Seismic Retrofitting of Multi-Storey RCC Building using Fluid Viscous Damper Bracings: A case study

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Abstract

In the past, a large number of building structures in India have been damaged by earthquakes and some of these structures have been repaired and strengthened. The strengthening of existing structure is required in cases where the buildings are constructed according to the old regulations, and they do not fulfill any more the requirements of the recent regulations. Most of the buildings in India are normally constructed to resist static loads without considering seismic action. However, this leads to deficiencies in the design of the structures. In our case, one newly built 15 storey RCC framed building which have experienced a strong earthquake and during that time the seismic vibration of the building was much high which settled a fear among the tenants about the safety of the structure. After the earthquake the structure was carefully observed but no cracks or any sorts of damages to the frame members were found except the wall on which hair cracks were developed. But for the safety against the future earthquakes and most importantly safety of the structure, the building is to be retrofitted with Fluid Viscous Dampers. Here we will analyze the changes in the storey displacement, storey drift, modal period and frequencies, storey stiffness, critical column and beam forces before and after retrofitting the structure with the dampers using ETABS. This will help to provide extra safety precaution to the beam - column joints of the structures also.

Keywords: Seismic hazard, RCC building, Fluid viscous dampers, Retrofitting, Global Safety precaution, Beam-Column joints safety

1 Introduction

Most of the buildings in India are normally constructed to resist static loads without considering exact seismic actions. However, this leads to deficiencies in the design of the structures. Typical deficiencies for the studied structure are the following:

- The boundary conditions of the supports. It is important to have proper supports, especially when considering seismic actions since a ductile behaviour of the structure is required.
- If the seismic zone changes for the particular area, the safety measure for the structure should be immediately be taken into consideration.
- If also building is seismically designed, the data input and the factors considered for seismic designing are not taken into major consideration such as Response Reduction Factor.
- Irregularities in mass and stiffness. The choice of material and element types is important since they affect the weight and strength of the structure.
- Another type of irregularity is the geometry of the structure, the more complex the structure is the more irregularities it tends to get.

- Moreover, the combination of different types of elements and their distribution in the structure affect the overall stiffness and behaviour of the structure.

In our case, newly built 15 storey RCC framed building which have experienced a strong earthquake and due to which the building was undulating at a greater velocity which settled a fear among the tenants about the safety of the structure. After the earthquake the structure was carefully observed but no cracks or any sorts of damages to the frame members were found except to the wall on which hair cracks were developed. But for the safety against the future earthquakes and most importantly safety of the structure, the building is to be retrofitted with Fluid Viscous Dampers. Here we will analyze the changes in the properties before and after retrofitting the structure with the damper. Though various past researchers worked on it but the retrofitting work using increased damping approach is still not tried yet which will retrofit the structure globally with beam – column joints safety also.

2 Seismic Retrofitting Techniques

Addition of concrete shear walls, use of Steel Braced Frames, use of Moment Resisting Steel Frames, using Concrete Diaphragm walls, Jacketing columns, Beam Jacketing, Jacketing of Beam-Column joints, FRP composites, Dampers such as FVD, Electro-rheological and Magneto-rheological Dampers, Base Isolation, Mass Reduction, Strengthening of footings are the various methods of seismic retrofitting techniques. Viscous damper functions on the principle of passive energy dissipation by adding damping of seismic forces in the structure. Previous study on response of structure to earthquakes provided with viscous damper shows that it can reduce storey drift, forces in members which lead to less damage to structure enabling it to resist large lateral forces. It is very important to safeguard the structures such as airports, fire department barracks, nuclear power plants, communication centers, hospitals, bus stops, institutions etc. from the earthquakes to reach higher level of safety. By the virtue of damping action of viscous dampers, it reduces forces in the members, enabling provision of smaller cross sections of structural members. This makes the structure safer against seismic action.

