International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

Structural Control of Multistorey Building Frame Using Piezoelectric Devices

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Abstract—*A Simulink model of MDOF (5 storey building) is developed in MATLAB and El Centro Earthquake is applied to the structure. Displacement and velocity responses are generated. This response (displacement/velocity) is applied to piezoelectric sensors which generate voltage and this voltage is applied to piezoelectric actuators which generate controlled displacement/velocity. Finally, velocity or displacement is controlled in the structure.*

Piezoelectric sensors and actuators are placed at different storeys like first storey, second storey or third storey etc. and controlled and uncontrolled responses are obtained at different storeys as well as other storeys at which no piezoelectric sensors and actuators are placed (e.g. if piezoelectric sensors and actuators are placed at first storey then corresponding responses are calculated at first storey as well as second, third storey etc.). The % reduction in response varies from 33-67 for displacement and 22-62 for velocity due to control.

Keywords— ***Piezoelectricity, active vibration control, MATLAB, Simulink, El Centro Earthquake***

I. INTRODUCTION

Piezoelectric material has the property of piezoelectricity. Piezoelectricity is a property of material by which a material produces current or voltage under mechanical loading or deformation, and conversely, if the current or voltage is applied to the material, it is stressed or deformed [1]. Nowadays, structural control using piezoelectric is emerging and multidisciplinary research area. The piezoelectric is used as sensors for getting the deformation of the structure under loading. The deformation is converted into current/voltage by piezoelectric. Then the voltage/current is sent to another piezoelectric to convert it into force. The generated force acts to the structure out of phase to the original force/vibration reducing the response. This is active vibration control of structures[2].

In this paper, a 5 storey building frame is analysed by applying piezoelectric sensor and actuator at different storey as well as storey without piezoelectric sensor and actuator. If piezoelectric sensor and actuator are placed at first storey then controlled and uncontrolled displacement/velocity of that storey as well as other (second or third or fifth etc.) storey.

II. METHODOLOGIES

Piezoelectric sensor and actuator works on the principal of –

i) piezoelectric sensor generates voltage/current under mechanical loads or deformation (displacement/velocity)

ii) piezoelectric actuator generates mechanical force or deformation (displacement/velocity) under electric voltage/current

A Simulink model consisting of structural frame with piezoelectric sensor and actuator has been developed in MATLAB (Fig 1) . The data used for the model are as follows:

Details of Piezo stack:
Stack area: 100 mm^2
Stack length: 36 mm
No-load displacement at V0 volts: .038 mm
Blocking force at V0 volts: 3.8 x 10^3
Test voltage V0: 120 V
Capacitance: 13 uF
Details of input for MDOF (5 storey):
Mass:
$m_1 = m_2 = m_3 = m_4 = 150 \times 10^3$ kg
$m_5 = 75 \times 10^3$ kg
Stiffness:
$k_1 = k_2 = k_3 = k_4 = k_5 = 200 \times 10^6$ N/m
$Z_i = 5\%$

