MEASURING REPORT

Eagles Meadow Footbridge/ Wrexham UK

Project: E-56794 SM / Wilson Bowden Developments Ltd.

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1. Introduction

On the 12th of May measurements for a vibration analysis have been performed at the Eagles Meadows Footbridge/Wrexham. The objective of these measurements wer the determination of the bridges modal paramters such as the dominant natural frequencies, mode shapes and damping ratios as well as the estimation of the bridges vibration susceptibility under various load cases. The results of the vibration analysis were used to verify the applied TMD concept and to perform a fine-tuning of the TMDs.

Finally the reduction effect of the TMDs should be evaluated for all suscepitble modes by comparing occuring vibrations and the increase of structural damping.

2. Measuring Equipment

For the performed analysis the below listed equipment has been applied. The measuring systems fulfils the device standard DIN 45669 C3 HV1-80 and is shown in Figure 1.

Sensors	velocity-proportional sensors, KEBE GmbH
Amplifier	STAC
Computer-Hardware	Dolch MegaPac Pentium 750 MHz mit FFT-Analyzer-PCI Card AD 420SC, STAC
Software	MSYS-Analyzer

Fig. 1 Measuring Equipment – velocity proportional sensors applied to the bridge-deck

3. Identification of dominant natural frequencies and corresponding mode shapes

To identify the dominantly excited natural frequencies of the bridge with installed but blocked TMD, the vertical vibrations under an ambient/ pedestrian induced excitation were recorded at the bridge (MP1–3 see Fig. 2).