3 Our case study: Modelling of the structure

ETABS is a computer software package for analysis and design of civil structures. It offers an intuitive yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects, so in the present study three dimensional analyses with the help of ETABS 18 is used for modelling and analysis of the structure. The work started with modelling and analysis of RCC building for two cases:

1. Analysis of the original building.

2. Analysis of that building with effectively using Fluid Viscous Dampers.

An existing 15 storey RCC building is modeled using ETABSs having the total building height of 46.1m including the base and top floor. Concrete grade of M35 and Fe500 grade steel were taken. Frame properties such as beams (450mm x 250mm) and columns (400mm x 500mm) are of these dimensions and slab thickness of 125mm. The existing building was designed according to seismic zone II following the IS 1893 (2016): Part-1. Loads such as Dead, Live, Seismic, Wind and default load combinations were applied. Then the fluid viscous dampers of brand were fitted at the four corner sides of the building and also at the staircase side areas and analyzed.

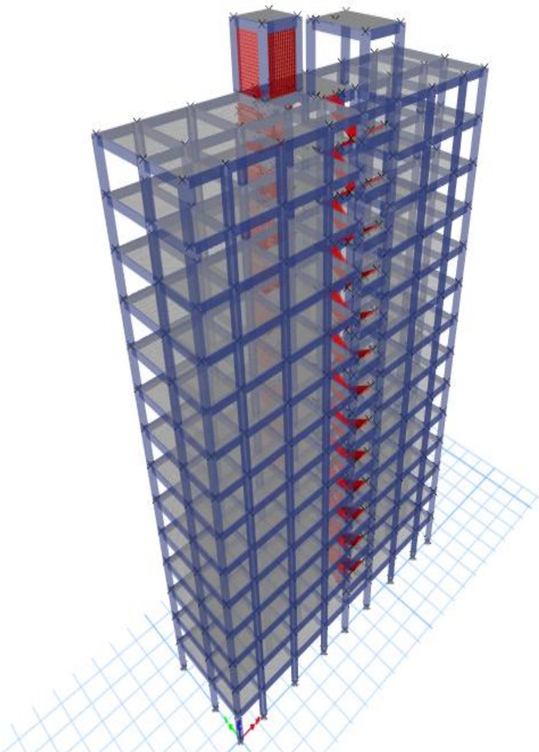

Figure 1. Without Dampers 3d View

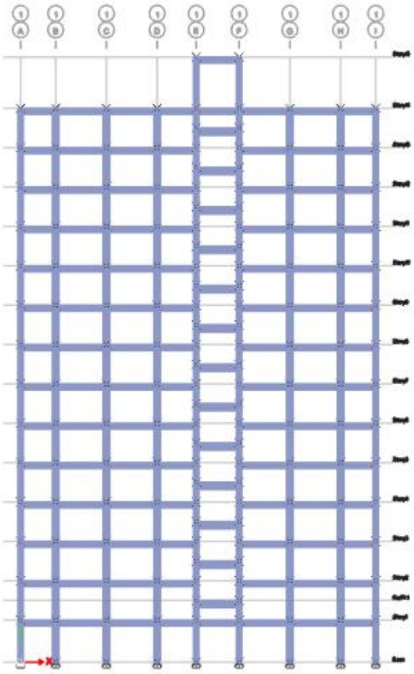

Figure 2. Front Elevation View

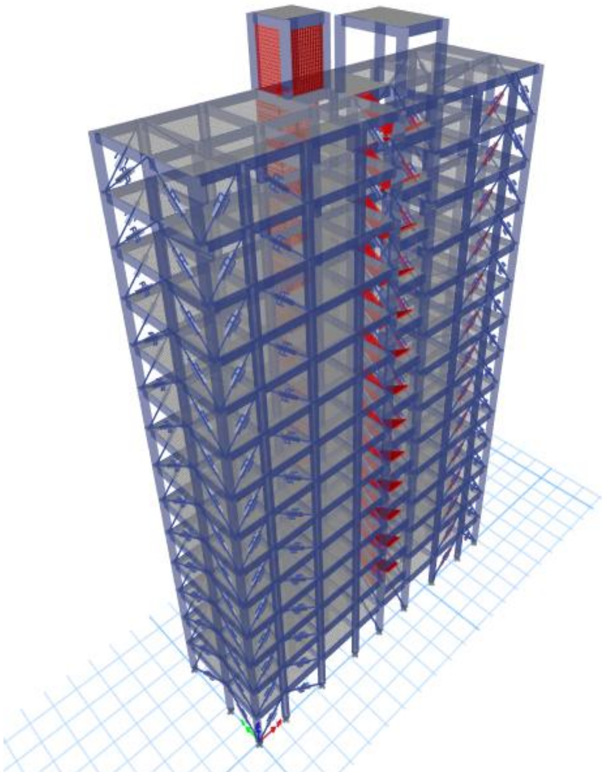

Figure 3. With Dampers 3d View

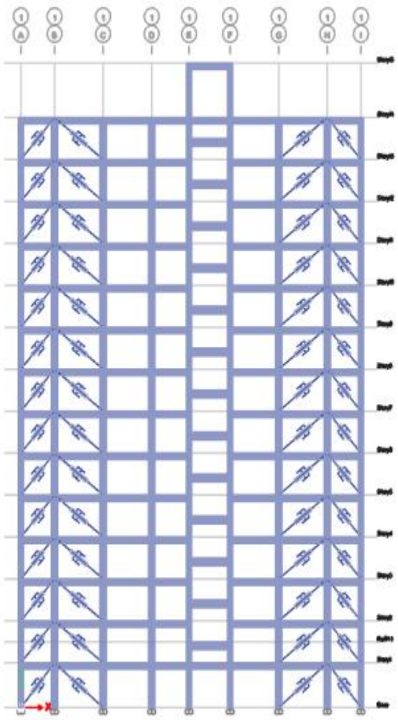

Figure 4. Front Elevation View

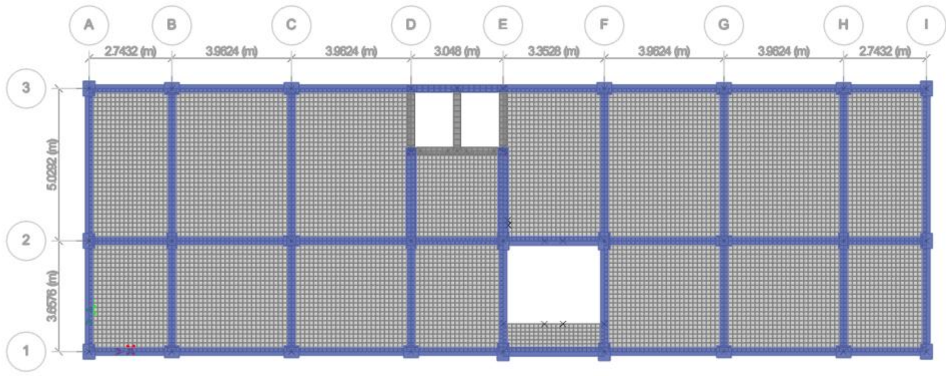

Figure 5. Without Dampers Plan View

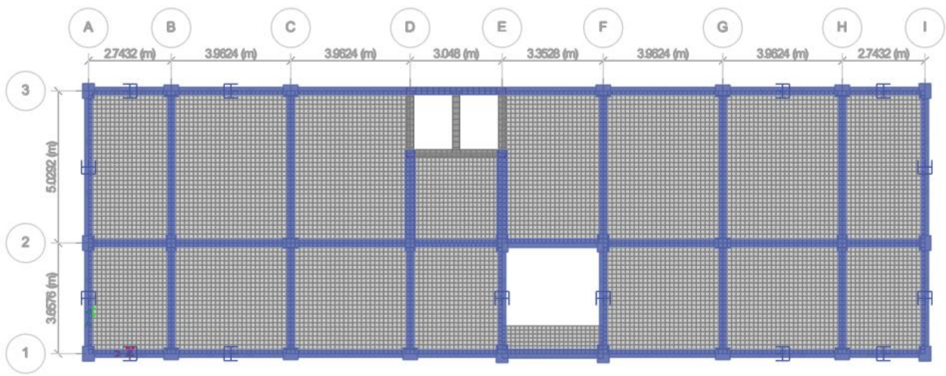

Figure 6. With Dampers Plan View

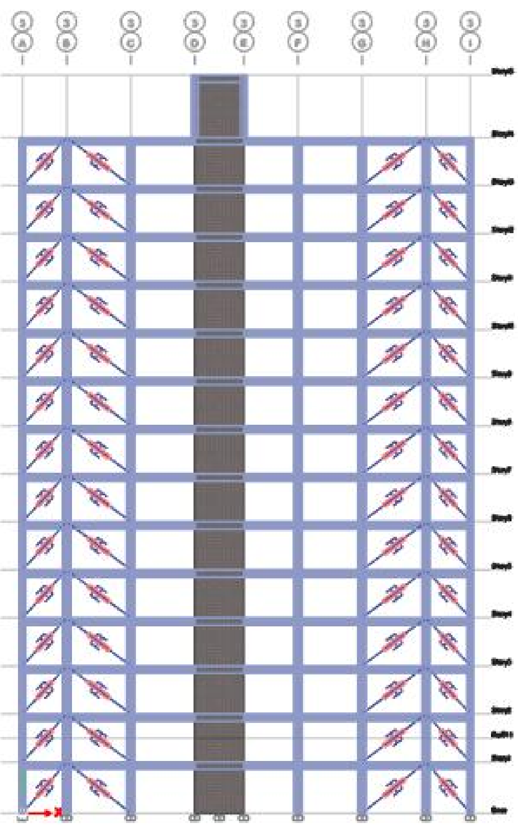

Figure 7. With Dampers Rear Elevation View

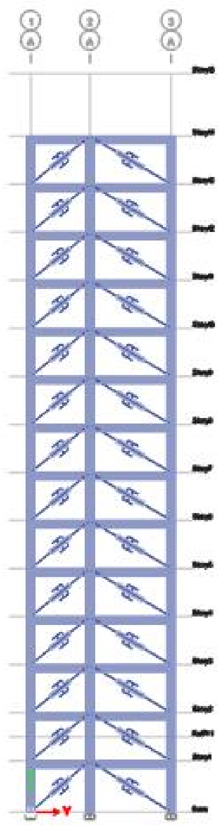

Figure 8. With Dampers Side View

4 Results

All the results have been obtained after successfully completing the seismic analysis of the model, once before applying the seismic retrofitting and another after applying the seismic retrofitting. The aim of the project, as mentioned before, is to analyze only the global behaviour without taking into consideration the local behaviour of the model. Therefore, there will not be any analysis regarding the connections between the structural elements, material properties and steel design of the elements. Our goal is to strengthen the building under seismic vibration; hence, the main focus will be on the frequencies and the displacements of the structure before and after modifying the structure with a retrofitting method. Improving the freque-ncies and minimizing the displacements will give rise to a more stable structure.

Table 1: Maximum Storey Displacements at 15th storey

Maximum Storey Displacement (mm)				
Load Case	Original		With Damper	
	Global x	Global y	Global x	Global y
Seismic X	162.66	46.51	70.28	3.02
Seismic Y	11.75	183.63	1.79	73.19

