

## **MOTION-BASED DESIGN OF ACTIVE TUNED MASS DAMPERS TO CONTROL PEDESTRIAN-INDUCED VIBRATIONS IN FOOTBRIDGES UNDER UNCERTAINTY CONDITIONS**

**Javier Fernando Jiménez-Alonso<sup>1</sup>, José Manuel Soria<sup>2</sup>, Carlos Martín de la Concha Renedo<sup>3</sup> and Francisco Guillen González<sup>4</sup>**

<sup>1-3</sup> Department of Continuum Mechanics and Structures. Universidad Politécnica de Madrid  
Profesor Aranguren, 3, 28040 Madrid (Spain)  
e-mail: {jf.jimenez, jm.soria, carlos.martindelaconcha}@upm.es

<sup>4</sup> Department of Differential Equations and Numerical Analysis. Universidad de Sevilla  
Calle Tarifa, s/n, 41002 Seville (Spain)  
guillen@us.es

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**Abstract.** *Two key aspect must be considered for the design of modern footbridges: (i) their sensitivity to human-induced vibrations; and (ii) the influence of the variation of the operational and environmental conditions on their modal properties. One possible option, to guarantee an adequate behavior of these structures under both conditioning factors, is the installation of a control system. Among the different systems, active damping devices have shown a great effectiveness when they are used to control the dynamic response of civil engineering structures under uncertainty conditions. Different design algorithms have been proposed to guarantee that structures, controlled by these damping devices, meet the design requirements without compromising the budget. Among these proposals, the motion-based design method has shown a high performance when it has been implemented to design passive damping devices for footbridges under uncertainty conditions. Herein, this design method has been adapted and further implemented for the robust optimum design of active tuned mass dampers when they are employed to control the human-induced vibrations in slender footbridges. According to this method, the design problem can be transformed into two coupled sub-problems: (i) a multi-objective optimization sub-problem; and (ii) a reliability analysis sub-problem. Thus, the main objective is to find the parameters of the active damping device which guarantee an adequate comfort level without compromising its cost. The compliance of this vibration serviceability limit state is computed via a reliability index (related to the probability of failure), which takes into account the effect of the variation of the operational and environmental conditions on the modal properties of the structure.*

## 1 INTRODUCTION

Modern footbridges have experienced an increase in their slenderness due to both the improvement of the strength of the construction materials and the aesthetic requirements of the current societies [1]. Accordingly, this higher slenderness has enhanced the sensitivity of these structures to two phenomena: (i) the human-structure interaction [2]; and (ii) the variability of their modal properties due to the modification of the operational and environmental conditions [3].

In order to overcome these limitations, external damping devices have been widely installed on these structures to guarantee their robust structural behavior during their overall life cycle [4]. Among these damping devices, active control systems have shown a high effectiveness when they have been used to control the dynamic response of civil engineering structures under stochastic conditions [5]. Different algorithms and control laws have been proposed to perform successfully the design process of these damping devices [6]. Among the different approaches, the motion-based design method [7] under a stochastic approach is presented and further implemented herein to design active tuned mass dampers (ATMD) when they are used to control the human-induced vibrations in slender footbridges under uncertainty conditions. Thus, the main contribution of this study is to adapt the abovementioned method, which has been previously implemented for the design of passive tuned mass dampers [8], for the design of ATMDs.

According to this method, the design problem may be transformed into two coupled sub-problems: (i) a multiple-objective optimization sub-problem [9]; and (ii) a reliability analysis sub-problem [10]. The multiple-objective function of the first sub-problem is defined in terms of two different elements: (i) the parameters of the ATMD, which are needed to be determined; and (ii) the design requirements of the structure which are needed to be met [2]. As the main objective of this design process is to control the human-induced vibrations in footbridges, the design requirements may be defined in terms of the comfort level of the structure. Thus, these design requirements are met if the maximum acceleration of the structure is lower than an allowable acceleration established by the designer [2]. Additionally, the aforementioned design requirements have been re-formulated based on a probabilistic approach due to the sensitivity of the modal properties of the structure to the variation of the operational and environmental conditions [11]. According to this approach, the design requirements are met if a reliability index,  $\beta$ , which reflects the probability of compliance of the mentioned vibration serviceability limit state (VSLS), is greater than an allowable reliability index,  $\beta_{lim}$  [10]. Sampling techniques are usually considered to compute this reliability index [10]. Herein a conventional Monte Carlo simulation has been considered [10]. Finally, the performance of the proposed algorithm has been validated via the analysis of a numerical case-study [2]. Concretely, the VSLS of a steel footbridge under uncertainty conditions has been met via the installation of an ATMD designed according to the proposed algorithm.