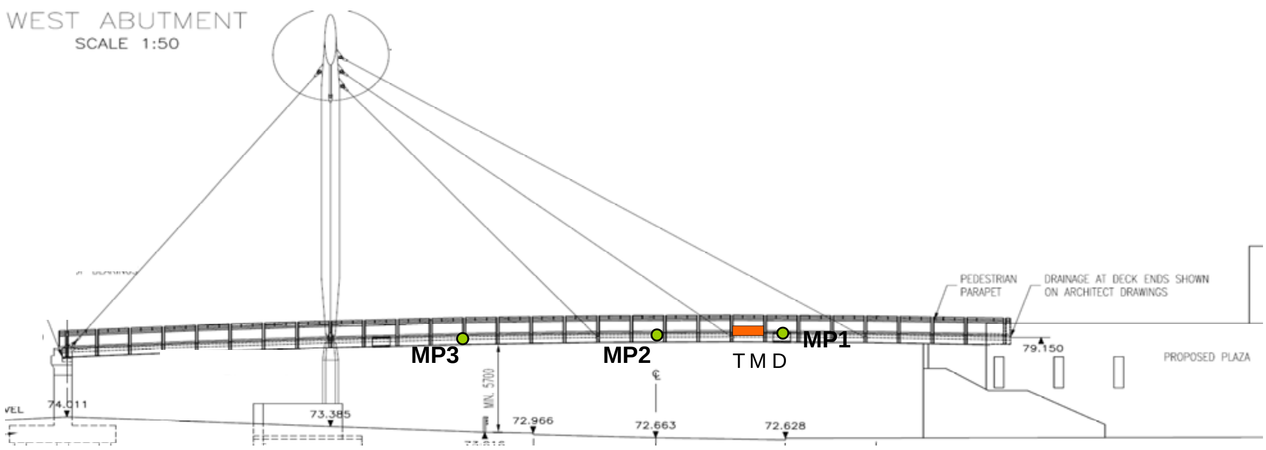

Fig. 2 Layout of the Measuring Points for the ambient modal analysis

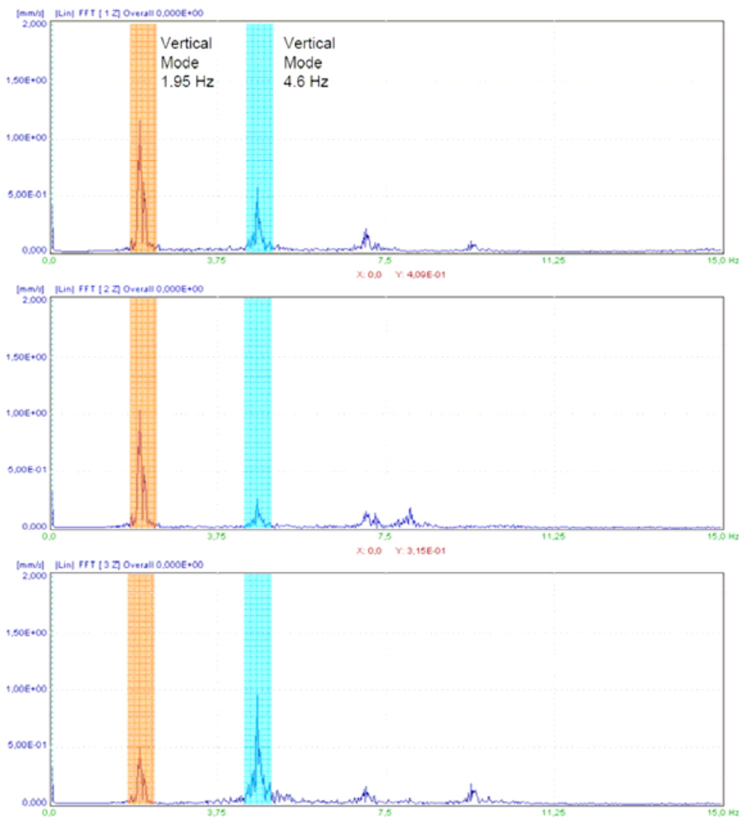

Fig. 3 Measured frequency spectra of vertical vibrations for ambient/pedestrian induced excitation with blocked TMD at MP1, MP2 and MP3

The measured time histories have been separated into several blocks which were transformed into frequency spectra and averaged. The resulting spectra for each examined point are shown in Figure 3 for the vertical direction at the 3 examined measuring points. Two dominant frequencies – 1.95 Hz and 4.6 Hz could be identified.

To determine the corresponding mode shapes, the vibrations in vertical direction have been recorded at the shown Measuring Points (see Figure 2) and related to a reference point. The vibration signal for each point will be transferred to the frequency domain which contains the deflection information for each dominant frequency as well as the phase information. Displaying these information for each examined point leads to the illustrations displayed in Figure 4 – Figure 5. These illustrations represent the dominantly occurring mode shapes of the bridge for pedestrian induced vibrations.

