Seismic Response Study and Evaluation of Vibration Control of Elevated RCC Structure using Friction Damper

S. Lakshmi Shireen Banu, Kothakonda Ramesh

Abstract: ***Earthquakes are the largest natural hazard in damaging the structures. The structural response control is necessary to create the safer structures against earthquakes. Vibration control systems are used to transfer the lateral loads imposed on a structure to the foundation. To reduce the dynamic response of the structures due to earthquake loading friction dampers are used. The present work deals with a 10 storey RCC building with square and rectangular columns with the square and rectangular shape of the structure was analyzed with and without friction damper in ETABS 2016. Four different cases of buildings with and without friction damper have been analyzed in ETABS 2016. The study performs response spectrum analysis and nonlinear time history analysis on these buildings. The time history data of Bhuj earthquake is used in the analysis. In the present study the effectiveness of friction damper in reducing the responses of a structure is evaluated. The responses of the structure in terms of pseudo spectral acceleration, pseudo spectral velocity and spectral displacement have been compared with and without friction damper.***

Key words: response control, vibration control system, friction damper, response spectrum analysis, nonlinear time history analysis.

I. INTRODUCTION

Increase in population in urban areas leads to increase in high rise buildings. In the present years earthquakes are the main natural hazards in damaging the structures. Earthquake cause ground vibration due to the sudden release of energy. This energy can be absorbed by using the vibration control device called friction damper. The reduction of structural response caused by dynamic effects became the subject of this study. Friction damper increases the stiffness of the building as a result vibration of the building is reduced. The structural response to the seismic excitation has reduced by applying friction dampers based on different construction techniques.

The large effects of the recent earthquakes such as 1991 Uttarkashi earthquake, 1993 Killari (Latur) earthquake, 2001 Bhuj earthquake, 2004 Great Sumatra earthquake, 2005 Kashmir earthquake and with regard to the close location of many of the cities of India to the active faults indicate the significance of the research. Over the recent years, the research studies concentrated on the study of impacts of ground motion in the near-field earthquake on the structural performance. The retrofitting of an existing building is a dominant task in decreasing seismic risk. The aim of improving the capacity of building leads to invention of new techniques for earthquake resistant structures.

Revised Manuscript Received on May 06, 2019

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Friction dampers come under passive seismic control system does not require any external energy source to operate and is activated by the earthquake input motion only. The friction surfaces of these systems are clamped with pre-stressing bolts. The behavior of these systems is perfect rectangular hysteretic. Since the amount of energy dissipated is proportional to displacement these systems are referred as displacement-dependent systems. Contact surfaces of these systems used are lead–bronze against stainless steel or Teflon against stainless steel.

II. MODELLING OF BUILDINGS FOR ANALYSIS

ETABS 2016 has been used for this study. The building was created with 10 storey RCC frame as per IS 1893:2002 for seismic zone II with soil type II. Four models namely square building with square column (SBSC), square building with rectangular column (SBRC), rectangular building with square column (RBSC) and rectangular building with rectangular column (RBRC) are modelled with square and rectangular columns of dimensions 700mmx700mm and 1400mmx350mm with story height of 3m.The base is restrained with fixed support.

For the modeling of building in ETABS, shell loads on slabs of D.L=1.5KN/m2 and L.L=4KN/m2 were assigned to the slabs and frame loads of D.L=5.25KN/m2 was assigned to all the frames. Seismic loads are considered according to code IS: 1893-2002 and wind loads according to IS: 875-1987. For seismic zone II, the seismic zone factor 0.10 with importance factor 1 and response reduction factor 5 is considered. The mass source includes total self-weight and 25% live load.

All the buildings are modelled with and without Friction damper. The dampers used in modelling these buildings are from Quake Tek friction dampers in Canada. They provide the data that can be used in ETABS 2016 for modelling of structure.

These dampers are installed at the extreme corners of all the sides of all the four types of models. It is modelled as a link element with link type damper exponential.

Damper properties used in the modelling are taken from data available at the Quake Tek friction dampers in Canada. In this modelling 80KN mass with 0.784kg weight damper is used with non- linearity along the direction U1.Directional properties of Effective stiffness=18947368.42KN/m, Effective damping=0, Yield strength=slip load=250KN, Post yield stiffness ratio=0.0001, Yielding exponent=10.

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Response function has been defined using IS1893: 2002 for a damping of 5% and Time history function has been defined using BHUJ earthquake data from the program file.

For all the types of models response spectrum analysis and time history analysis was done in ETABS2016.

