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PERFORMANCE OF MTMD SYSTEMS BASED ON REALISTIC LOAD CONTRIBUTIONS DUE TO WALKING

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Summary

Tuned mass dampers (TMD) are widely acknowledged as state-of-the-art solution for mitigating structural vibrations. In this context, the robustness of a TMD system is an essential parameter which describes the sensitivity in regard to deviations in both parameters natural frequency of the empty structure and excitation frequency. Studies can be found revealing that the robustness of a TMD solution can be further increased with a Multi TMD System (MTMD). However, the analyzed scenarios are based on controlled harmonic excitation sources. In case of pedestrian induced vibrations the load process of natural walking is subject to random deviations in both the basic walking parameters and the load parameters. In this study, in order to analyze the performance of MTMD systems for realistic load conditions structural response calculations are performed for different MTMD setups. The respective load time histories are obtained from experiments based on an instrumented walkway. The results lead to the conclusion that within the introduced analysis environment MTMD systems reveal similar effectiveness in regard to vibration mitigation but higher robustness, however, at the expense of the TMD travel where considerable larger displacements are obtained if compared to the single TMD system.

Keywords: tuned mass dampers; MTMD performance; dynamics; walking induced loads; random imperfections; vertical vibrations; lightweight structures; inter-harmonics

1. Introduction

Tuned mass dampers are widely acknowledged as state-of-the-art solution for mitigating structural vibrations. Beside retrofitting purposes TMDs are often already involved in the structural design concept and often are the only reasonable solution to realize lightweight structures which comply with the underlying serviceability criteria. The robustness of a TMD system is an essential parameter which describes the sensitivity in regard to deviations in both parameters natural frequency of the structure and excitation frequency. Studies can be found revealing that the robustness of a TMD solution can be further increased with a Multi TMD System (MTMD). The investigated scenarios usually are based on periodic excitation sources. The aim of the present study is to evaluate the performance of MTMD systems for the load scenario natural walking.

2. Characterization of the induced loads due to walking

The process of natural walking is subject to imperfections in both the load and the locomotion parameters and is characterized by inter-harmonic frequency content which usually cannot be reproduced with common modelling approaches as introduced in recent standards and guidelines. The randomness of walking has been investigated in [1,2] based on experiments using a 28 m walkway with an instrumented section of 16 m length. The basic shape of the monitored load time histories leads to the identification of the parameters step frequency, step length and step width where the latter two are obtained from the change of the position of the effective load based on equilibrium conditions of the measured forces. Altogether 454 load time histories obtained from 227 subjects and 2 crossings have been monitored. The observed step frequencies range from approximately 1.5 Hz to 2.3 Hz. The mean value is determined with 1.92 Hz.

3. MTMD evaluation based on structural response calculations

In the next analysis step structural response calculations are performed which are based on an analytical model of a simple beam bridge using the above introduced walking load patterns. The dominant natural frequency matches the mean value of the observed step frequencies from the walkway tests. For the evaluation of the performance of MTMD systems different setups are considered with an increasing number of TMDs up to 7 units. The setups for the single TMD system and the MTMD system made up of 7 units are shown in fig. 1. The TMD parameters tuning frequency and damping are optimized with regard to achieve minimum structural accelerations. The spacing of the TMD units is equidistant. For each individual the response calculations consider the step-by-step change of the position on the bridge.

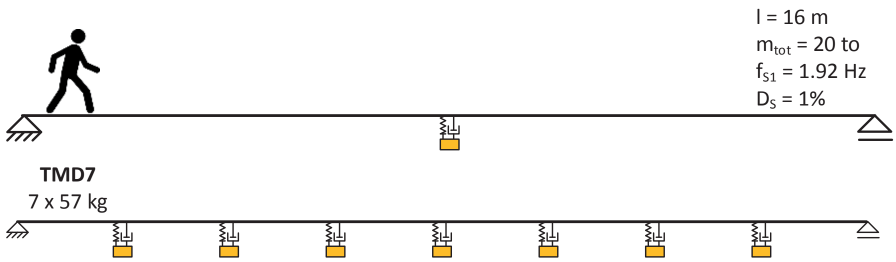

Fig. 1. Structural model of the bridge with different TMD setups single unit and 7 units

In fig. 2 (left) the non-exceedance probabilities of the maximum observed accelerations at bridge mid-position are plotted. The plots reveal that the vibration mitigation effects of the MTMD systems are all in a similar range with considerable reduced accelerations if compared to the original bridge without TMD (TMD0). The ratio of the maximum accelerations obtained from the responses due to an individual load pattern for both scenarios original bridge and bridge equipped with TMDs leads to the reduction factor. Exemplified by the systems consisting of a single TMD unit and 7 TMD units, in fig. 2 (right) it is shown that the largest reduction factors are obtained for resonant or near resonant step frequencies. Here, the TMD1 system shows the better performance. However, beyond the resonant range the MTMD systems are more effective with larger reduction factors and thus reveal a higher robustness.

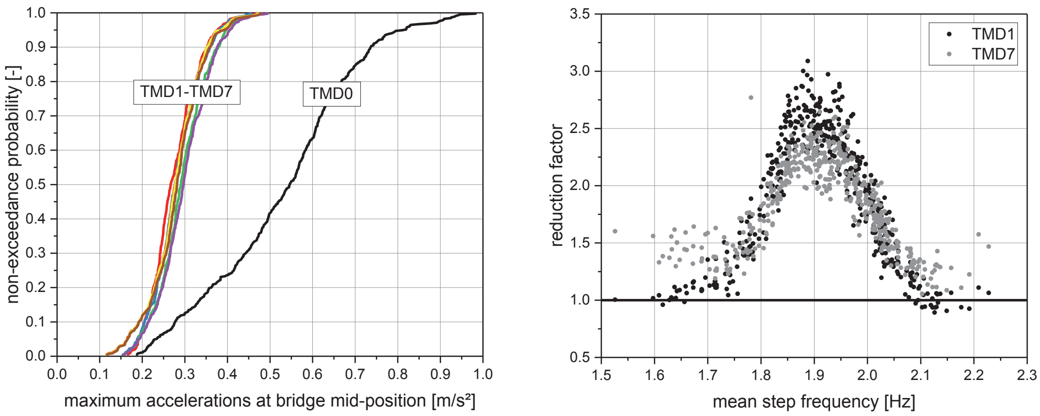

Fig. 2. Observed maximum accelerations and reduction factor in dependency of the mean step frequency

However, from the calculations it is also found that the relative displacement (TMD travel) considerably increases with increasing number of TMD units. It can be concluded that the MTMD systems reveal similar effectiveness in regard to vibration mitigation but higher robustness, however, at the expense of the TMD travel where considerable larger displacements are obtained if compared to the single TMD system.

4. References

[1] SAHNACI C., “Menscheninduzierte Einwirkungen auf Tragwerke infolge der Lokomotionsformen Gehen und Rennen: Analyse und Modellierung”, PhD Thesis at Ruhr-University Bochum, 2013.

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