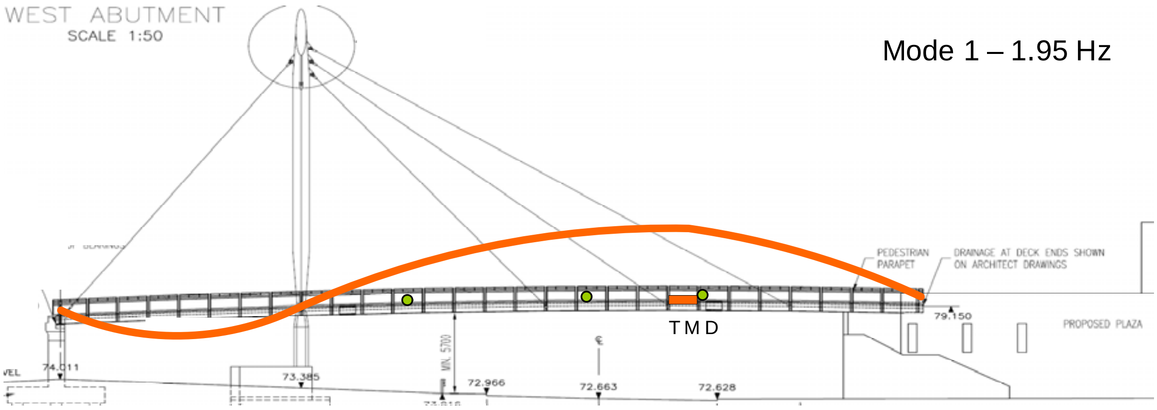

Fig. 4 Determined vertical mode shape for a natural frequency of 1.95 Hz

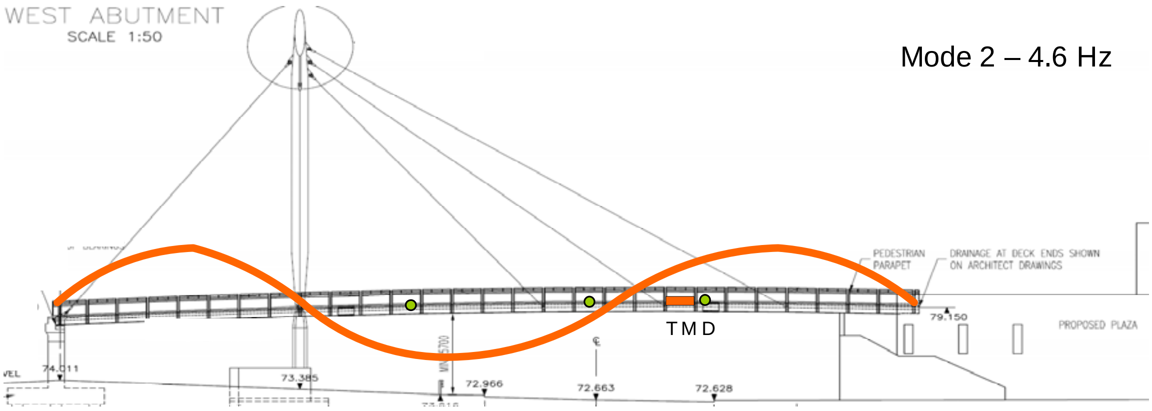

Fig. 5 Determined vertical mode shape for a natural frequency of 4.6 Hz

4. Occurring vibrations with blocked TMD and activated TMD

The occurring human induced vibrations for regular pedestrian traffic crossing the bridge were recorded with blocked and activated TMD. Figure 6 shows the time histories of the recorded vibrations at the most representative point MP1 for a duration of 102 seconds. The maximum vibration that have been determined with blocked TMD are about 45 mm/s which corresponds to an RMS acceleration value of 0.39 m/s². The maximum value of the occurring vibrations with activated TMD amounts to 12 mm/s which corresponds to an RMS acceleration value of 0.1 m/s².

The TMD has been adjusted for an effective frequency of 1.8 Hz after the relevant natural frequency of 1.95 Hz has been determined.

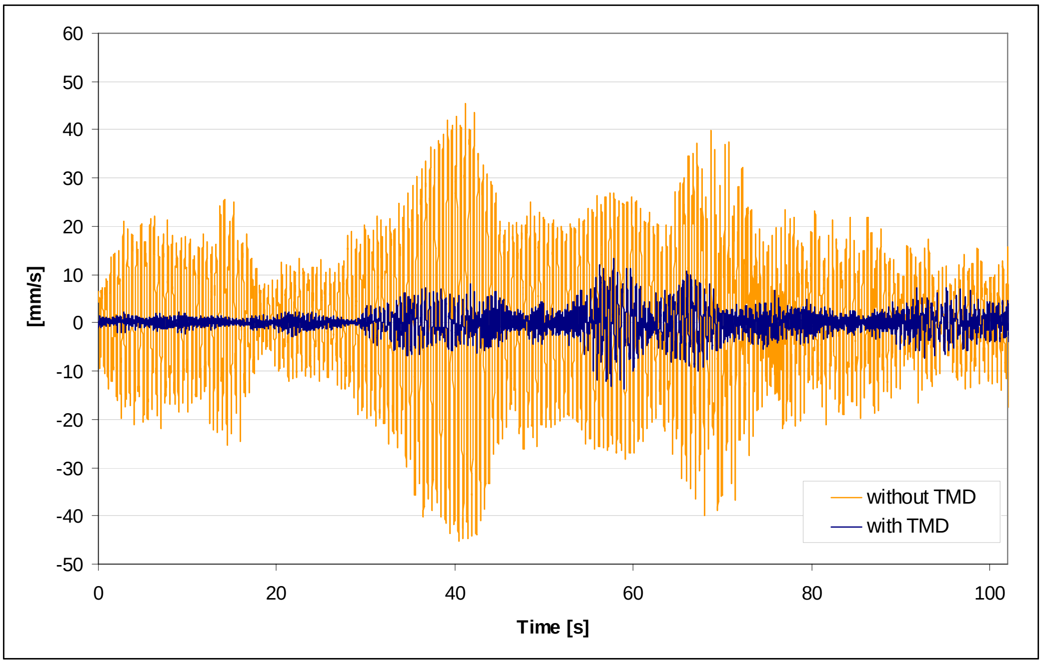

Fig. 6 Time histories of the recorded vibrations with blocked and activated TMD at the most representative point MP1 for a duration of 102 seconds

