COMPARISON BETWEEN STRUCTURES WITH PASSIVE AND SEMI-ACTIVE VARIABLE STIFFNESS TUNED MASS DAMPER

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1. INTRODUCTION

Several studies indicated that Tuned Mass Damper (TMD) is most effective when its fundamental frequency is tuned to that of structure[1]. In this paper, instead of tuning to structure's frequency, response reduction efficiency of semi-active variable stiffness TMD (STMD) tuned to instant frequency of excitation is considered. Using the same method as Satish and Ertan's study[2], structure response under two seismic waves, El Centro and Kobe earthquake, are calculated and compared to show differences between STMD and its passive counterpart (PTMD). At first, Short Time Fourier Transform (STFT) with some window length is applied for tracking frequency from input excitations. In the next step, TMD stiffness is varied based on frequency-time results and Newmark's method is used for response analysis.

2. MODEL PROPERTIES[2]

(1) Main structure model properties:
A 5-stories building is modeled as 5-DOF system with uniform structural parameters including mass, stiffness and damping (M, K, C).

(2) TMDs model properties:
TMDs are modeled as SDOF systems with parameters including TMD mass and damping ratio (m, ξ), and different TMD stiffness which are tuned to excitation frequency for STMD (k_j).

(3) Optimum parameters study:
Optimum TMD parameters including normalized frequency (γ) and damping ratio (ξ_n) are considered. As fundamental mode of MDOF system (first mode) can be represented by SDOF system, above mentioned parameters are estimated by models of SDOF with PTMD and STMD respectively subjected to harmonic excitation and El Centro earthquake excitation. Optimum parameters study results are displayed and summarized in Fig 2,3 and Table 1.

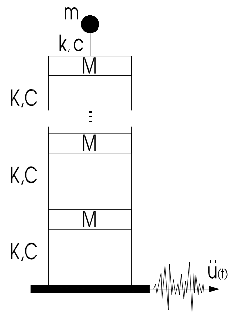

Fig 1: MDOF model under seismic excitation with STMD/PTMD

Table 1: Optimum parameters of PTMDand STMD

PTMD	γ	0.99
	ξ_{tmd}	0.006
STMD	ξ_{tmd}^{ref}	0.006

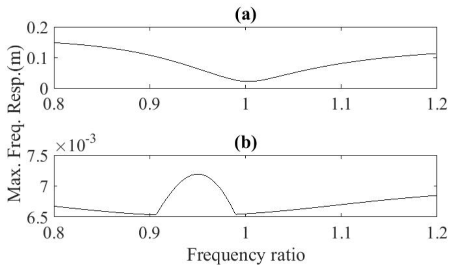

Fig 2: Maximum response versus Frequency ratio
(a) Harmonic force; (b) El Centro Earthquake

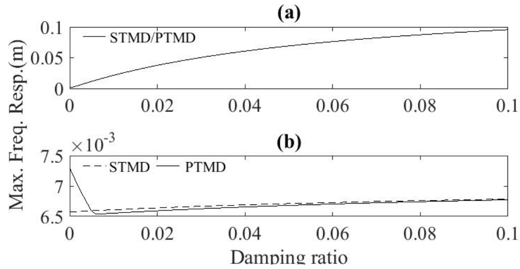

Fig 3: Maximum response versus Damping ratio
(a) Harmonic force; (b) El Centro Earthquake

3. SEMI-ACTIVE CONTROL ALGORITHM

STFT is applied to track the dominant frequency of the excitation signal (frequency with maximum amplitude in power spectrum) at each instant of time. STFT is mathematically described by equation (1)[2]

$$STFT(t,\omega) = S(t,\omega) = \int s_{(\tau)} w_{(\tau - t)} e^{-j\omega t} d_\tau \tag{1}$$

The procedure for excitation signal starts by selecting window length (WL; refers to number of data points in one window), time lapse (TL; the gap between 2 consecutive windows) and averaging length (AL; refers to number of domi-