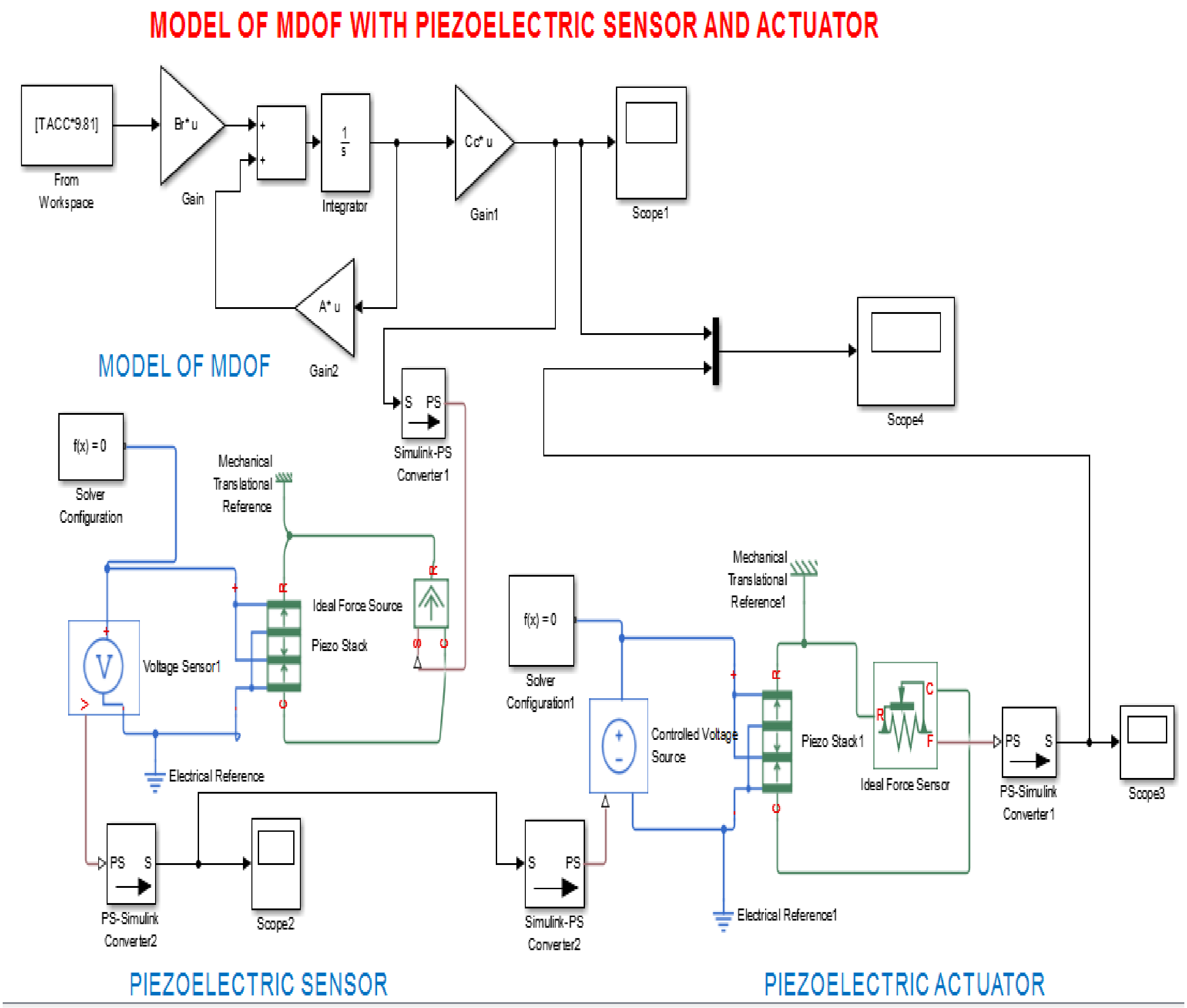

Fig. 1 Simulink Model

III. RESULTS AND DISCUSSION

The output depicting the controlled and uncontrolled response of the structure under seismic loading from MATLAB Simulink is presented graphically (Fig 2 to 21) and in tabular form (Table 1 and 2) in this section for different cases considered.

Piezoelectric sensor and actuator are applied at first floor:

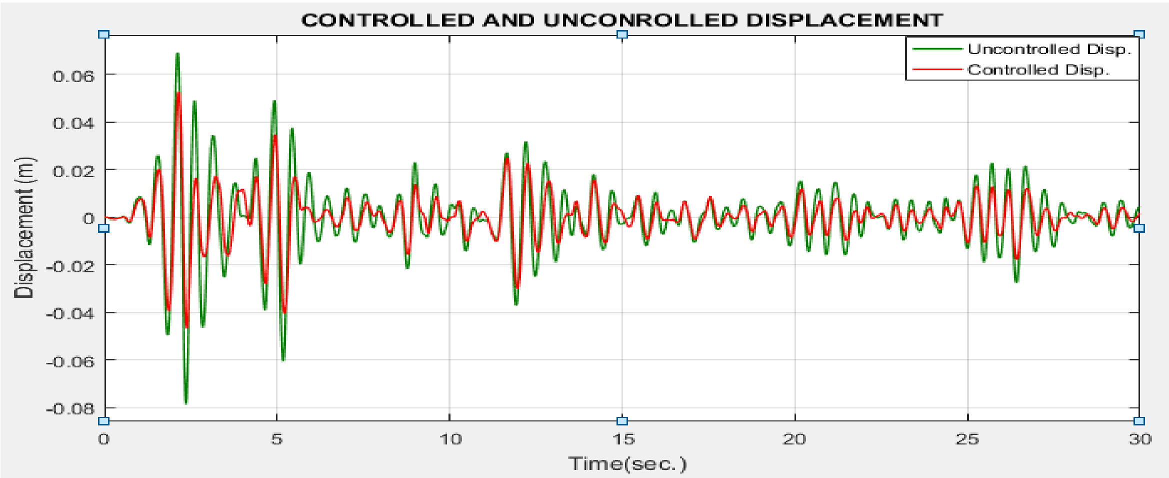

Fig. 2 First storey controlled and uncontrolled displacement

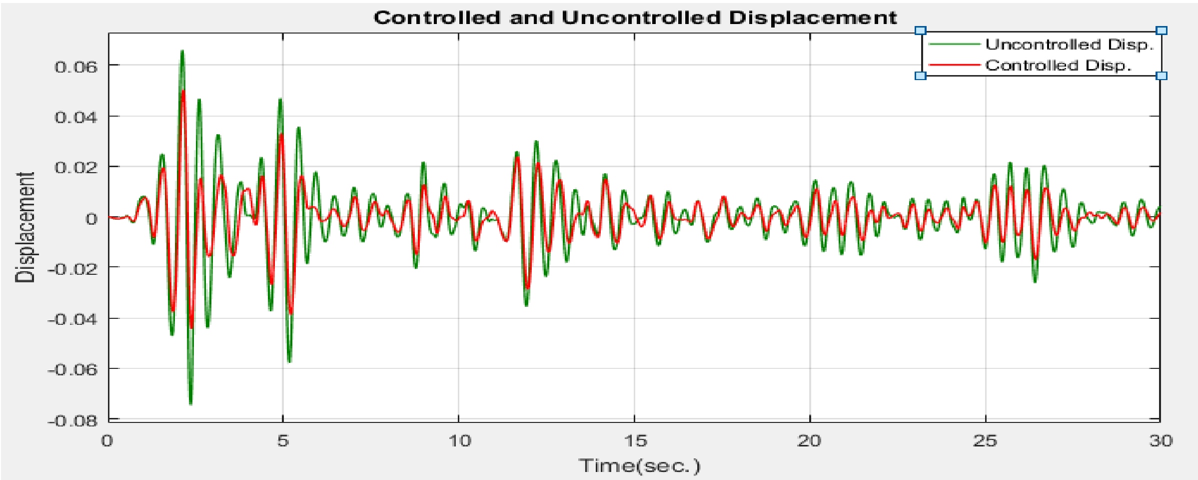

Fig. 3 Second storey controlled and uncontrolled displacement

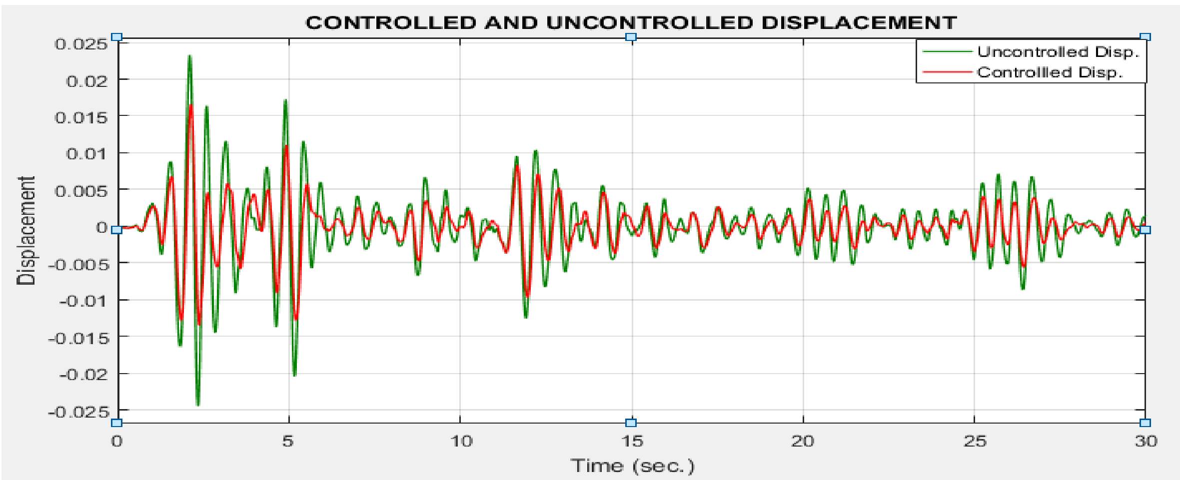

Fig. 4 Fifth storey controlled and uncontrolled displacement

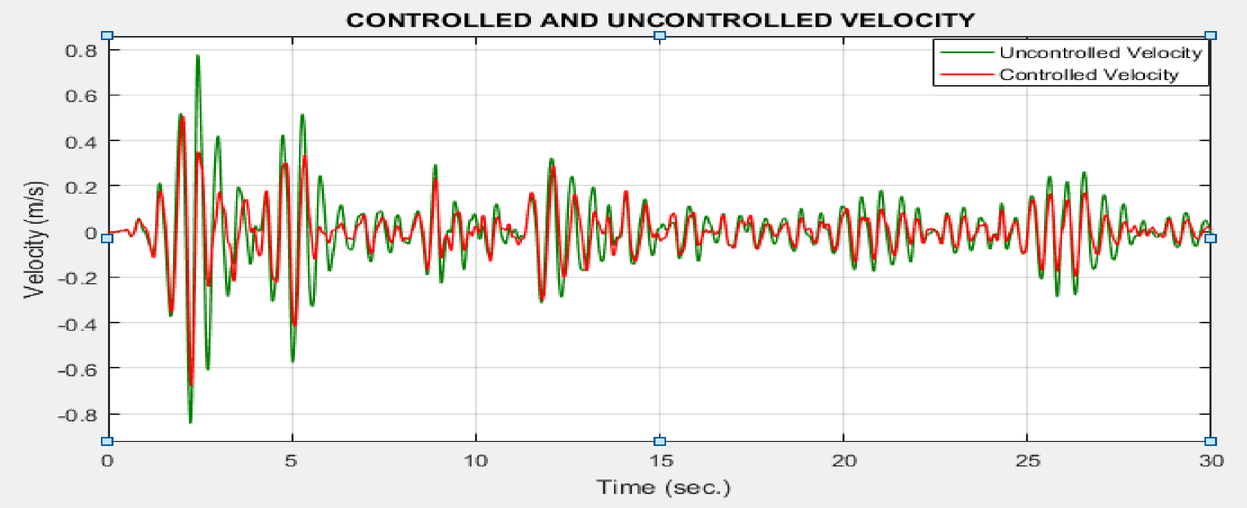

Fig. 5 First storey controlled and uncontrolled velocity

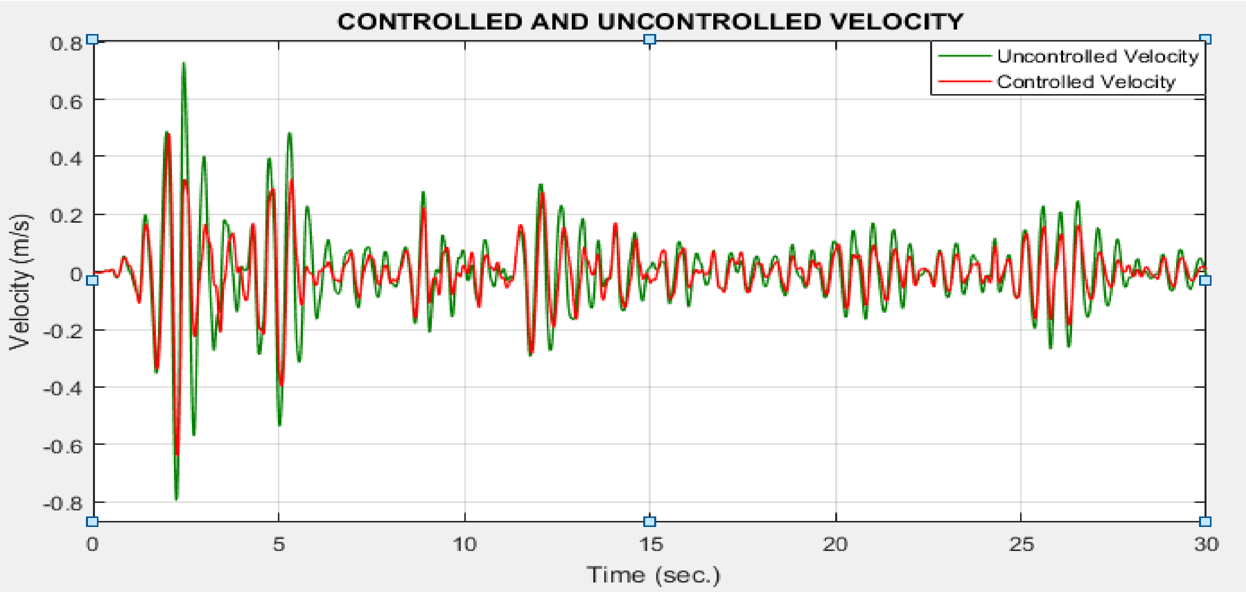

Fig. 6 Second storey controlled and uncontrolled velocity