The occurring vibrations with activated TMD are significantly smaller (Factor 3.5) which means that the TMD effectively reduces human induced vibrations in the first relevant vertical mode.

The resulting vibrations of the bridge for human induced vibrations with an RMS acceleration value of 0.1 m/s² are smaller than the defined comfort criteria RMS-value of 0.35 m/s² for pedestrians and also of 0.21 m/s² for standing persons according to *ISO 10137: Basis for design of structures- Serviceability of buildings and walkways against vibrations.*

In addition, the vibrations after a resonance-like excitation through bouncing with a beat that corresponds to the natural frequency of the bridge (load case vandalism) were examined. Figure 7 shows the time histories of the recorded vibrations while 2 persons induce vibrations by bouncing with 120 bpm with blocked and activated TMD

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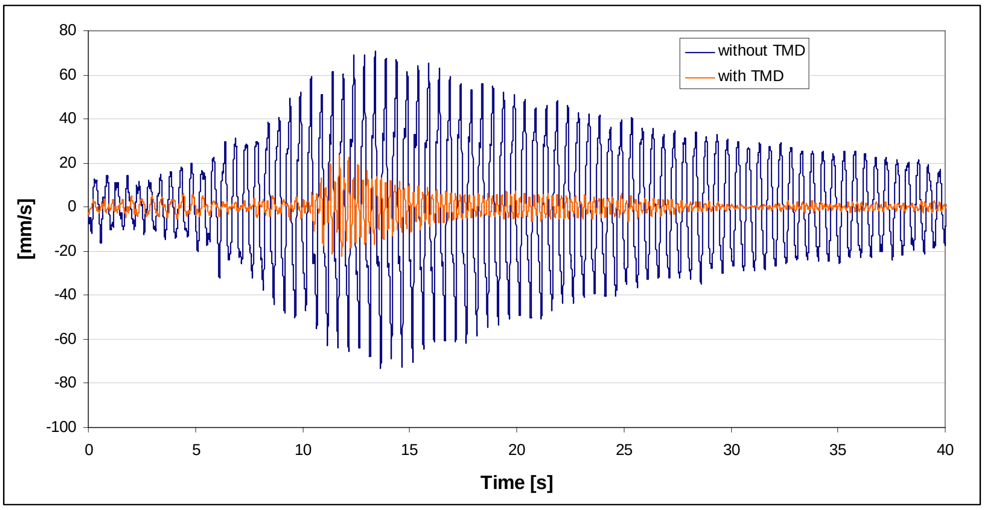

Fig. 7 Time histories of the recorded vibrations while 2 persons induce vibrations by bouncing with 120 bpm with blocked and activated TMD

Again, the reduction of the resulting vibration is apparent as well as the change in the decaying behaviour. The resulting vibrations with activated TMD abate much quicker than with blocked TMD. The maximum vibration values for this load case with activated TMDs are 22 mm/s which corresponds to a RMS acceleration value of 0.19 m/s². To estimate the amount of people, which might cause vibrations that are above the comfort criteria, the √n approximation can be applied. According to that 9 persons to cause vibrations that exceed the mentioned comfort criteria level.

5. Structural Damping Ratios

The effectiveness of the installed TMD can also be recognized by the increase of the structural damping for the relevant vertical mode. Therefore the decaying behaviour after resonance like excitation has been examined.

