Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

A simulation study on the optimal control of buffeting displacement for the Sutong Bridge with multiple tuned mass dampers

Keywords: Long-span cable-stayed bridge; Buffeting response; Vibration control; Multiple Tuned Mass Dampers (MTMD); Control efficiency

Cite this as: Wang Hao, Tao Tian-you, Cheng Huai-yu, Li Ai-qun, 2014. A simulation study on the optimal control of buffeting displacement for the Sutong Bridge with multiple tuned mass dampers. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 15(10):798-812. [doi:10.1631/jzus.A1400194]

Engineering Background

Sutong Cable-stayed Bridge

- Cable-stayed Bridge
- Length of span: 1088m
- Height of tower: 300.4m
- Longest cable: 577m

It was the longest cable-stayed bridge in the world when it was open to traffic in 2008.

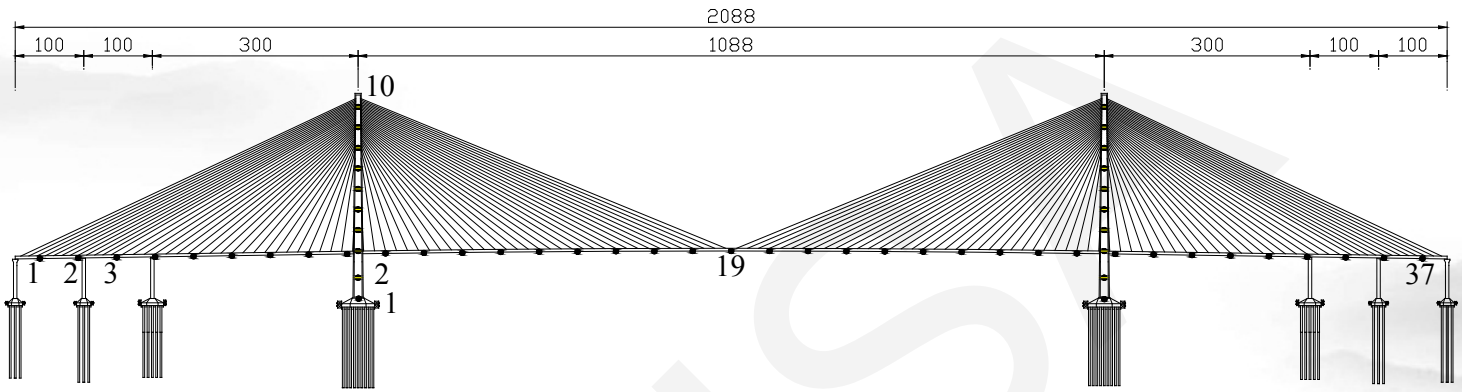
Geographic location

- Located in the lower reach of the Yangtze River

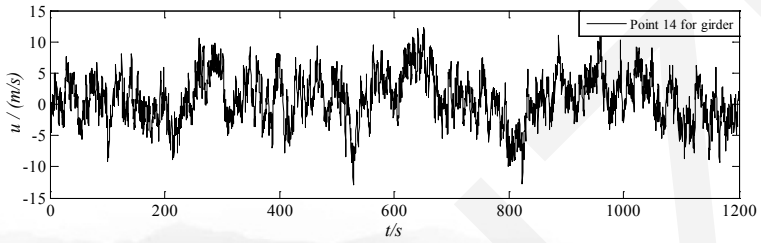
Climate feature

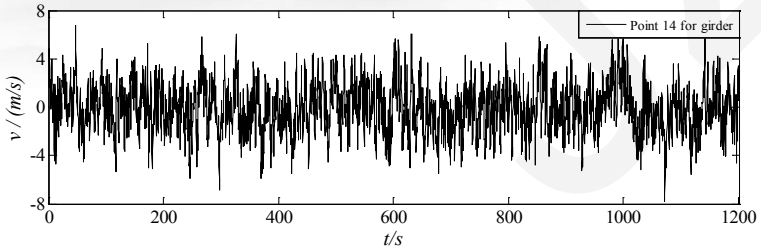
- Typhoon in summer
- Strong north wind in winter

Simulation of Fluctuating Wind Field



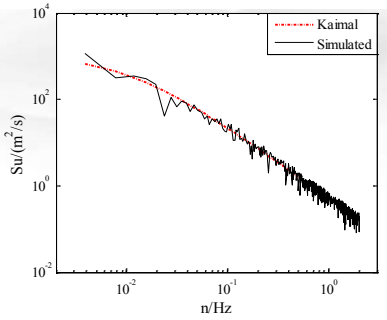
Distribution of the simulated points for the fluctuating wind of the SCB