Modelling of building without damper in ETABS 2016

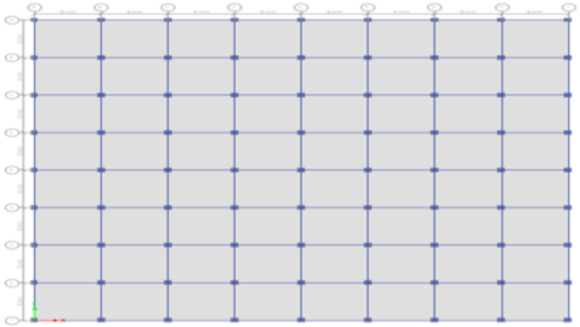

Fig1. Plan view of a square building with square column

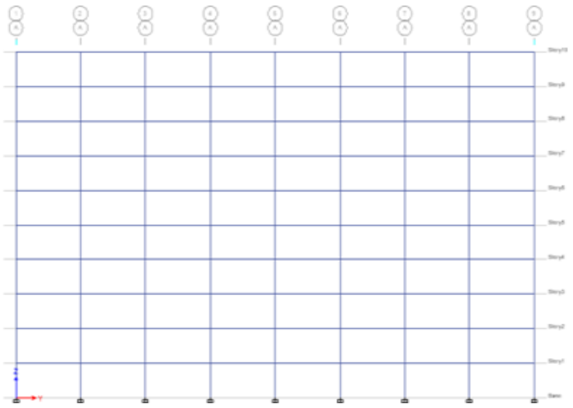

Fig2. Sectional view of a square building with square column

Modelling of building with damper in ETABS 2016

The dampers used in modelling these buildings are from Quake Tek friction dampers in Canada. They provide the data that can be used in ETABS 2016 for modelling of structure.

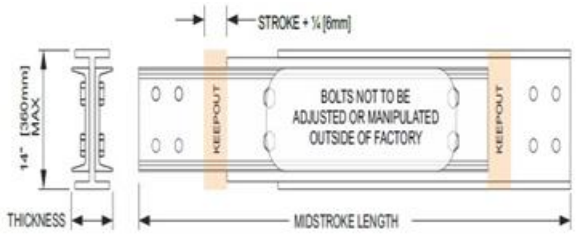

Fig3. Friction damper

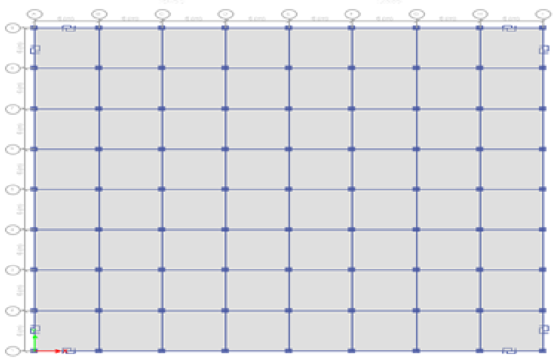

Fig4. Plan view of square building with square column using dampers

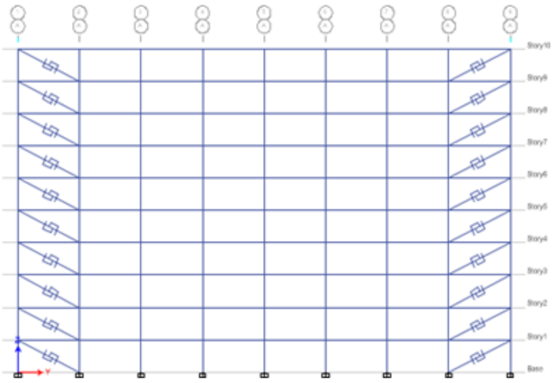

Fig5.Sectional view of square building with square column using dampers

III. RESULTS

Time history responses

Maximum pseudo spectral acceleration and spectral acceleration with and without Friction damper.

Table1.Maximum pseudo spectral acceleration and spectral acceleration at zero damping with and without Friction Damper.