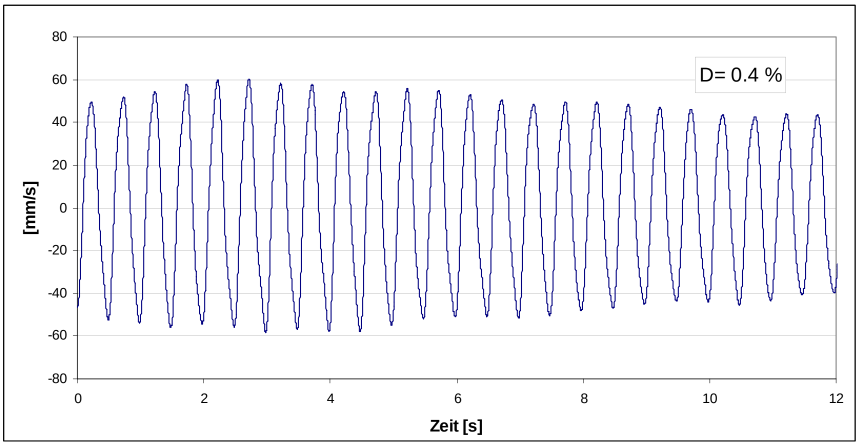

Fig. 8 Decaying behaviour with blocked TMD – determined structural damping D= 0.3 % (of crit. Damping)

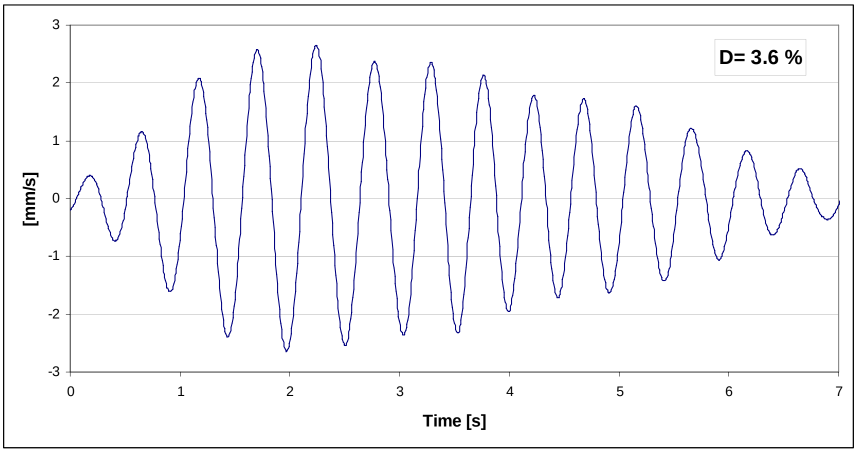

Fig. 9 Decaying behaviour with activated TMD – determined structural damping D= 3.6 % (of crit. Damping)

The figures 8 and 9 show the time histories of the recorded vibrations after an resonance-like excitation due to 2 persons bouncing with 120 bpm. The decaying behaviour was analyzed to determine the increase of structural damping of D=0.3 % to D= 3.6% due to the activation of the TMD.

6. Summary and Conclusion

Measurements were performed at the Eagles Meadow footbridge in Wrexham/UK to identify the as "perturbing" rated vibration state. To reduce the occurring vibrations a Tuned Mass Damper was installed. To fine-tune the applied system and to verify the applied TMD concept., another objective of the performed measurements was to identify the mode in which the pedestrian induced vibrations dominantly occur as well as the corresponding natural frequencies. To document the effectiveness of the TMD the occurring vibrations with blocked and activated TMD as well as the structural damping ratios for both cases were determined. Two modes could clearly be identified for a pedestrian load – for which the first vertical bending mode at 1.95 Hz was recognized as the relevant mode with a deflection maximum in range of the installed TMD. According to the identified natural frequency, the TMD was fine – tuned to a optimum tuning frequency of 1.8 Hz.

After activation of the TMD the occurring vibrations for a pedestrian load were significantly reduced. And the structural damping increased to D= 3.6 % of critical damping. The occurring vibrations for regular pedestrian traffic (RMS acceleration value: 0.1 m/s^2) are below the as a comfort criteria for pedestrians and standing persons in *ISO 10137: Basis for design of structures- Serviceability of buildings and walkways against vibrations* defined values.

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