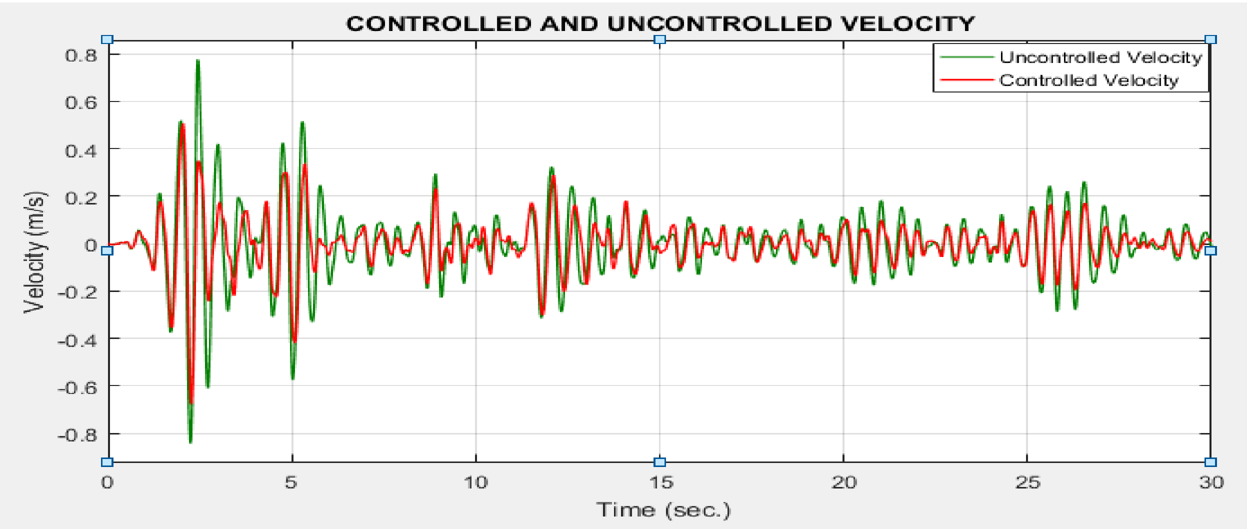

Fig. 7 Fifth storey controlled and uncontrolled velocity

Piezoelectric sensor and actuator are applied at second floor:

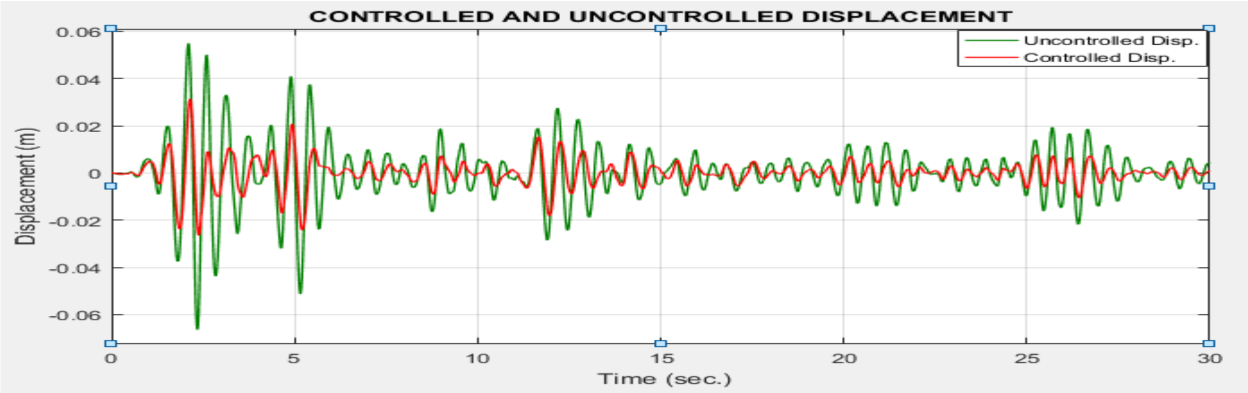

Fig. 8 Second storey controlled and uncontrolled displacement

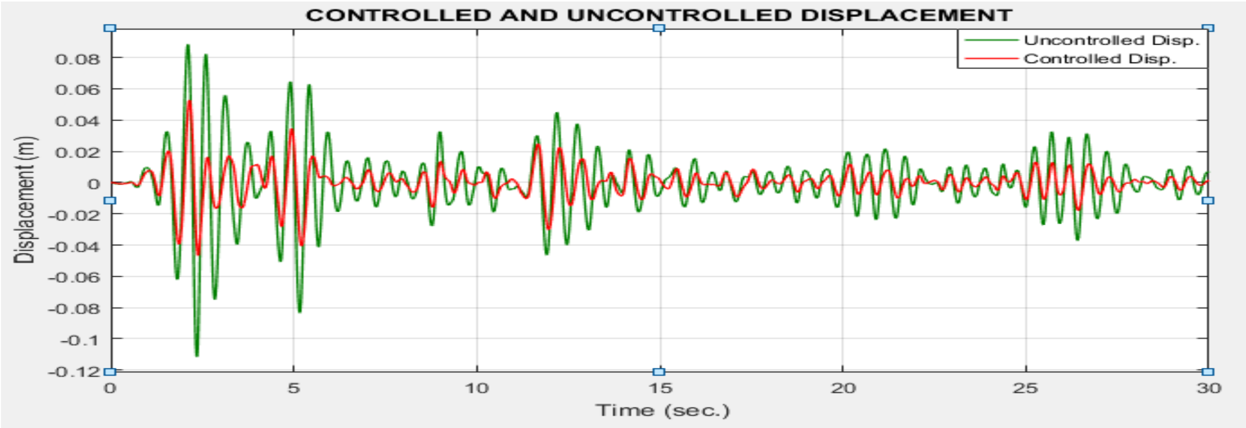

Fig. 9 Fifth storey controlled and uncontrolled displacement

3.1.4When piezoelectric sensor and actuator are applied at second floor then controlled and uncontrolled velocity –