The paper is organized as follows. In section 2, the mathematical model of the ATMD-footbridge interaction system is formulated and its dynamic response under pedestrian action is computed numerically in time domain. Subsequently, in section 3, the motion-based design method under a stochastic approach is described in detail. Later, in section 4, a numerical case-study is presented to assess the performance of the proposed method when it is implemented for the design of an ATMD used to control the dynamic response of a steel footbridge under pedestrian action. Finally, some concluding remarks are included in section 5 to finish the paper.

## 2 ACTIVE TUNED MASS DAMPER-FOOTBRIDGE INTERACTION MODEL UNDER PEDESTRIAN LOAD

In order to design an active damping device, according to the mentioned proposal, the dynamic response of an ATMD-footbridge interaction system under pedestrian action must be computed numerically. Thus, four steps must be given: (i) the formulation of the ATMD-footbridge interaction model; (ii) the definition of the pedestrian load; (iii) the selection of the control law which defines the driving force; and (iv) the numerical integration of the equations of motion which governs the ATMD-footbridge interaction model.

For the formulation of the ATMD-footbridge interaction model, the following assumptions have been considered herein: (i) the dynamic response of the structure may be approached (modal coordinates) by a single vibration mode [6], since it is assumed that only a vibration mode is prone to suffer from human-induced vibrations; (ii) the ATMD is modelled via a single degree of freedom system (physical coordinates) [5]; (iii) the pedestrian load is simulated by an equivalent harmonic load [2]; and (iv) the ATMD is located at the point with the maximum modal displacement. Figure 1 shows a scheme of the ATMD-footbridge interaction model.

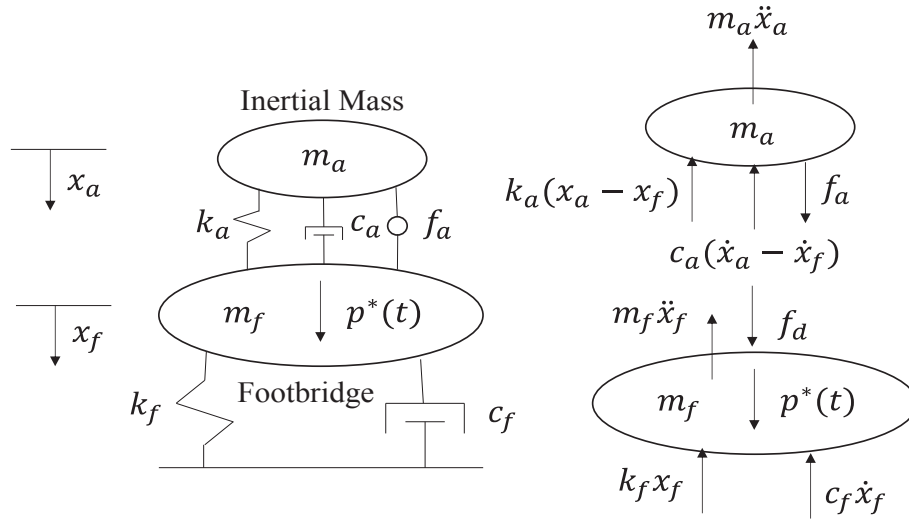


Figure 1: The ATMD-footbridge interaction model.