Shape of building	Time history case	Max. pseudo spectral acceleration and spectral acceleration at zero damping			
		Without damper		With damper	
		Time period (sec)	PSA(mm/sec) SA(mm/sec2)	Time period (sec)	PSA(mm/sec) SA(mm/sec2)
SBSC	THAX/X	0.346	690.95	1.111	1319.59
	THAX/Y	0.330	427.66	0.277	295.57
	THAY/X	0.330	427.66	0.277	295.57
	THAY/Y	0.346	690.95	1.111	1319.59
SBRC	THAX/X	0.276	1333.06	1.111	1305.40
	THAX/Y	0.276	495.16	0.277	162.13
	THAY/X	0.585	372.62	0.277	175.33
	THAY/Y	0.276	661.88	1.111	1152.19
RBSC	THAX/X	0.293	859.75	1	1602.16
	THAX/Y	0.555	662.42	0.25	151.27
	THAY/X	0.555	430.27	0.25	136.73
	THAY/Y	0.261	298.27	1	1286.06
RBRC	THAX/X	0.432	925.68	0.303	1538.64
	THAX/Y	0.452	259.66	0.666	182.35
	THAY/X	0.454	695.64	0.277	144.18
	THAY/Y	0.454	1853.98	1.081	994.50

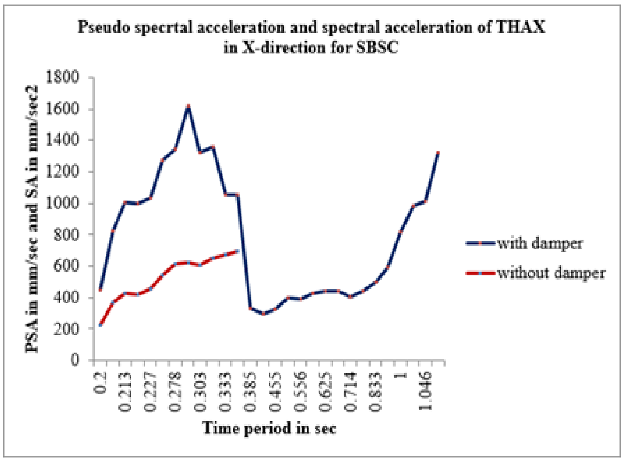

Fig6. Pseudo spectral acceleration and Spectral acceleration of THAX in X-direction

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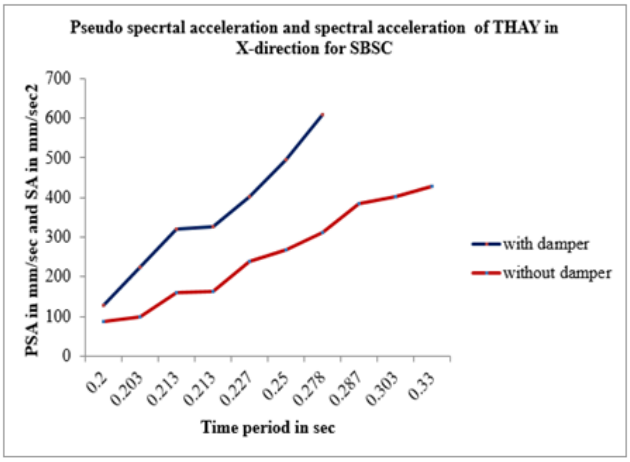

Fig7. Pseudo spectral acceleration and Spectral acceleration THAY in X-direction

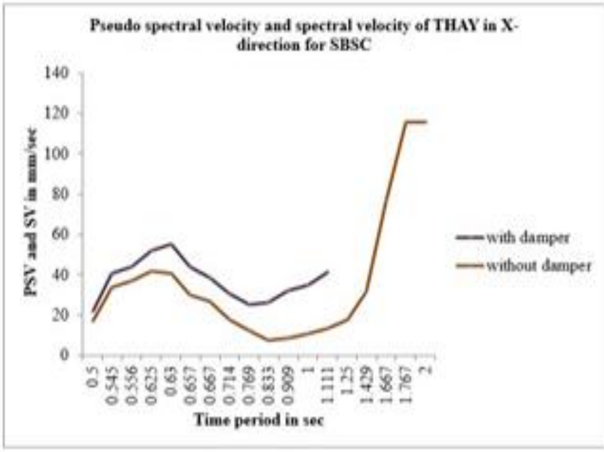

Fig9. Pseudo spectral velocity and spectral Velocity of THAY in X-direction

Maximum pseudo spectral velocity and spectral velocity with and without Friction damper

Table2.Max. pseudo spectral velocity and spectral velocity at zero damping with and without Friction damper