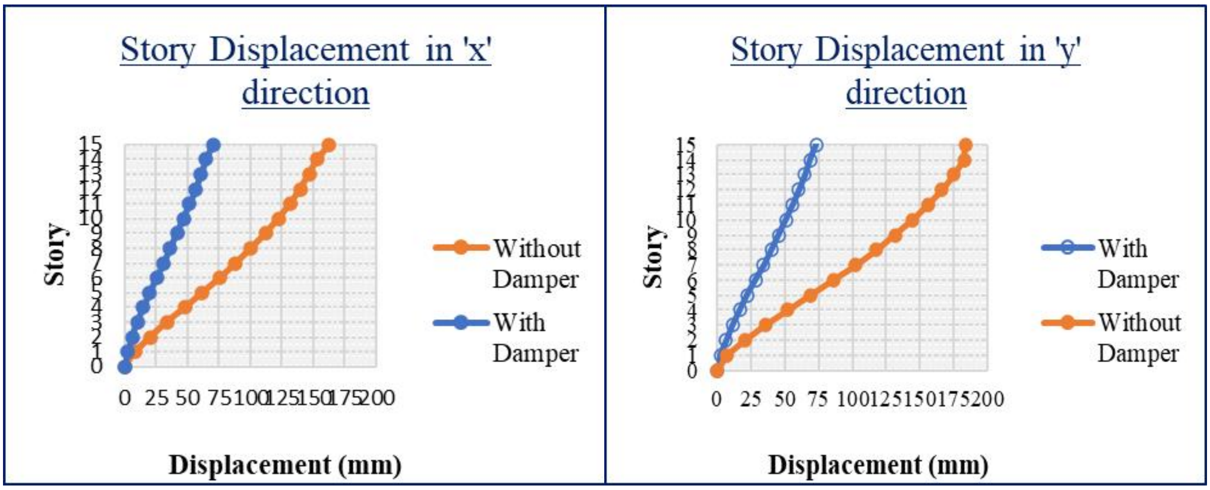

Figure 9. Storey Displacements of Original and Retrofitted Building

Table 2: Modal Periods and Frequencies

Modal Periods and Frequencies					
Case	Mode	Period sec	Period sec	Frequency cyc/sec	Frequency cyc/sec
		Normal	With Damper	Normal	With Damper
Modal	1	1.95	1.065	0.513	0.939
Modal	2	1.742	1.02	0.574	0.98
Modal	3	1.487	0.662	0.672	1.51
Modal	4	0.63	0.3	1.586	3.335
Modal	5	0.486	0.282	2.058	3.548
Modal	6	0.399	0.208	2.507	4.803

