismic weight).

Table 2 Load Assigns

LOAD TYPE	WEIGHT (KN)
Gravity Load (DL)	129850
Super Imposed Load (SDL)	65947
Imposed Load IL1 > 3 kN/m ²	35991
Imposed Load IL2 < 3 kN/m ²	16146
Seismic Weight (W)	203898

Load Cases

EQX & EQY= Earthquake Load along X & Y direction.

RSX & RSY = Response spectrum load along X & Y direction.

Seismic Load Combination

Seismic loads where assigned as per the provisions provided in IS 1893 2016 part I criteria for earthquake resistant design of structures as per clause 6.3.3 design of vertical earthquake effects should be considered for structure in earthquake Zone IV & V and table 3 shown represents the seismic load combination assigned

Table 3 Seismic Load Combination

COMB01	1.2[DL+1.2IL+/-EQX+/-0.3EQY+/-0.3EQZ]
COMB02	1.2[DL+1.2IL+/-EQY+/-0.3EQX+/-0.3EQZ]
COMB03	1.5DL[+/-EQX+/-0.3EQY+/-0.3EQZ]
COMB04	1.5DL[+/-EQY+/-0.3EQX+/-0.3EQZ]
COMB05	0.9DL+/-1.5[EQX+/-0.3EQY+/-0.3EQZ]
COMB06	0.9DL+/-1.5[EQY+/-0.3EQX+/-0.3EQZ]



IV. MODAL ANALYSIS

Modal analysis was performed to find the natural period and natural frequency of the structural system. Natural time period and natural frequency are some of the important factors which govern the seismic response of the structure. Table 4 shown below represents the natural period and natural frequency of the model with and without passive energy control system.

Table 4 Modal Analysis

MODEL	Natural Period	Frequency
	Secs	Hertz
M-FVD	1.97	0.507
M-LRB	3.7	0.285

V. RESPONSE SPECTRUM ANALYSIS

Analysis was carried out to the structural steel building system by varying the passive energy control devices to the model with base isolators and viscous dampers. Response Spectrum analysis was carried out as per IS 1893 2016 PART I to apply earthquake loads to the structure and considering seismic zone to be Zone III. Response Spectrum method was carried out adopting an initial damping of 5%. The table 5 shown below represents the response spectrum parameters.

Table 5 Design Response Spectrum Parameter

Description	Notation	Assigns
Soil Type	I,II,III	II (medium Stiff)
Zone Factor	Z	0.24
Importance Factor	I	1.2
Response Reduction Factor	R	5
Scale Factor	Ig/2R	1.177

VI. ANALYSIS RESULTS

Static analysis was performed assigning various gravity loads to the structure and finally applying the seismic load as per design response spectrum method IS 1893 2016 Part I. The seismic behaviour of the structural steel building system such as maximum storey displacement, Storey lateral load, Base Shear, Energy absorption plot were studied along X direction and Y direction due to response spectrum considering site type and seismic zone under various seismic load cases were studied i.e EQX & EQY (Earthquake Load along X direction and Y direction). Similarly base shear due RSX & RSY (Response spectrum along X & Y direction).

Load Vs Displacement

Displacement is an important parameter which govern the failure pattern of the structure. Maximum storey displacement was plotted for M-FVD & M-LRB. Table 6 & 7 shown below represents the Load Vs displacement along X axis & Y axis due various seismic load cases EQX & EQY. Fig 3,4,5,6 represents the lateral load vs displacement plot for M-FVD and M-LRB along X direction and Y direction respectively.

Table 6 Load Vs Displacement due to EQX

M-FVD		M-LRB	
EQX		EQX	
LOAD (kN)	DISPLACEMENT (mm)	LOAD (kN)	DISPLACEMENT (mm)
599.3801	47.507	318.3992	73.916
559.7772	44.319	297.3616	69.795
492.7638	40.277	261.7631	65.596



430.0212	37.062	228.4334	61.408
371.5497	32.947	197.3725	57.23
317.3491	29.796	168.5803	53.075
267.4195	25.693	142.057	48.961
221.7609	22.699	117.8025	44.91
180.3732	18.77	95.8168	40.945
143.2565	16.018	76.0999	37.092
110.4107	12.448	58.6517	33.378
81.8359	10.056	43.4724	29.832
57.5321	7.034	30.5619	26.481
37.4993	5.162	19.9201	23.352
21.7374	2.9	11.5472	20.468
10.2464	1.715	5.4431	18.134
3.1651	0.461	1.6813	15.537
0	0	0	13.564