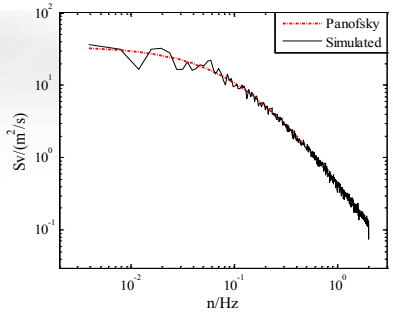


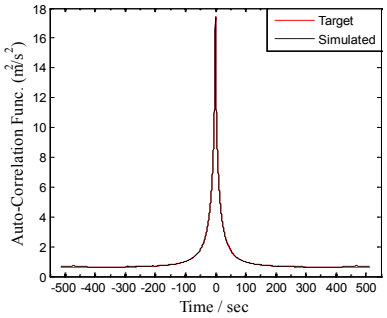


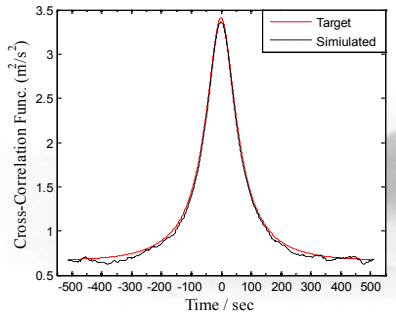
Simulated samples

Verification

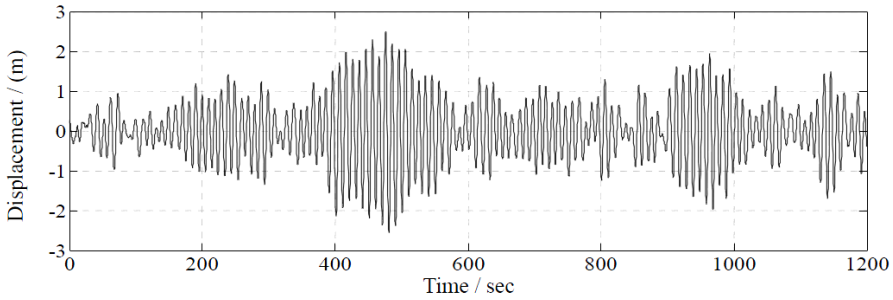




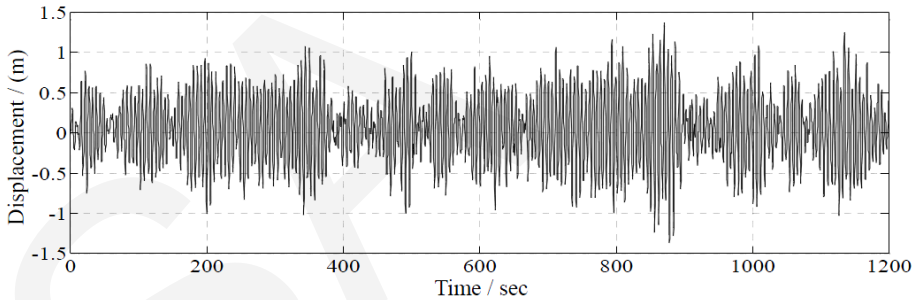




Time-domain Buffeting Analysis of the SCB



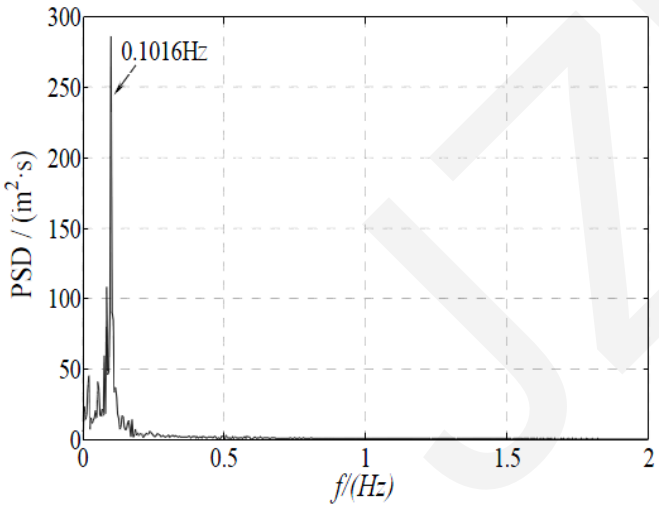
(a) Lateral



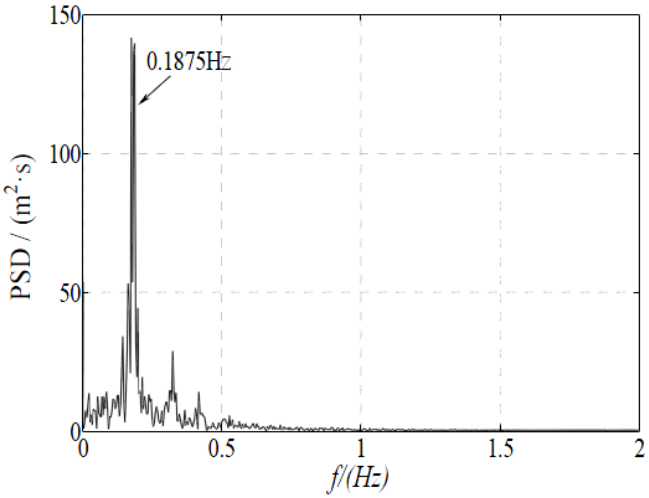
(b) Vertical

Buffeting displacement in the middle of the main span

FFT



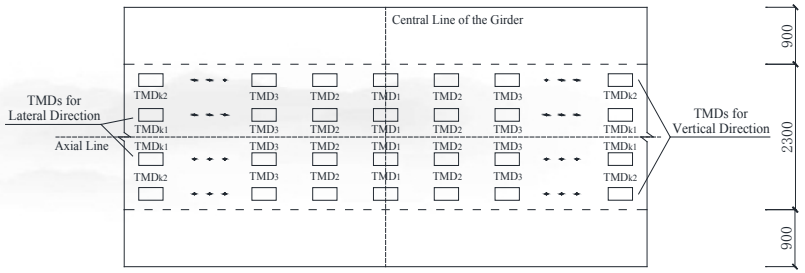
(a) lateral



(b) vertical