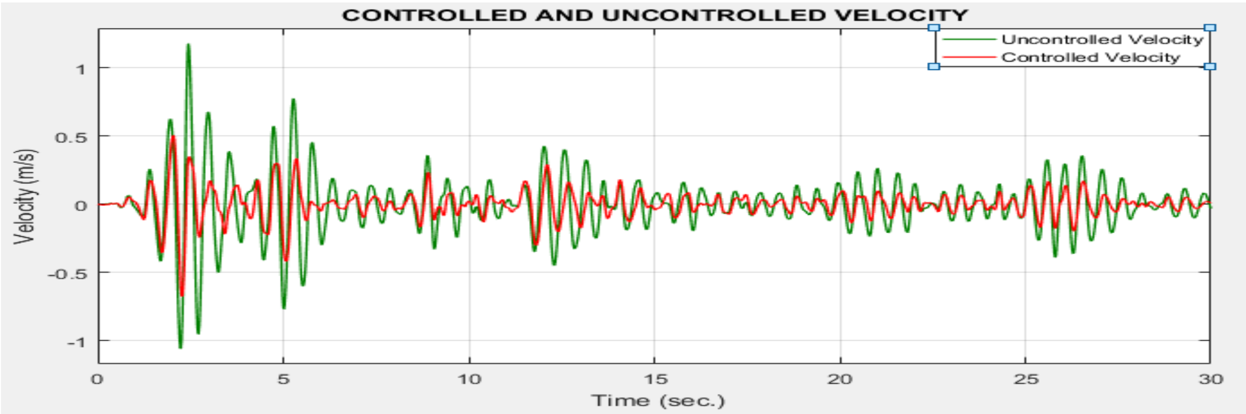

Fig. 10 Second storey controlled and uncontrolled velocity

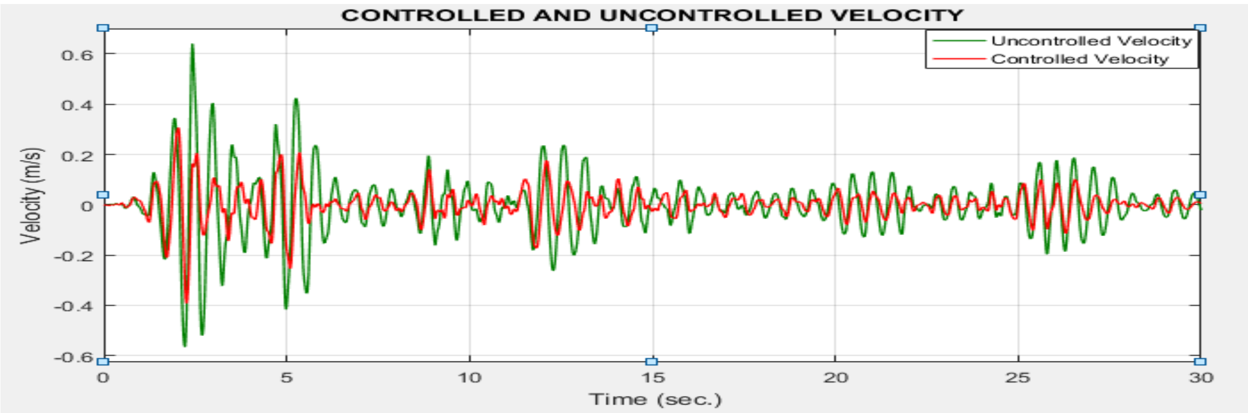

Fig. 11 Fifth storey controlled and uncontrolled velocity

Piezoelectric sensor and actuator are applied at third floor:

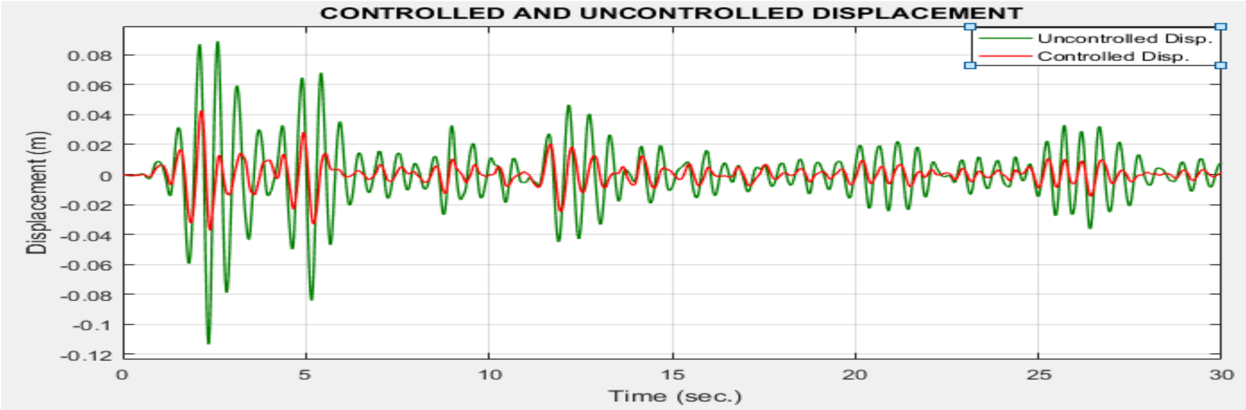

Fig. 12 Third storey controlled and uncontrolled displacement

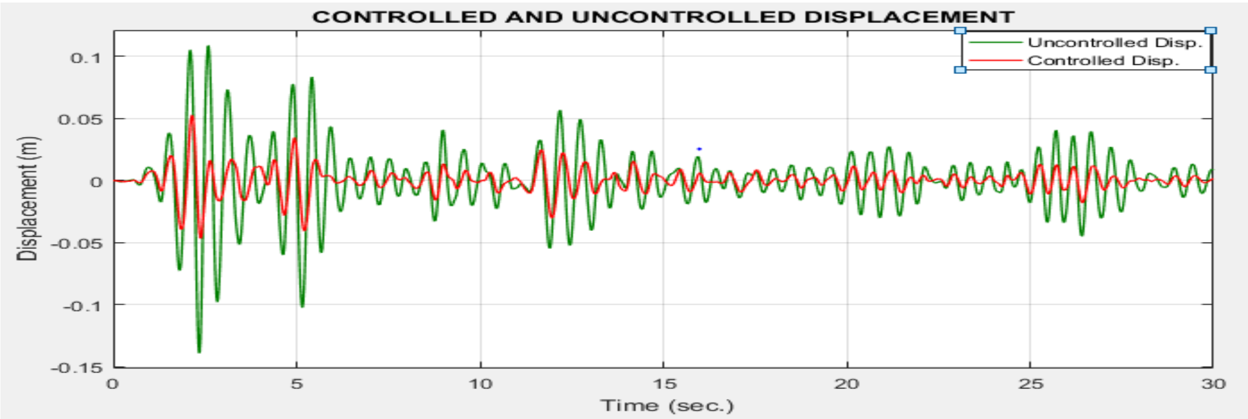

Fig. 13 Fifth storey controlled and uncontrolled displacement

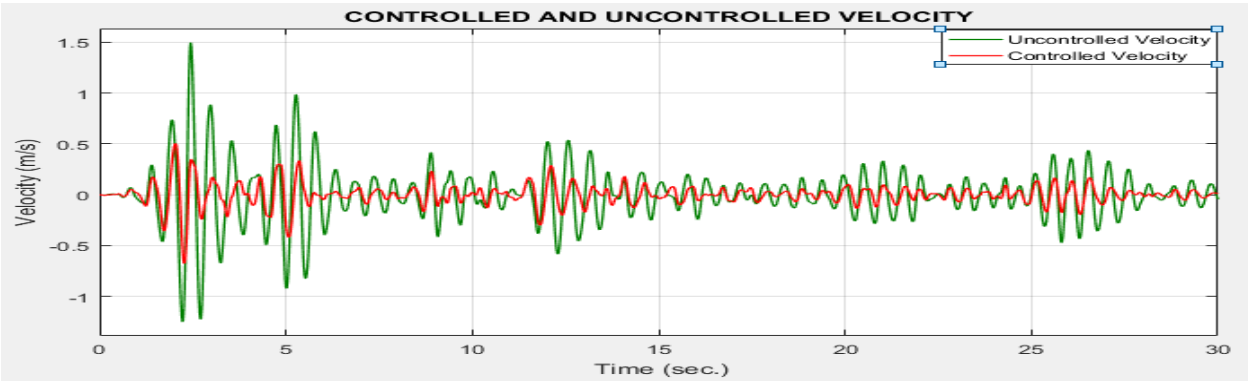

Fig. 14 Third storey controlled and uncontrolled velocity

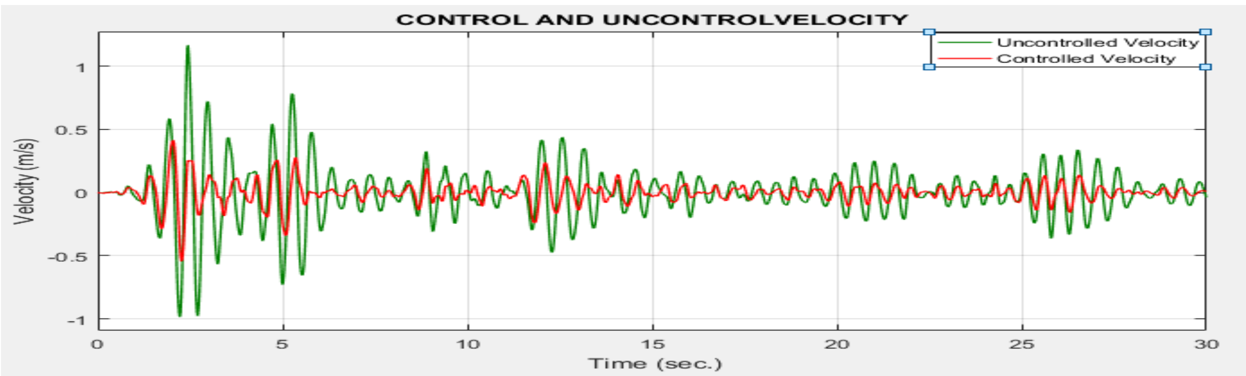

Fig. 15 Fifth storey controlled and uncontrolled velocity

Piezoelectric sensor and actuator are applied at fourth floor:

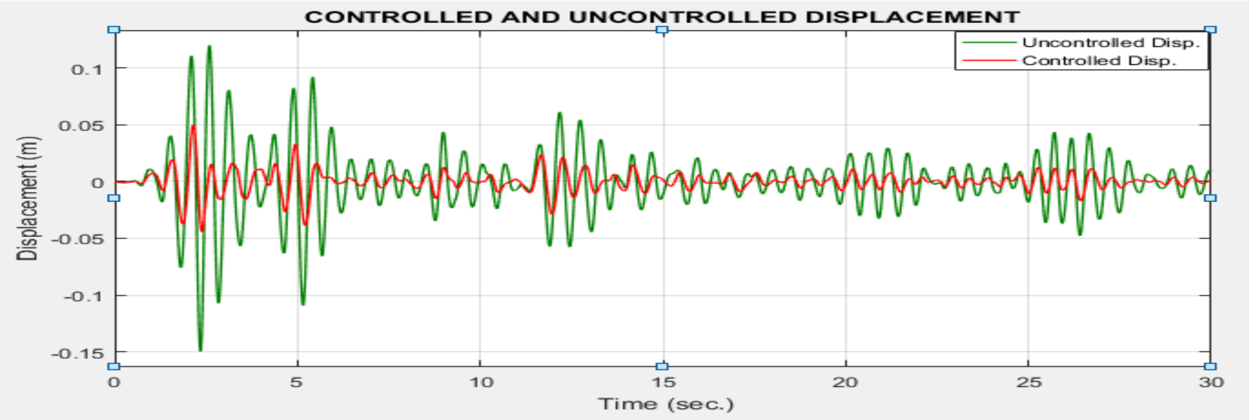

Fig. 16 Fourth storey controlled and uncontrolled displacement

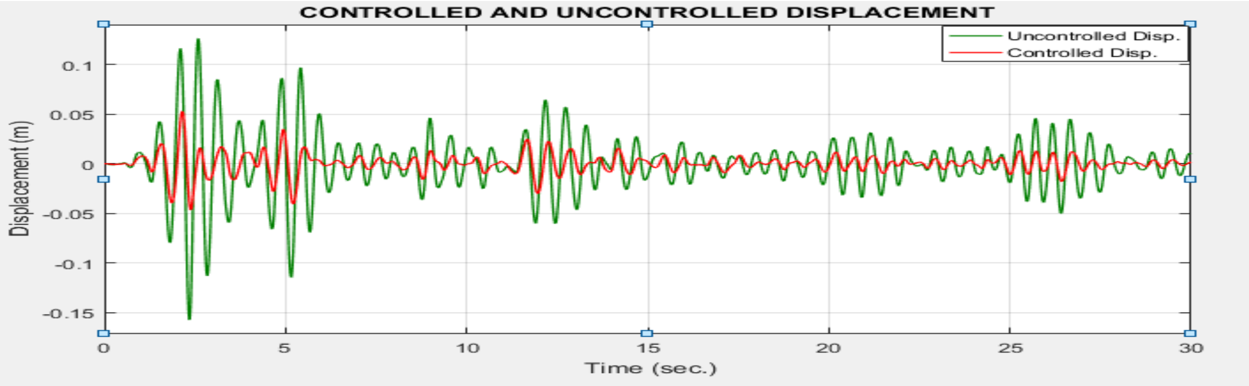

Fig. 17 Fifth storey controlled and uncontrolled displacement

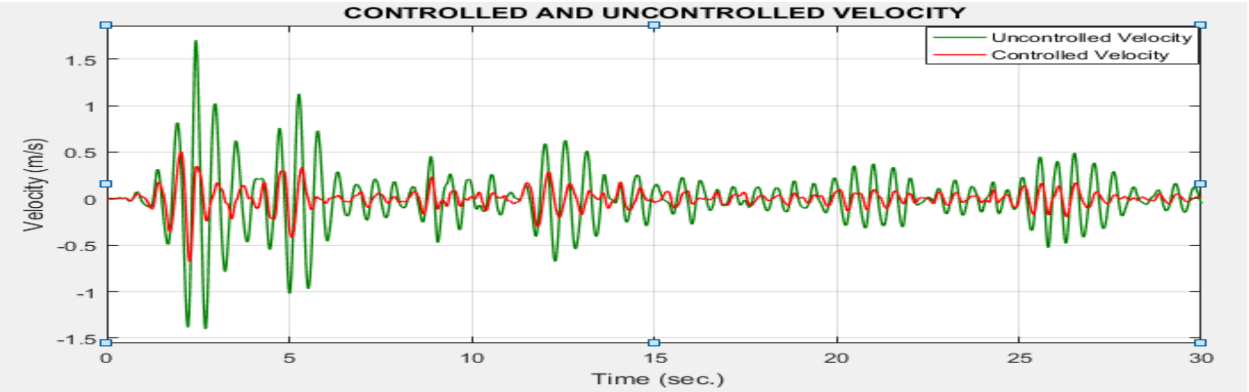

Fig. 18 Fourth storey controlled and uncontrolled velocity

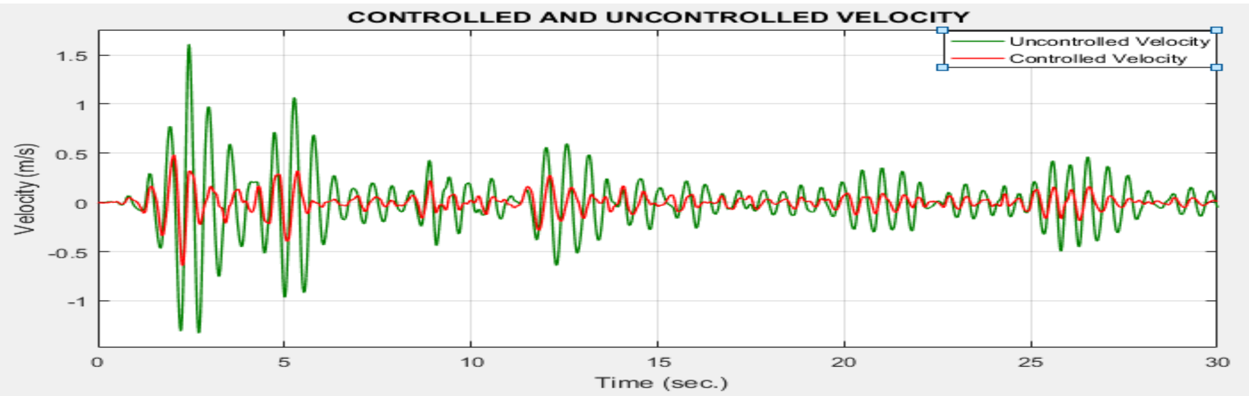

Fig. 19 Fifth storey controlled and uncontrolled velocity

Piezoelectric sensor and actuator are applied at fifth floor:

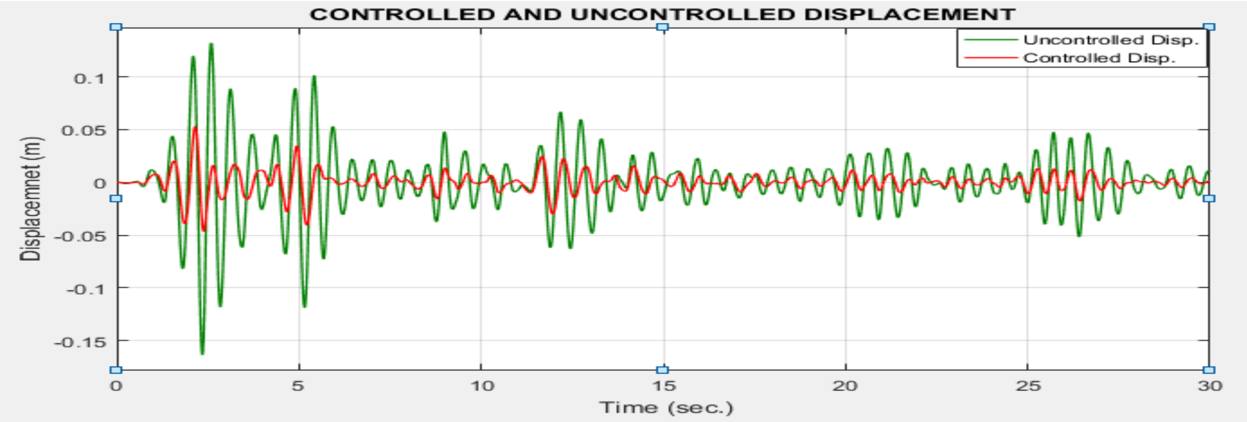

Fig. 20 Fifth storey controlled and uncontrolled displacement

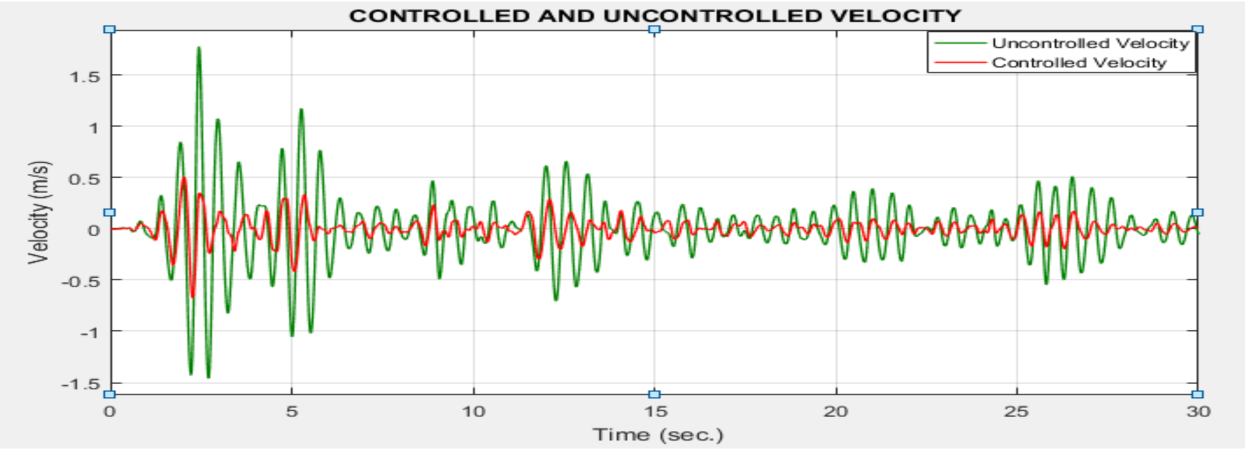

Fig. 21 Fifth storey controlled and uncontrolled velocity

TABLE 1
% REDUCTION IN DISPLACEMENT AT DIFFERENT STOREYS

S. No.	Storey details	Absolute max. uncontrolled disp. (m)	Absolute max. controlled disp. (m)	% reduction
1.	**Piezoelectric patches are placed at first floor**			
	First storey	7.859×10^{-2}	5.268×10^{-2}	32.96
	Second storey	7.461×10^{-2}	5.009×10^{-2}	32.86
	Fifth storey	2.446×10^{-2}	1.657×10^{-2}	32.25
2.	**Piezoelectric patches are placed at second floor**			
	Second storey	6.645×10^{-2}	3.128×10^{-2}	52.9
	Fifth storey	1.115×10^{-1}	5.268×10^{-2}	52.75
3.	**Piezoelectric patches are placed at third floor**			
	Third storey	1.135×10^{-1}	4.276×10^{-2}	62.32
	Fifth storey	1.392×10^{-1}	5.268×10^{-2}	62.15
4.	**Piezoelectric patches are placed at fourth floor**			
	Fourth floor	1.5×10^{-1}	5.009×10^{-2}	66.60
	Fifth floor	1.574×10^{-1}	5.268×10^{-2}	66.50
5.	**Piezoelectric patches are placed at fifth floor**			
	Fifth floor	1.637×10^{-1}	5.268×10^{-2}	67.81

TABLE 2

% REDUCTION IN VELOCITY OF DIFFERENT STOREYS

S. No	Storey details	Absolute max. uncontrolled velocity (m/s)	Absolute max. controlled velocity (m/s)	% reduction
1.	**Piezoelectric patches are placed at first floor**			
	First storey	8.427×10^{-1}	6.645×10^{-1}	19.7
	Second storey	7.964×10^{-1}	6.411×10^{-1}	19.5
2.	**Piezoelectric patches are placed at second floor**			
	Second storey	1.177	6.765×10^{-1}	42.52
	Fifth storey	6.411×10^{-1}	3.925×10^{-1}	38.77
3.	**Piezoelectric patches are placed at third floor**			
	Third storey	1.498	6.765×10^{-1}	54.83
	Fifth storey	1.167	5.441×10^{-1}	53.37
4.	**Piezoelectric patches are placed at fourth floor**			
	Fourth floor	1.705	6.765×10^{-1}	60.32
	Fifth floor	1.609	6.411×10^{-1}	60.15
5.	**Piezoelectric patches are placed at fifth floor**			
	Fifth floor	1.776	6.765×10^{-1}	61.90

It has been observed from the results that the reduction of the structural response is increasing, if the piezoelectric patches are bonded in the upper storeys of the frame. The percentage reduction of the response is found to be 33-67 for displacement and 22-62 for velocity.

IV. CONCLUSIONS

Present work deals with the spring mass dashpot of MDOF (5 storey building) for the active vibration control with piezoelectric materials. A voltage develops across the electrodes while the material deforms and conversely, the elements strain when a voltage is applied across their electrodes and it reduces vibration of the system.

Piezoelectric sensor and actuator are placed at different storey like first storey, second storey or third storey etc. and controlled and uncontrolled responses are obtained at different storey as well as other storey at which no piezoelectric sensor and actuator are placed. The responses are obtained for different storeys. The % reduction in response varies from 33-67 for displacement and 22-62 for velocity. This methodology can be applied to machine and different engineering systems to control the vibration under dynamic loading.

V. REFERENCES

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