Shape of building	Time history case	Max. pseudo spectral velocity and spectral velocity at zero damping			
		Without damper		With damper	
		Time period (sec)	PSV(mm/sec) SV(mm/sec2)	Time period (sec)	PSV(mm/sec) SV(mm/sec2)
SBSC	THAX/X	2.048	138.15	1.111	233.55
	THAX/Y	2	115.86	1.111	27.55
	THAY/X	2	115.86	1.111	27.55
	THAY/Y	2.048	138.15	1.111	233.55
SBRC	THAX/X	2	240.99	1.111	230.84
	THAX/Y	1.941	85.71	1.111	17.65
	THAY/X	2	83.93	1.111	20.87
	THAY/Y	2	148.24	1.111	203.75
RBSC	THAX/X	1.859	159.33	1	254.99
	THAX/Y	1.666	129.34	1	23.02
	THAY/X	1.666	84.38	1	17.49
	THAY/Y	1.666	128.21	1	204.68
RBRC	THAX/X	2.341	228.31	1.111	270.97
	THAX/Y	1.666	39.53	0.666	19.34
	THAY/X	1.666	85.94	1.081	18.03
	THAY/Y	1.610	188.07	1.111	175.11

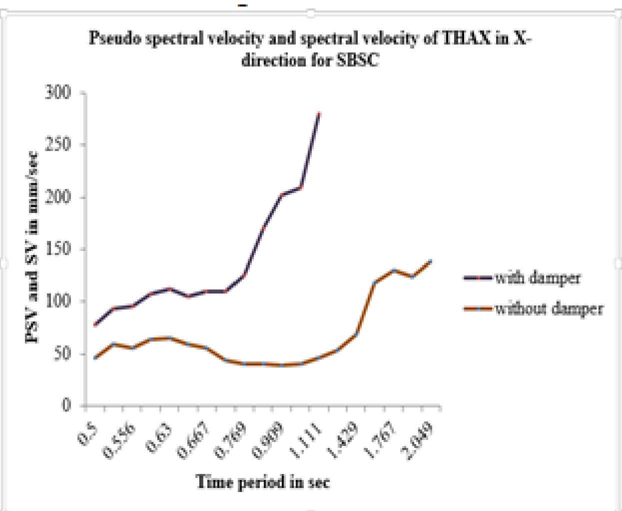

Fig8. Pseudo spectral velocity and spectral Velocity of THAX in X-direction

Maximum spectral displacement with and without Friction damper

Table3. Spectral displacement at zero damping with and without Friction damper

Shape of building	Time history case	Max. Spectral displacement at zero damping			
		Without damper		With damper	
		Time period (sec)	SD (mm)	Time period (sec)	SD (mm)
SBSC	THAX/X	2.048	45.05	1.111	41.26
	THAX/Y	2	36.88	1.111	4.87
	THAY/X	2	36.88	1.111	4.87
	THAY/Y	2.048	45.05	1.111	41.26
SBSC	THAX/X	2.009	76.77	1.111	40.82
	THAX/Y	1.941	26.47	1.111	3.122
	THAY/X	2.009	26.80	1.111	3.69
	THAY/Y	2	47.18	1.111	36.03
RBSC	THAX/X	1.859	47.14	1	40.58
	THAX/Y	1.666	34.31	1	3.66
	THAY/X	1.859	22.65	1	2.78
	THAY/Y	1.666	34.01	1	32.57
RBRC	THAX/X	2.341	85.07	1.111	47.91
	THAX/Y	2.341	12.33	1.081	3.06
	THAY/X	1.666	22.79	1.111	3.12
	THAY/Y	1.610	48.21	1.111	30.96