Table 7 Maximum Load Vs displacement due to EQY

M-FVD		M-LRB	
EQY		EQY	
LOAD (kN)	DISPLACEMENT (mm)	LOAD (kN)	DISPLACEMENT (mm)
1127.4	70.811	579.3766	94.229
1052.909	66.171	541.0954	90.314
926.8603	60.932	476.3184	86.307
808.8452	56.163	415.6699	82.259
698.8636	50.709	359.1497	78.166
596.9155	45.938	306.758	74.031
503.0007	40.354	258.4948	69.864
417.1195	35.702	214.3599	65.677
339.2716	30.151	174.3535	61.485
269.4572	25.786	138.4755	57.305
207.6762	20.506	106.7259	53.156
153.9287	16.638	79.1048	49.062
108.2146	11.939	55.6121	45.051
70.534	8.824	36.2478	41.151
40.8867	5.106	21.0119	37.39
19.273	3.041	9.9045	34.234
5.9533	0.766	3.0594	30.103
0	0	0	26.103

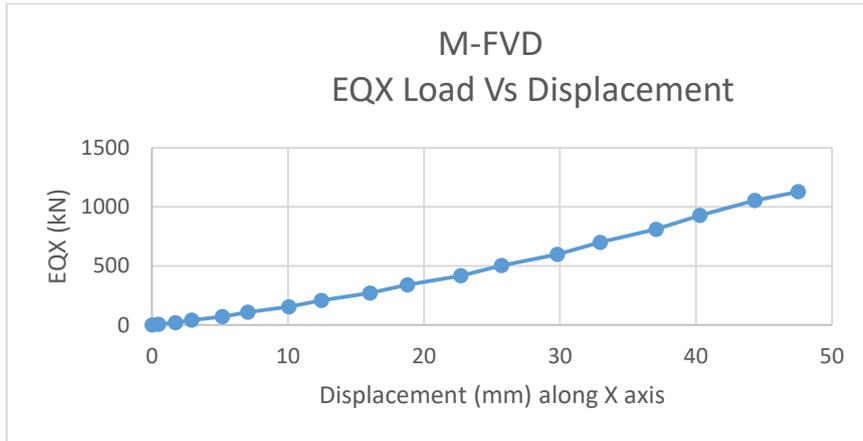


Fig 3 EQX Load Vs Displacement along X direction

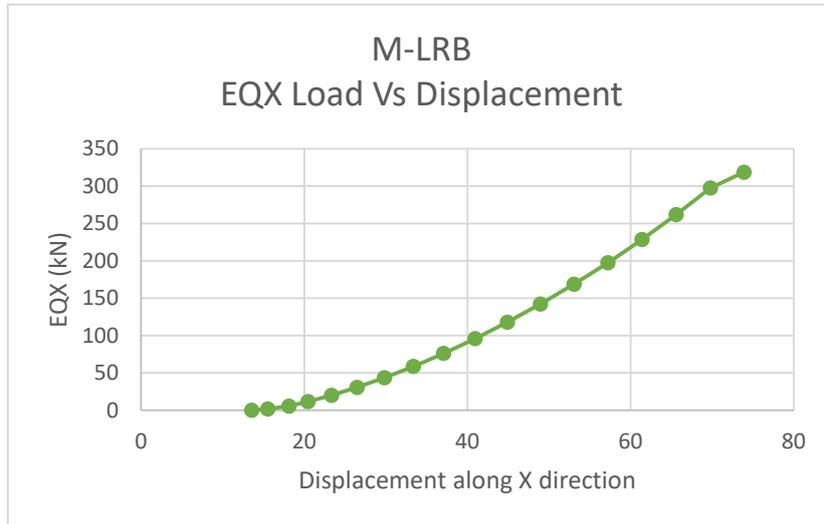


Fig 4 EQX Load Vs Displacement along X direction

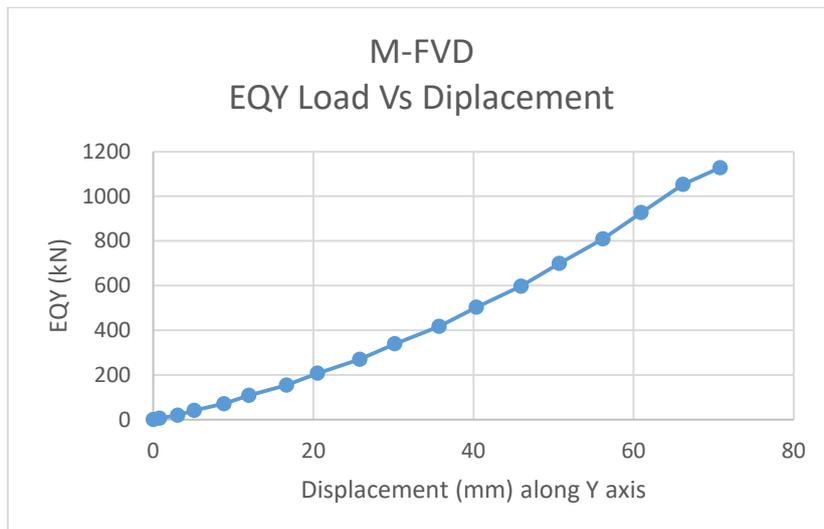


Fig 5 EQY load Vs Displacement along Y direction

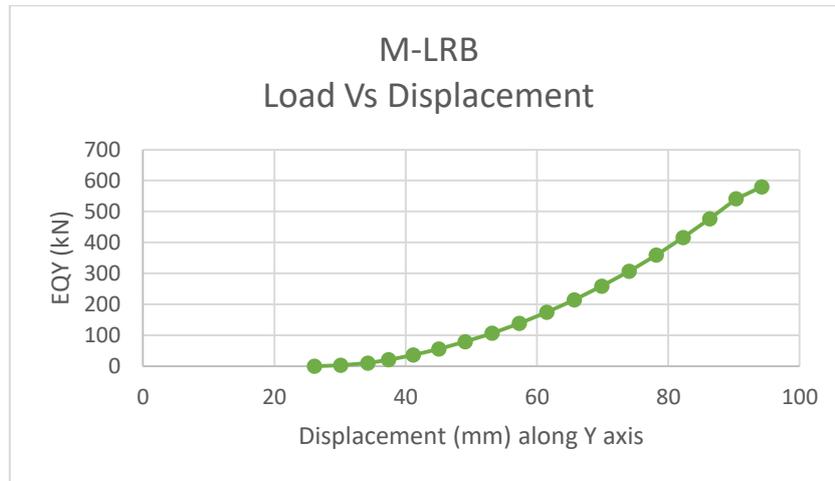


Fig 6 EQY Load Vs Displacement along Y direction

From the analysis results of load vs displacement due to EQX & EQY (Seismic Load along X & Y axis) it was found that M-FVD had lesser displacement but experienced more seismic load and M-LRB had more displacement but experienced lesser seismic load.

Base Shear