Thus, the equations of motion of the ATMD-footbridge interaction model can be obtained via the implementation of the second Newton's law to the two masses (ATMD and equivalent modal mass). These equations may be expressed as follows:

$$m_f \ddot{x}_f(t) + c_f \dot{x}_f(t) + k_f x_f(t) = p^*(t) + f_d(t) \quad (1)$$

$$m_a \ddot{x}_a(t) + c_a (\dot{x}_a(t) - \dot{x}_f(t)) + k_a (x_a(t) - x_f(t)) = f_a(t) \quad (2)$$

$$f_d(t) = c_a (\dot{x}_a(t) - \dot{x}_f(t)) + k_a + k_a (x_a(t) - x_f(t)) - f_a(t) = -m_a \ddot{x}_a(t) \quad (3)$$

where  $m_f$  [kg],  $c_f$  [sN/m] and  $k_f$  [N/m] are respectively the mass, damping and stiffness of the considered vibration mode of the footbridge;  $p^*(t) = \phi^T p(t)$  [N] is the projection of the pedestrian load on the considered vibration (being  $p(t)$  the pedestrian load [N],  $\phi$  the considered vibration mode and  $^T$  the transpose function);  $\ddot{x}_f(t)$  [m/s<sup>2</sup>],  $\dot{x}_f(t)$  [m/s] and  $x_f(t)$  [m] are respectively the acceleration, velocity and displacement of the footbridge;  $m_a$  [kg],  $c_a$  [sN/m] and  $k_a$  [N/m] are respectively the mass, damping and stiffness of the ATMD;  $\ddot{x}_a(t)$

$[m/s^2]$ ,  $\dot{x}_a(t)$   $[m/s]$  and  $x_a(t)$   $[m]$  are respectively the acceleration, velocity and displacement of the ATMD;  $f_a(t)$   $[N]$  is the driving force generated by the actuator of the ATMD; and  $f_d(t)$   $[N]$  is the control force generated by the ATMD.

These equations can be re-organized in matrix form as follows:

$$\begin{bmatrix} m_f & 0 \\ 0 & m_a \end{bmatrix} \begin{Bmatrix} \ddot{x}_f(t) \\ \ddot{x}_a(t) \end{Bmatrix} + \begin{bmatrix} c_f + c_a & -c_a \\ -c_a & c_a \end{bmatrix} \begin{Bmatrix} \dot{x}_f(t) \\ \dot{x}_a(t) \end{Bmatrix} + \begin{bmatrix} k_f + k_a & -k_a \\ -k_a & k_a \end{bmatrix} \begin{Bmatrix} x_f(t) \\ x_a(t) \end{Bmatrix} = \begin{Bmatrix} 1 \\ 0 \end{Bmatrix} p^*(t) + \begin{Bmatrix} -1 \\ 1 \end{Bmatrix} f_a(t) \quad (4)$$

$$[M]\{\ddot{x}(t)\} + [C]\{\dot{x}(t)\} + [K]\{x(t)\} = \{B_0\}p^*(t) + \{B_c\}f_a(t) \quad (5)$$

where  $[M] = \begin{bmatrix} m_f & 0 \\ 0 & m_a \end{bmatrix}$  is the mass matrix;  $[C] = \begin{bmatrix} c_f + c_a & -c_a \\ -c_a & c_a \end{bmatrix}$  is the damping matrix;  $[K] = \begin{bmatrix} k_f + k_a & -k_a \\ -k_a & k_a \end{bmatrix}$  is the stiffness matrix;  $\{B_0\}$  is the input vector associated with the pedestrian load;  $\{B_c\}$  is the input vector associated with the driving force;  $\{\ddot{x}(t)\}$  is the acceleration vector;  $\{\dot{x}(t)\}$  is the velocity vector and  $\{x(t)\}$  is the displacement vector.

In order to integrate this equation system and make easier the determination of the driving force,  $f_a(t)$ , the abovementioned equation system must be transformed into a state space formulation [6]. According to this formulation, the dynamic behavior of a linear invariant system may be expressed by the following differential equation system with initial conditions ( $\{z(0)\} = z_0$ ):

$$\{\dot{z}(t)\} = [A]\{z(t)\} + [B]\{p^*(t)\} + [B]\{f_a(t)\} \quad (6)$$

$$\{y(t)\} = [E]\{z(t)\} + [D]\{f_a(t)\} \quad (7)$$

where  $\{z(t)\}$  is the state vector;  $\{y(t)\}$  is the output vector;  $[A]$  is the system matrix;  $[B]$  is the input matrix;  $[E]$  is the output matrix; and  $[D]$  is the feedthrough matrix [6]. It is possible via matrix transformations to convert the abovementioned equation system into its state space formulation [6]. The state space matrices can be defined as:

$$[A] = \begin{bmatrix} 0 & I \\ -[M]^{-1}[K] & -[M]^{-1}[C] \end{bmatrix} \quad (8)$$

$$[B] = \begin{bmatrix} 0 \\ -[M]^{-1}\{B_i\} \end{bmatrix} \text{ where } \{B_i\} = \begin{cases} \{B_0\} & \text{for } p^*(t) \\ \{B_c\} & \text{for } f_a(t) \end{cases} \quad (9)$$

$$[E] = -[E_a][[M]^{-1}[K] \quad [M]^{-1}[C]] \quad (10)$$

$$[D] = [E_a][M]^{-1}[B] \quad (11)$$

where the state vector  $\{z(t)\} = \{x_f(t) \quad x_a(t) \quad \dot{x}_f(t) \quad \dot{x}_a(t)\}$  is defined in terms of the displacements and velocities of both the footbridge and the ATMD; and the output vector,  $\{y(t)\}$ , is defined in terms of the accelerations experienced by the footbridge (being  $[E_a]$  the acceleration matrix which indicates the elements in which the acceleration is computed).

In order to obtain the response of this state space equation system both the pedestrian force,  $p(t)$ , and the driving force,  $f_a(t)$ , which simulates the behavior of the actuator of the ATMD, must be defined.

The pedestrian force,  $p(t)$ , has been simulated based on the recommendations of the French guidelines [2]. Only the vertical contribution of the walking pedestrian action has been considered herein. According to these guidelines, the walking pedestrian action,  $p(t)$ , can be determined via an equivalent harmonic force defined as follows:

$$p(t) = 280 \cdot \cos(2\pi \cdot f_f \cdot t) \cdot n_{eq} \cdot \psi \quad (12)$$

where  $f_f$  [Hz] is the natural frequency of the considered vibration mode of the structure;  $n_{eq}$  [-] is the equivalent number of pedestrians; and  $\psi$  is a reduction factor which takes into account the probability that the natural frequency is within the range which characterizes the human-structure interaction in vertical direction ( $1.25 \leq f_f \leq 2.3$  Hz) [2].

The driving force,  $f_a(t)$ , is determined via the implementation of a feedback controller to the above mentioned system in the state space [6]. Figure 2 shows the general layout of the feedback controller considered.

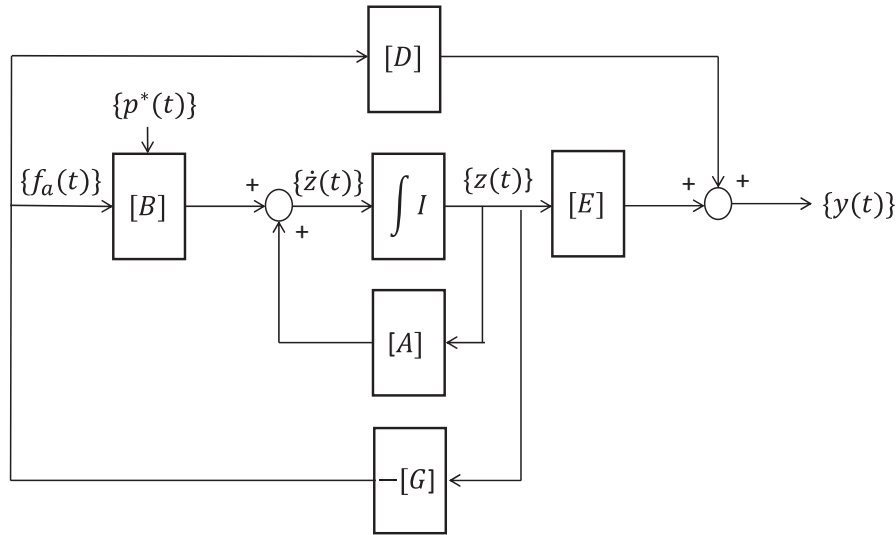


Figure 2: Design of a feedback controller in a state space formulation [6].

The implementation of this feedback controller allows modifying the system equation as follows:

$$\{\dot{z}(t)\} = [A]\{z(t)\} + [B_0]\{p^*(t)\} + [B_c]\{f_a(t)\} \quad (13)$$

where  $[B_0]$  and  $[B_c]$  are obtained from equation (9) considering as pattern load vectors  $\{B_0\}$  and  $\{B_c\}$  respectively.