PSDs of buffeting displacements in the middle of the bridge deck

Application of MTMD in Buffeting Control of the SCB



Layout of TMDs on the main girder

Design parameters for MTMD

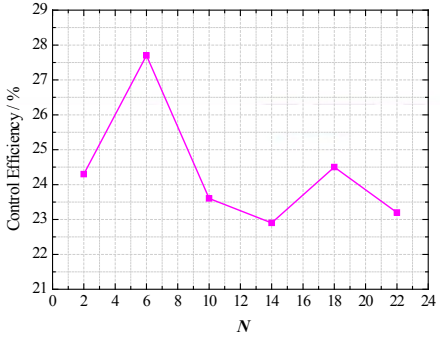
The mass ratio $\mu = \sum_{i=1}^{N} m_i \Big/ M$

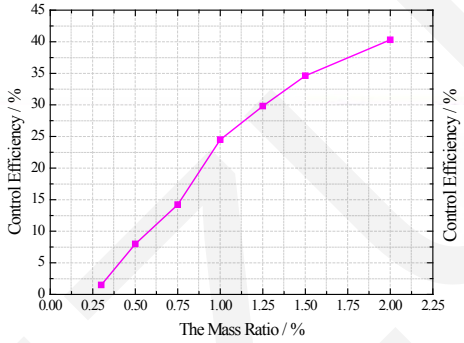
The central frequency $f_0 = \frac{1}{k}\sum_{i=1}^{k} f_i$

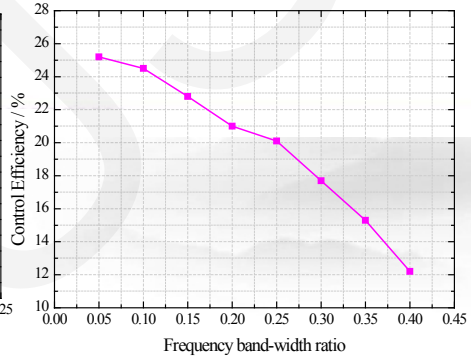
Frequency band-width ratio $\gamma = \frac{|f_k - f_1|}{f_s}$

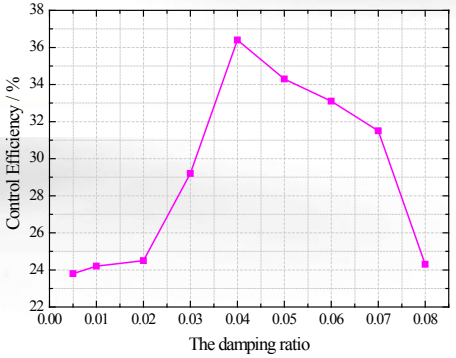
The control efficiency $\delta = \frac{\alpha - \beta}{\beta} \times 100\%$

