Earthquake Resistance Technique by PTMD (Pendulum Tuned Mass Damper)

Shubham Sawant, Ashpak Shaikh, Pratik Pawar and Hiran Sharma

March 1, 2021

VIVA-Tech International Journal for Research and Innovation
ISSN(Online): 2581-7280

Volume 1, Issue 4 (2021)
Article No. X
PP XX-XX

VIVA Institute of Technology
9th National Conference on Role of Engineers in Nation Building – 2021 (NCRENB-2021)

VIVA-TECH IJRI
ANNUAL RESEARCH JOURNAL

VIVA-TECH INTERNATIONAL JOURNAL FOR RESEARCH AND INNOVATION
ANNUAL RESEARCH JOURNAL
ISSN(ONLINE): 2581-7280

EARTHQUAKE RESISTANCE TECHNIQUE BY PTMD (PENDULUM TUNED MASS DAMPER)

SHUBHAM SHIVDAS SAWANT, ASHPAK RAHEMAN SHAIKH, PRATIK PRAKASH PAWAR, HIRAN SHRIKANT SHARMA

(Bachelor of Engineering Department of Civil Engineering Mumbai University/Viva Institute of Technology Mumbai-401 305)

Abstract *: The objective of this thesis is to describe the design, construction, implementation and performance of a prototype adaptive pendulum tuned mass damper (PTMD). Furthermore the thesis aims at demonstrating the performance improvements obtained when the pendulum tuned mass damper (PTMD) parameters are optimized. The study considers the effect of adjusting the PTMD tuned frequency and damping ratio on a two storey test structure subjected to broadband and narrowband excitation. An analytical model of the PTMD for a single-degree-of-freedom (SDOF) structure is used to demonstrate the performance improvements when the PTMD parameters are optimized. The optimized model considers the effects of adjusting the frequency ratio, damping ratio, and mass ratio of the combined system to reduce the maximum deflection dynamic vibration absorber when the structure is subjected to a harmonic excitation force. The analytical model is used to simulate the optimal performance of the PTMD system. The experimental PTMD is capable of identifying the structural vibration modes in real time and tuning to the desired mode. The structural vibration control modes are identified by calculating the windowed power spectral density of the structure's acceleration, followed by peak-picking algorithm to identify the modal frequencies. Tuning is performed by moving the pivot location of the pendulum arm via a tuning frame along a set of rails. The design also allows for changes in the external dampening force. An adjustable damper is attached to the pendulum mass to allow for control of the PTMD damping ratio.*

Keywords: *pendulum tuned mass damper, dynamic vibration absorber, mass ratio, vibration control, damping ratio.*

I. INTRODUCTION

The Wind-induced vibrations impose large demands on structural components and connections for tall structures. Taller, lighter, and more slender modern construction is a consequence of the advances in structural materials, design efficiencies and technologies. Tall structures are susceptible to vibrations due to their flexibility, lack of sufficient inherent structural damping, and the larger wind loads these structures are subjected to due to their height. These demands in many cases lead to considerable discomfort to the occupants, particularly at upper floors Since the designer has little control over the wind loads, aside from optimization the shape of the structure, the available options to minimize the vibrations include reducing the building's flexibility or enhancing the vibrational dissipation capacity through increased damping. The flexibility of a structure can be reduced by increasing its stiffness, using larger or a greater number of structural components, resulting in structures with increased weight. Heavier structures consume more materials, require increased construction effort and time, necessitate larger foundations, and are generally more costly. Methods to increase damping in structures are an active area of research. The basic concept of damping is to dissipate vibrational energy through heat, thus reducing the impact of the imposed forces on the structure. One method of mitigating the effects of wind-induced vibrations is through the use of auxiliary damping devices, known as tuned mass dampers TMD.

II. METHODOLOGY

1. Pendulum Tuned Mass Damper.

The problems associated with the bearings can be eliminated by supporting the mass with cables which allow the system to behave as a pendulum. Shows a simple pendulum attached to a floor. Movement of the floor excites the pendulum. The relative motion of the pendulum produces a horizontal force that opposes the floor motion. This action can be represented by an equivalent SDOF system that is attached to the floor.

- The equation of motion for the horizontal direction is
  T sinθ Wd g -- u ·· u ·· + ( ) + d = 0

- Where T is the tension in the cable
  $u_d = L\sin\theta \approx L\theta$

  T=Wd

- The natural frequency of the pendulum is related to by
  $\omega d\ 2 = k_{eq}/mg = g/L$

- The natural period of the pendulum is
  $T_d = 2*22/7*(L/g)$

III. TABLE

Table: Type of Structure of PTMD.