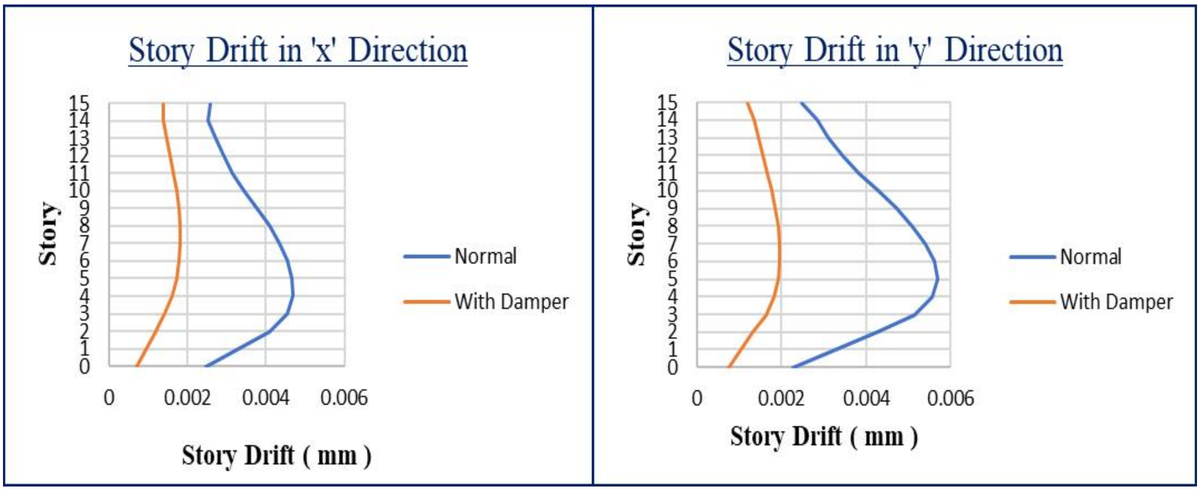

Figure 10. Storey Drift of Original and Retrofitted Building

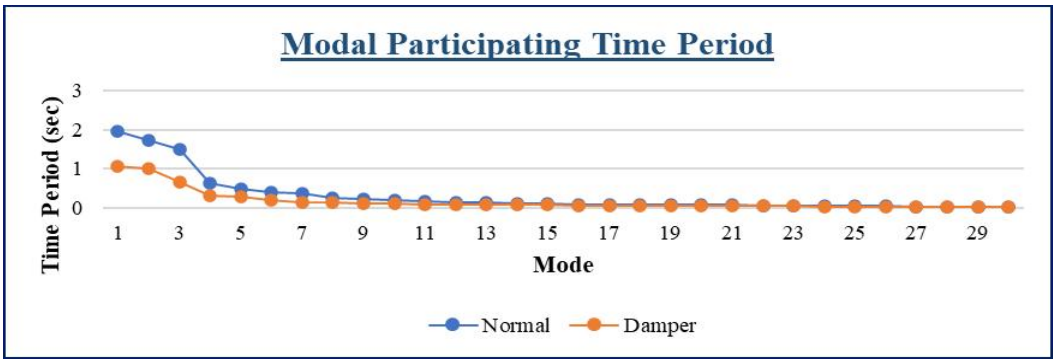

Figure 11. Modal *Periods*

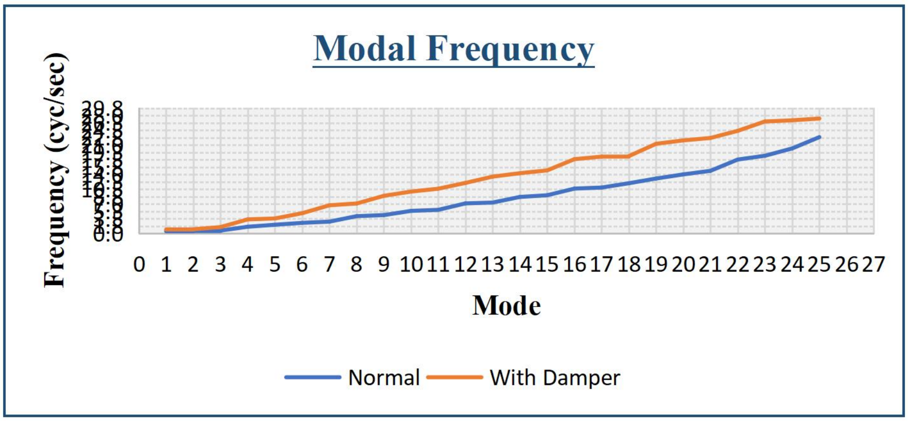

Figure 12. Modal Frequencies

Table 3 to 6. Critical Column and Beam Forces

Loading Case : Seismic load along X- direction (Seismic X)											
Storey Number	Column Number	Critical Column Forces									
		Axial Force (kN)		Shear Force V2 (kN)		Shear Force V3 (kN)		Moment M2 (kN-m)		Moment M3 (kN-m)	
		Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper
1	C1	857.1	2239.5	58.33	14.46	60.1	6.95	156.9	14.41	145.87	40.19
	C3	900.01	2343.53	25.56	11.37	56.26	5.09	152.89	12.47	69.51	33.81
	C11	1106.66	353.23	85.17	28.07	5.43	2.62	21.4	5.19	169.77	58.18
	C12	2430.42	739.46	61.23	21.12	39.02	3.35	99.69	7.69	144.64	51.02
14	C1	25.56	1.14	10.74	1.69	16.43	0.4	23.53	1.05	16.49	3.16
	C3	14.16	0.65	21.44	0.43	15.68	2.09	22.13	3.01	29.05	1.49
	C11	212.26	111.07	25.15	24.35	60.98	40.37	82.25	55.14	33.9	35.19
	C12	49.97	22.77	52.9	45.71	5.18	1.86	8.93	4.85	67.33	59.1