Lateral direction

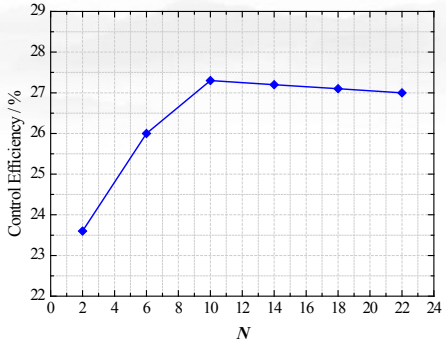


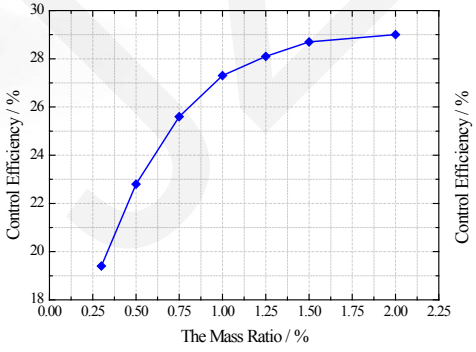


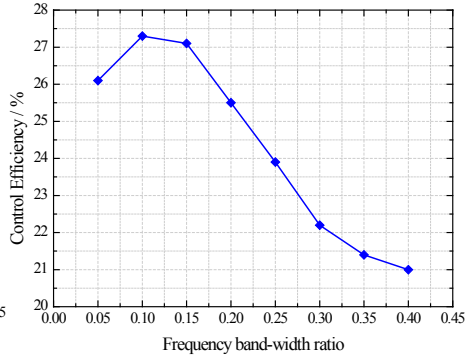


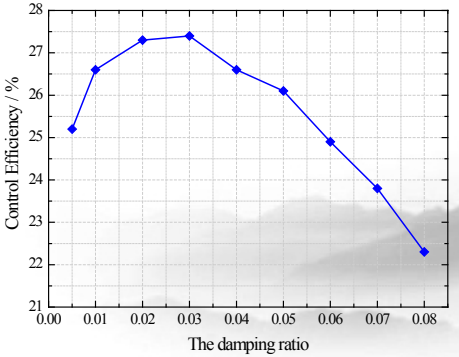


Vertical direction









Influence of design parameters on the control efficiency of MTMD

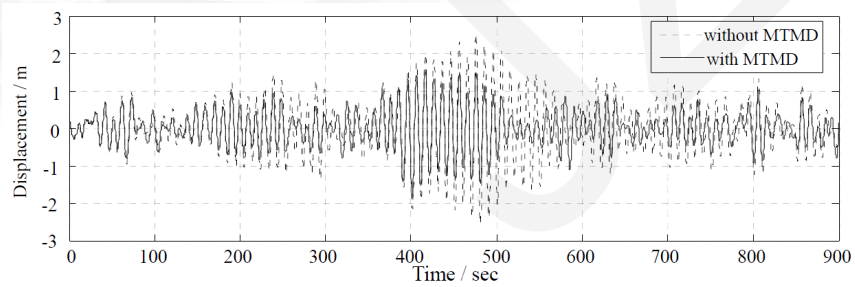
Application of MTMD in Buffeting Control of the SCB

Objective function

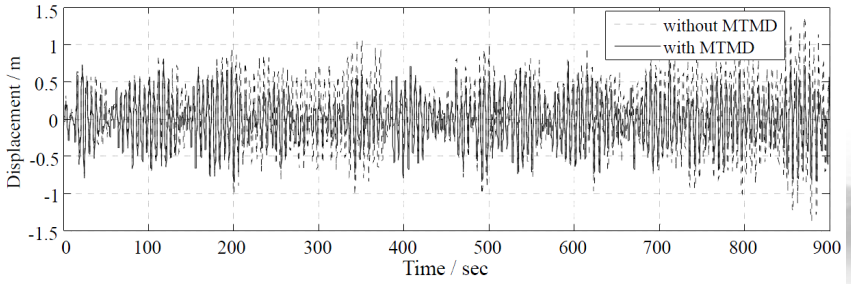
Minimize $$J = \frac{E(\mu,\zeta)C(N)}{F(\delta)R(N,\eta)}$$

General optimal parameters for the MTMD system on the SCB

Direction	Number of TMDs	Mass ratio	Damping ratio	Frequency band-width ratio
Lateral	18	1%	0.04	0.10
Vertical	10	1%	0.03	0.10



Lateral



Vertical

Buffeting displacements of the SCB with and without MTMD

Conclusions

- The PSDs of the buffeting displacements show that the first-order lateral bending mode dominates the lateral wind-induced buffeting responses of the SCB, and the first-order vertical bending mode dominates the vertical wind-induced buffeting responses.
- The control efficiency is sensitive to the parameters of MTMD including the number of TMD, mass ratio, frequency band-width ratio and damping ratio. The mass ratio and frequency band-width ratio are relatively sensitive among these influence parameters.
- By using the optimization module in ANSYS, the optimal parameters of the MTMD system on the SCB can be conveniently obtained based on the first-order optimization method. And the optimal results can then be verified by the zero-order optimization method.
- Both the vertical and the lateral vibrations can be effectively controlled when the optimal design parameters of MTMD system are used. And the lateral MTMD system performs a better control effect than the vertical MTMD system, which has been proved in both time-domain and frequency-domain. Therefore, MTMD systems with optimal mechanical parameters are thought to be an efficient method to suppress buffeting responses of the SCB.