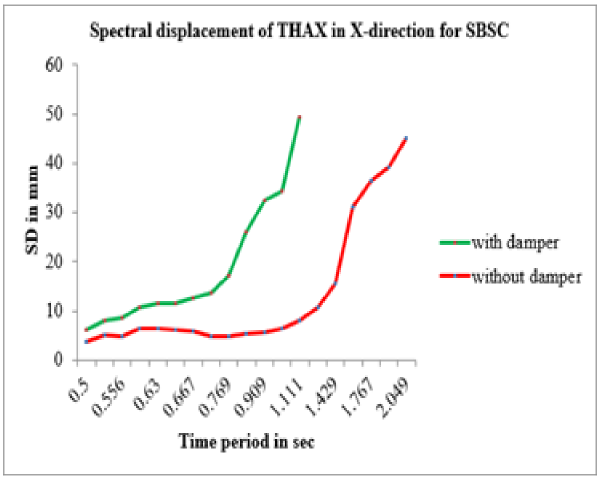

Fig10. Spectral displacement of THAX and in X-direction

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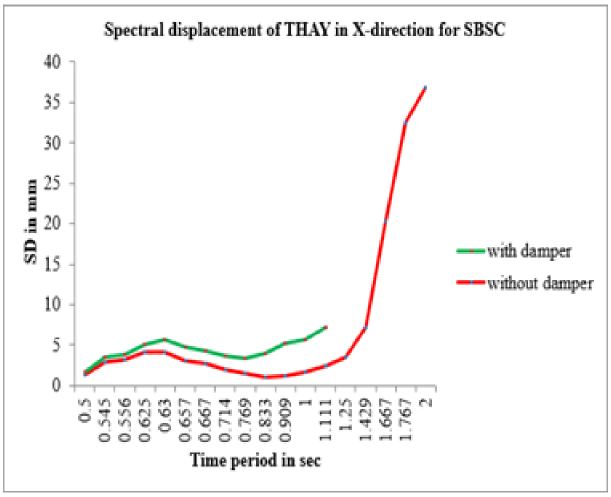

Fig11. Spectral displacement of THAY in X-direction

Base shear

Maximum base shear due to time history THAX and THAY for different shapes of the building with and without Friction damper are compared in the below table.

Table4.Comparison of maximum base shears with and without Friction damper

Shape of the building	Time history case	Without damper	With damper
SBSC	THAX Max	1632.33	1520.75
	THAY Max	217.00	51.22
SBRC	THAX Max	1652.50	1588.72
	THAY Max	145.18	49.91
RBSC	THAX Max	1252.27	1053.17
	THAY Max	118.49	29.33
RBRC	THAX Max	1471.68	959.75
	THAY Max	67.98	12.26

Maximum storey displacements

Maximum storey displacements are compared for SBSC with and without Friction damper

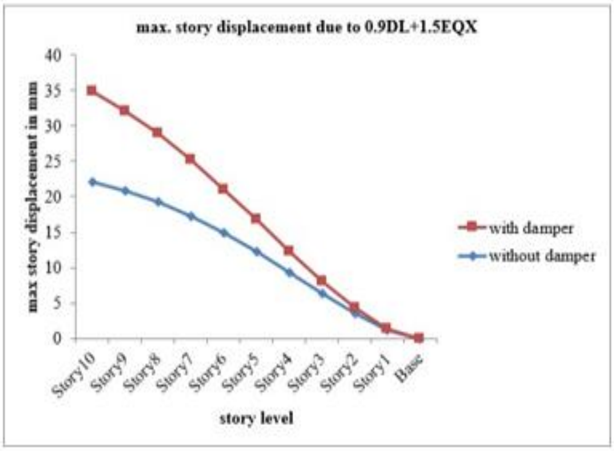

Fig12. Maximum storey displacement due to load combination0.9DL+1.5EQX in X-direction for SBSC

3.4.Maximum storey drifts

Maximum storey drifts are compared for SBSC with and without Friction damper

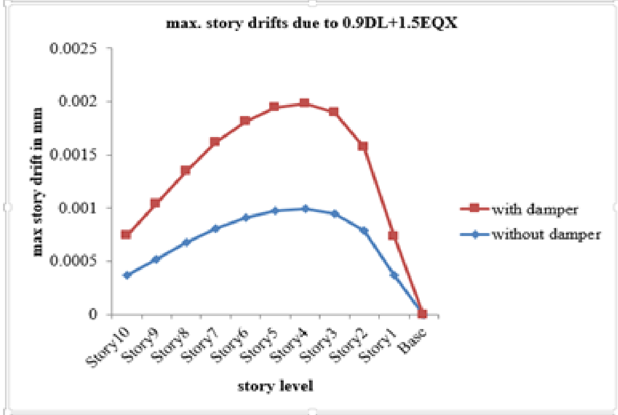

Fig13.Maximum storey drifts due to load Combination 0.9DL+1.5EQX in X-direction For SBSC

3.5. Storey shears

Storey shears are compared for SBSC with and without Friction damper

Fig14. Storey shears at top and bottom due to load combination0.9DL+1.5EQX in X-direction for SBSC

IV. CONCLUSIONS

The storey responses from the time history analysis in terms of PSA, PSV and SD have been reduced with the use of friction dampers. The response spectrum curves of PSA, PSV and SD shows the reduction over time period with the use of dampers compared to the buildings without dampers. 90% mass participation is achieved in 7th and 8th modes of all types of buildings. The base shear for building with dampers is higher than that for building without damper due to over the time scale of the event different storey's of the building with damper experience higher force over the run of the event as compared to the building without damper. The base shear in case of building with damper can be attributed to the increased mass by addition of damper brace system at each storey level. The responses can be further reduced by the selection of damper, position of damper and shape and type of construction of the building involved.

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