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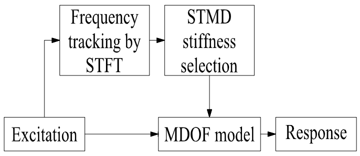
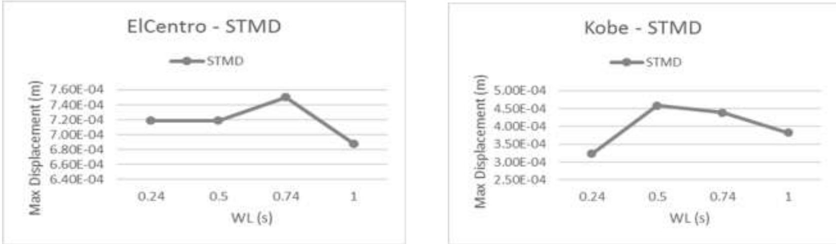
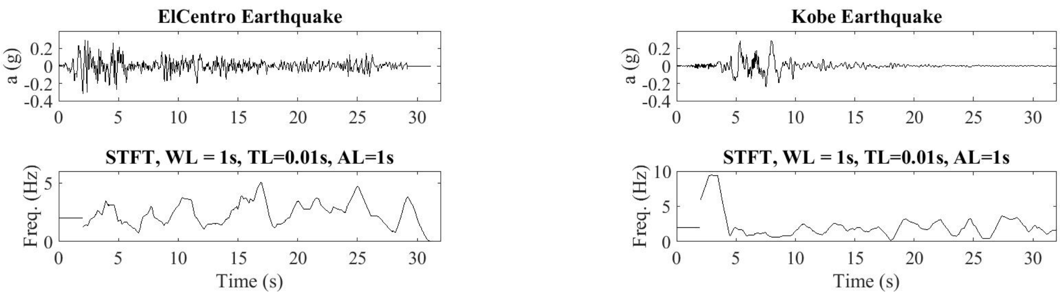
-nant frequencies considered for averaging). After signal processing, dominant frequencies in time domain are determined and used to tuned to STMD frequency by varying STMD's stiffness correspondingly. General control algorithm block diagram (Fig 4), relation between some WL versus maximum responses (Fig 5) and results of frequency tracking for El Centro and Kobe earthquake with rectangular window, WL=1s, TL=0.01, AL=1s (Fig 6) are as follow





(a) (b)

Fig 4: Control algorithm [2] **Fig 5:** Maximum response versus WL (a) El Centro Earthquake; (b) Kobe Earthquake



(a) (b)

Fig 6: Frequency tracking (a) El Centro Earthquake; (b) Kobe Earthquake

4. STRUCTURE RESPONSE COMPARISION

Analysis in time domain are conducted as shown in Fig 7,8. For maximum responses of El Centro and Kobe earthquake cases, responses of PTMD, STMD cases are 136.67%, 88.93% respectively compared to no TMD in El Centro case; and are 83.36%, 93.26% respectively compared to no TMD in Kobe case.

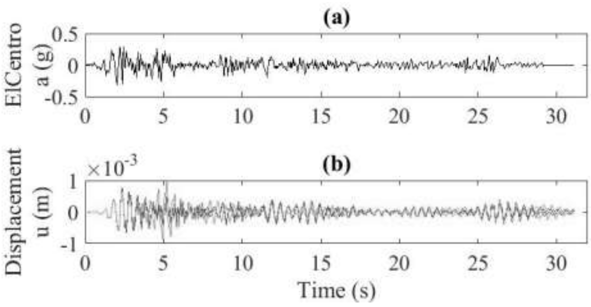


Fig 7: Dynamic response of based excited 5DOF system ($f_{n1} = 2Hz$) under El Centro earthquake excitation: (a) Excitation; (b) no TMD, PTMD, STMD

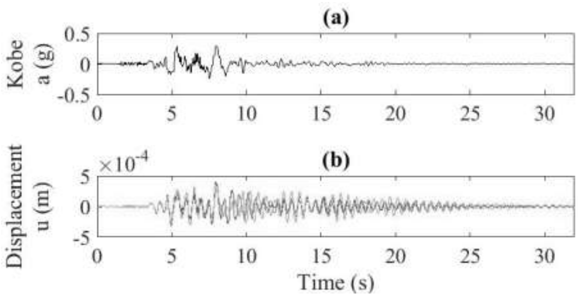


Fig 8: Dynamic response of based excited 5DOF system ($f_{n1} = 2Hz$) under Kobe earthquake excitation: (a) Excitation; (b) no TMD, PTMD, STMD

5. CONCLUSION

There has been agreement of results in this paper and Satish and Ertan's research in terms of that in El Centro earthquake case, STMD is more effective in maximum response reduction than PTMD which even has response exceeding no TMD case. Reversely, in Kobe earthquake case, both types of TMD successfully reduce top floor displacement but PTMD is more effective. Further investigations are required for determining optimum response control algorithm for many seismic waves.

6. REFERENCES

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