Thus, according to the feedback controller (Figure 2), the driving force,  $f_a(t)$ , may be determined in terms of a gain matrix,  $-[G]$ , and the state vector,  $\{z(t)\}$ . Thus, the system equation may be expressed as:

$$\{\dot{z}(t)\} = [A]\{z(t)\} + [B_0]\{p^*(t)\} - [B_c][G]\{z(t)\} \quad (14)$$

$$\{\dot{z}(t)\} = ([A] - [B_c][G])\{z(t)\} + [B_0]\{p^*(t)\} \quad (15)$$

There are several algorithms [6] to determine the value of the gain matrix,  $-[G]$ . Among these algorithms, the linear quadratic regular (LQR) method [6] has been considered herein due to its extensive use for practical engineering applications [5]. According to this method, the

value of the gain matrix,  $-[G]$ , is obtained via the minimization of the following performance-index function,  $J$ :

$$J = \int_0^{\infty} [\{z(t)\}^T [Q] \{z(t)\} + \{[G]\{z(t)\}\}^T [R] \{[G]\{z(t)\}\}] dt \quad (16)$$

where  $[Q]$  and  $[R]$  are two weighting matrices which may be computed in terms of the mass,  $[M]$ , and stiffness,  $[K]$ , matrices of the interaction model [6]. According to the recommendations of several authors [6], the weighting matrices may be determined as follows:

$$[Q] = \alpha_d \begin{bmatrix} [K] & 0 \\ 0 & [M] \end{bmatrix} \quad (17)$$

$$[R] = \beta_d [I] \quad (18)$$

where  $\alpha_d$  [-] and  $\beta_d$  [-] are the weighting factors; and  $[I]$  is the identity matrix. In this manner, once the value of these factors has been fixed, the value of the different element of the gain matrix,  $-[G]$ , which minimizes the value of the performance-index function,  $J$ , is obtained.

Subsequently, the response of the ATMD-footbridge interaction model has been obtained via the integration of the abovementioned state space system using a Runge-Kutta method, as it is implemented in the Matlab software [12].

Therefore, an adequate value of the driving force,  $f_a(t)$ , is obtained via the adjustment of the value of the weighting factors,  $\alpha_d$  and  $\beta_d$ . For this purpose, the following iterative process must be addressed: (i) to develop a linear model of the ATMD-footbridge interaction model in the state space domain (where the value of the mass and stiffness of the ATMD are fixed); (ii) to adjust the value of the weighting matrices,  $[Q]$  and  $[R]$  in terms of an original value of the weighting factors,  $\alpha_d$  and  $\beta_d$ ; (iii) to determine an optimum value of the driving force,  $f_a(t)$ , via the minimization of the performance-index function,  $J$ ; (iv) to simulate numerically the response of the linear system; and (v) to modify the values of the weighting factors,  $\alpha_d$  and  $\beta_d$ , and repeat the steps (ii) to (iv) until the dynamic response of the footbridge meets the design requirements established by the designer [2].

### 3 MOTION-BASED DESIGN UNDER UNCERTAINTY CONDITIONS

The aforementioned control algorithm has been hybridized with the motion-based design method under uncertain conditions [8] to improve the performance of the design process of active damping devices. The performance-based design method [13] transforms the design problem into two coupled sub-problems: (i) a multi-objective optimization sub-problem; and (ii) a reliability analysis sub-problem. Thus, the main objective of this design problem is to determine the parameters of the ATMD that, minimizing its cost, ensures the compliance of the design requirements [2]. As the design requirements, which need to be accomplished, are defined in terms of the accelerations of the structure,  $\ddot{x}_f(t)$ , this design process may be understood as a motion-based design optimization method [7].

Therefore, the general formulation of the proposed method may be expressed as follows [13]:

$$\begin{aligned} & \text{Find } \theta_i \quad i = 1, \dots, n_d \\ & \text{Minimizing } \mathbf{f}(\theta_i) = [f_1(\theta_i) \quad \dots \quad f_j(\theta_i) \quad \dots \quad f_{n_f}(\theta_i)] \\ & \text{Subjected to } \theta_i^l \leq \theta_i \leq \theta_i^u \end{aligned} \quad (19)$$

where  $\mathbf{f}(\theta_i)$  is the multi-objective function;  $f_j(\theta_i)$  is the  $j^{th}$  terms of the multi-objective function;  $n_f$  is the number of terms of multi-objective function;  $\theta_i$  is the  $i^{th}$  design variable;  $\theta_i^l$  is the lower bound of the  $i$ th design variable;  $\theta_i^u$  is the upper bound of the  $i$ th design variables, and  $n_d$  is the total number of design variables.