Base Shear is the shear value obtained from the sum of design lateral forces at the various storey levels due to various load cases i.e EQX & EQY (Earthquake Load along X direction and Y direction). Similarly base shear due RSX & RSY (Response spectrum along X & Y direction) were tabulated. The tables 4 & 5 shown below represents the base shear experienced by M-FVD, M-LRB due various Seismic load combinations and load cases.

Table 4 Comparative Base Shear Various Seismic Load Combination

COMBINATION	M-FVD		M-LRB	
	FX(+/-)	FY(+/-)	FX(+/-)	FY(+/-)
COMB01	4830.2507	166.0163	2565.8388	1400.6823
COMB02	1449.0752	553.3876	769.7517	4668.9411
COMB03	6037.8134	207.5204	3207.2985	1750.8529
COMB04	1811.344	691.7345	962.1896	5836.1763
COMB05	6037.8134	207.5204	3207.2985	1750.8529
COMB06	1811.344	691.7345	962.1896	5836.1763

Table 5 Base Shear for various Load Cases

LOAD CASE	M-FVD		M-LRB	
	FX (kN)	FY (kN)	FX (kN)	FY (kN)
RSX	4759.21	16.52	2135.29	34.56
RSY	32.76	7517.94	36.96	3885.71
EQX	4025.20	0	2138.19	0
EQY	0	7517.94	0	3890.78

From the comparison it was noted that storey base shear of M-LRB was very less due to base getting isolated from the substructure than that of M-FVD, base shear was experienced by M-FVD structural model was more than that of the M-FB model due to increased stiffness.