Sr. No.	Name	Type of Structure	Height	No Floors	Location	Year Completed	TMD
1	CN Towet	Tower	553m	75	Toronto. Canada	1976	2PTMD Weight= 18 ton
2	Steel Chimney	Chimney	90m	-	Bangkok. Thailand	1999	PTMD Frequency= 0.8Hz. Weight= 4ton
3	Aspire Tower	Tower	300m	36	Doha, Qatar	2007	PTMD Frequency= 0.22 Hz Weight = 140 ton
4	ShenZhen WuTong Mountain Tower	Tower	198 m	-	ShenZhen, China	2009	PTMD Weight= 10 ton
5	Taipei 101	Tower	509.2 m	101	Taipei, Taiwan	2004	PTMD Weight =756 ton

IV. CONCLUSION

- The PTMD presented here is a novel TMD system developed to provide the capability to autonomously tune to the structural frequency while providing control of the external damping to the PTMD mass.
- The objective of these tests was to demonstrate the performance improvements over various detuned conditions when the structure is tuned to the structural natural frequency.
- The narrowband tests revealed a 7.8% to 17.2% improvement in the measured top floor response when comparing the tuned and off-tuned test conditions.
- While the experiment results are certainly positive, they are meant to demonstrate the importance of optimizing the TMD tuning parameters to reduce structural vibrations.
- In comparison to passive TMD systems the PTMD will perform as well or better, depending on the disparity between the optimal TMD tuning parameters and the calibrated TMD parameters.
- Full size prototype PTMD testing would provide a more clear idea of the obstacles that may emerge if the existing design is to be utilized in a real structure.
- The ultimate goal in developing the PTMD is for the technology to become a superior alternative to existing passive TMD technologies.

Acknowledgements

We are using this opportunity to express our gratitude to everyone who has supported us throughout the completion of this project. We are thankful for their guidance, constructive criticism and friendly advice, during the project work. We express our gratitude to Prof. Akshay Mistry for giving us an opportunity to carry out project on “EARTHQUAKE RESISTANT TECHINQUE BY PTMD (PENDULUM TUNED MASS DAMPER)”.
We would also like to thank Dr. Arun Kumar, the Principal for their whole hearted support. Lastly, we express our gratitude towards all those who directly or indirectly helped us in the completion studies.

REFERENCES

- Baker, W.F., Korista, S., and Novak, L.C., 2007. Burj Dubai: Engineering the World’s Tallest Building, *The Structural Design of Tall and Special Buildings*, 16(4), pp.361-375
- Brownjohn, J.M.W., Carden, E.P., Goddard, C.R., and Oudin, G., 2010. Real-Time Performance Monitoring of Tuned Mass Damper System for a 183 m Reinforced Concrete Chimney, *Journal of Wind Engineering and Industrial Aerodynamics*, 98(3), pp.169-179
- Carpineto, N., Lacarbonara, W., and Vestroni, F., 2010. Mitigation of Pedestrian-Induced Vibrations in Suspension Footbridges via Multiple Tuned Mass Dampers, *Journal of Vibration and Controls*, 16(5), pp.749-776

- Chang, M.L., Lin, C.C., Ueng, J.M., and Hsieh, K.H., 2010. Experimental Study onAdjustable Tuned Mass Damper to Reduce Floor Vibration Due to Machinery, *Structural Control and Health Monitoring*, 17(5), pp.532-548

- Chen, G., and Wu, J., 2001. Optimal Placement of Multiple Tuned Mass Dampers for Seismic Structures, *Journal of Structural Engineering*, 127(9), pp.1054-1062

- Chey, M.H., Carr, A.J., Chase, J.G., and Mander, J.B., 2007. Design of Semi-Active Tuned Mass Damper Building Systems using Resettable Devices, *8th Pacific Conference on Earthquake Engineering*, Singapore, Dec 5-7

- Chey, M.H., Chase, J.G., and Mander, J.B., Carr, A.J., 2010. Semi-Active Tuned MassDamper Building Systems: Design, *Earthquake Engineering and Structural Dynamics*, 39(2), pp.119-139

- Lourenco, R., Roffel, A.J., and Narasimhan, S., 2009. Adaptive Pendulum Mass Damper for Control of Structural Vibration, *CANSMART Workshop*, Montreal, Quebec, Canada

- Matlab, 2007a, *The Mathworks*. Natick, MA, 2007.

- Mendis, P., Ngo, T., Haritos, N., Hira, A., Samali, B., and Cheung, J., 2007. Wind Loading on Tall Buildings, *Electronic Journal of Structural Engineering*, 7(Special Issue), pp.41-54

- Nagarajaiah, S., and Varadarajan, N., 2005. Short Time Fourier Transform Algorithm for Wind Response Control of Buildings with Variable Stiffness TMD, *Engineering Structures*, 27(3), pp.431-441

- Nagarajaiah, S., and Sonmez, E., 2007. Structures with Semiactive Variable Stiffness Single/Multiple Tuned Mass Dampers, *Journal of Structural Engineering*, 133(1), pp.67- 77