Loading Case : Seismic load along Y- direction (Seismic Y)											
Storey Number	Column Number	Critical Column Forces									
		Axial Force (kN)		Shear Force V2 (kN)		Shear Force V3 (kN)		Moment M2 (kN-m)		Moment M3 (kN-m)	
		Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper	Normal	Damper
1	C1	829.53	2518.87	10.36	1.3	12.73	14.42	65.98	51.51	24.09	2.83
	C3	479.04	2461.15	0.73	1.72	11.23	13.75	64.41	50.83	1.57	3.03
	C11	361.26	1229.48	6.38	2.15	95.21	44.33	248.81	111.9	15.47	3.84
	C12	1041.43	1641.52	10.01	1.83	74.4	31.51	242.01	99.6	19.28	2.58
14	C1	27.76	3.42	1.21	3.4	25.89	0.14	38.83	2.31	1.93	4.36
	C3	22.05	5.27	1.71	4.34	30.92	0.82	46.88	3.38	2.27	5.56
	C11	276.19	273.19	28.63	15.99	124.87	77.98	178.33	110.29	40.94	21.84
	C12	108.35	145.2	12.88	1.28	38.66	17.61	61.59	26.73	15.91	1.96

Loading Case : Seismic load along X- direction (Seismic X)					
Storey Number	Beam Number	Critical Beam Forces			
		Shear Force (kN)		Moment (kN-m)	
		Normal	Damper	Normal	Damper
1	B31	166.58	54.27	147.2	49.47
	B26	100.53	18.82	101.47	19.22
	B19	100.09	18.53	101.38	18.95
	B34	93	27.42	67.46	22.28
14	B47	90.68	49.44	85.97	46.14
	B32	71.71	40.74	56.29	39.87
	B29	67.54	36.41	50.27	33.39
	B33	64.02	23.92	40	14.31

Loading Case : Seismic load along Y- direction (Seismic Y)					
Storey Number	Beam Number	Critical Beam Forces			
		Shear Force (kN)		Moment (kN-m)	
		Normal	Damper	Normal	Damper
1	B46	107.17	65.8	14.17	75.65
	B47	106.37	63.37	94.34	61.13
	B15	90.25	25.96	82.32	22.36
	B13	78.72	23.89	72.27	22.1
14	B47	279.88	185.31	105.99	68.51
	B47	129.63	71.98	82.6	81.98
	B12	63.26	34.36	51.04	27.87
	B7	60.71	27.2	36.36	12.23

5 Conclusions

A general overview of the results showed that a better structural seismic performance of the model after the seismic retrofitting was accomplished and proves that the chosen structural methodology of this modification is a sufficient optimized design for this existing building.

More detailed, applying FVD as bracing, improved the structure's characteristics such as --

- Storey Displacement got reduced by almost 60%
- Storey Drift also got reduced
- The Frequency of the structure also got improved
- The Stiffness also got improved
- Column Shear Force and Moment got reduced (design will be governed by the axial force mainly)
- Beam Shear Force and Moment got reduced

The stiffness was mainly enhanced by the added FVD at two sides of staircase along transverse direction, which increased the frequency remarkably. Moreover, the structure became more ductile primarily because of the FVD applied; hence, an improved capability to undergo plastic deformation before fracture is achieved. After performing the seismic retrofitting, the strength of the structure was developed. Since our research is regarding an existing structure, all the existing conditions and properties must be maintained as much as possible the same, such as support types, connections between the structural elements, sizes of each structural element, soil type and so forth. The reason is to adjust to the current situation and achieve more realistic results. In conclusion, we maintained as much as possible all the properties and conditions of the structure; therefore, the obtained results are reasonable and realistic. However, another conclusion is that we should not have enormous expectations on the level of strengthening improvements of the structure against seismic hazards since, the present conditions limit the analysis. This research study provides gaining more knowledge concerning the global strengthening of existing structures under seismic vibrations.

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