Base shear for the structural model with viscous damped control system M-FVD was higher due to the stiffness of the structure and experienced a max base shear of 4759.21 kN along X axis and 7517.94 kN along Y

direction due the response spectra analysis. By comparing M-FVD with M-LRB base shear experienced was much lesser with base shear of 2135.83 kN along X direction and 3885 kN along Y direction due to separation of substructure for super structure.

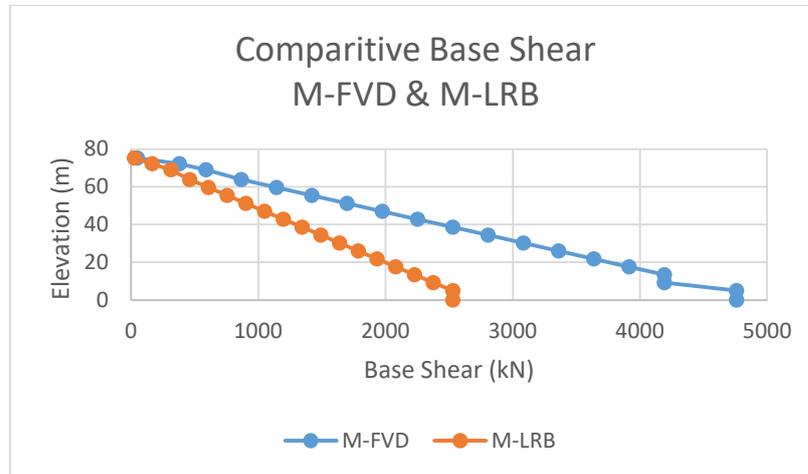


Fig 7 Comparative Base Shear plot along X direction

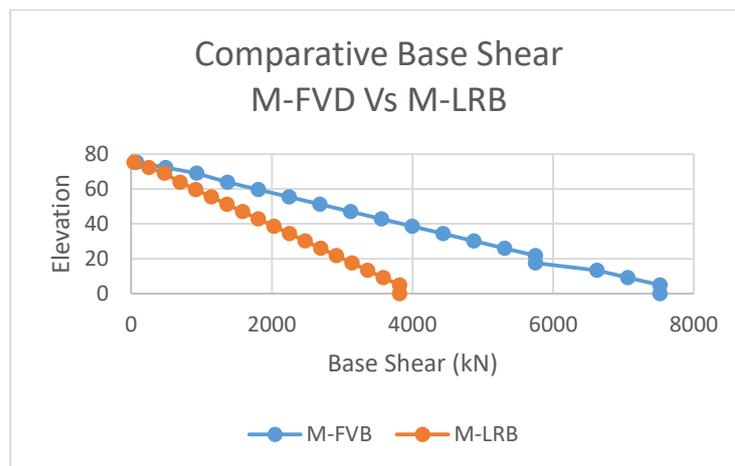


Fig 8 Comparative base Shear plot along Y direction

VII. CONCLUSIONS

Dynamic analysis was performed by plotting Design Response Spectrum curve as per IS 1893 2016 Part I. From the analysis difference in storey displacement, base shear were plotted and conclusion are as follows.

- Modal analysis was performed with initial structural damping of 5% for structural models, for M-FD natural period was 2.37 secs and for M-FVD and M-LRB were 1.97 and 3.7 secs. Therefore lesser the natural period structure lesser will be torsional effects.
- By comparison of lateral load experienced by M-FVD and M-LRB due earthquake loads EQX and EQY it has noted lateral load of M-LRB was less than M-FVD and experienced 46% less lateral load along X direction and 48% less lateral load along Y direction due to base getting isolated to superstructure.
- Similarly, base shear due to EQX and EQY were compared for M-LRB & M-FVD, it was noted that base shear experienced by M-LRB was lesser than M-FVD. Base Shear of M-LRB was 52% less than that of M-FVD along X direction and 55% less along Y direction.
- Maximum displacement of M-FVD along X and Y direction were 47 mm and 70 mm respectively and for M-LRB maximum displacement along X and Y direction were 73 mm and 94 mm respectively. Maximum displacement of M-LRB was higher than M-FVD due to base isolation.



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