For this case, the design of an ATMD, the above multi-objective function may be formulated in terms of two aspects: (i) the different parameters of the ATMD; and (ii) the compliance of the VSLS of the footbridge. According to the most advances guidelines [2], the VSLS is met if the maximum acceleration of the structure,  $\ddot{x}_f(t)$ , is lower than an allowable value,  $\ddot{x}_{lim}$ , established by the designer [2].

Additionally, in order to take into account the random character of the modal properties of the footbridge, which are sensitive to the variation of the operational and environmental conditions [3], the VSLS is re-formulated via a probabilistic approach [10]. According to this approach, the modal properties of the footbridge are assumed to be random variables which follow a normal probability distribution function. Hence, the response of the system is also a random variable, and it is possible to determine the probability of failure associated with the compliance of the different design requirements (in this case, the VSLS). According to this, the VSLS is defined in terms of a reliability index,  $\beta$ , which reflects the probability of failure associated with the compliance of this limit state. Thus, the limit state is met if this reliability index,  $\beta$ , is greater than an allowable value,  $\beta_{lim}$ , established by the design guidelines [14]. In order to compute the reliability index,  $\beta$ , analytical and numerical method can be used [11]. Among these methods, a Monte Carlo simulation has been considered herein [10].

In order to establish the formulation of this design problem, based on the motion-based design, the design parameters must be determined. For this particular case, five are the design variables: (i) the mass ratio of the ATMD,  $\mu = m_a/m_f$  [-]; (ii) the frequency ratio of the ATMD,  $\delta = f_d/f_f$  [-] (where  $f_d$  [Hz] is the natural frequency of the ATMD); (iii) the damping ratio of the ATMD,  $\zeta_a$ ; and (iv) the weighting factors,  $\alpha_d$  and  $\beta_d$  (which characterize the driving force,  $f_a(t)$ ). In order to reduce the number of design variables, simplifying the problem, a hybrid strategy has been considered herein [2]. Thus, both the frequency,  $\delta$ , and damping,  $\zeta_a$ , ratios of the ATMD have been established according to a conventional criterion for the design of passive tuned mass dampers [2]. According to this, the frequency ratio of the ATMD is set as,  $\delta = 1/(1 + \mu)$ ; and the damping ratio of the ATMD is set as,  $\zeta_a = \sqrt{3\mu/(8(1 + \mu))}$ .

In this manner, the formulation of the motion-based design method under uncertainty conditions for this particular problem can be formulated as follows:

$$\begin{aligned} &\text{Find } \mu, \alpha_d, \beta_d \\ &\text{Minimizing } \{\mathbf{f}(\mu, \alpha_d, \beta_d)\} = \{f_1(\mu) \quad f_2(\mu, \alpha_d, \beta_d)\} = \{\mu \quad \frac{\beta_{lim}}{\beta}\} \\ &\text{Subjected to } \mu \in [0.01 \ 0.10] \ \alpha_d \in [10 \ 1000] \ \beta_d \in [10^{-5} \ 10^{-8}] \end{aligned} \quad (20)$$

Subsequently, in order to solve this optimization problem, global optimization algorithms are normally employed due to their good efficiency to find optimum solutions in nonlinear optimization problems [13]. Among these computational algorithms, a nature-inspired computational algorithm, genetic algorithms, has been considered herein [9]. As result of this optimization process, a set of non-dominated solutions is obtained [9]. This set of solutions may be represented in a functional space, generating the so-called Pareto front [9]. Finally, a subsequent decision-making problem must be addressed, the selection of the best solution among the dif-

ferent elements of the Pareto front. Therefore, an additional condition,  $\beta_{lim}/\beta$ , has been included herein to select the best element of the Pareto front. Figure 3 illustrates the additional condition considered to solve the decision-making problem.

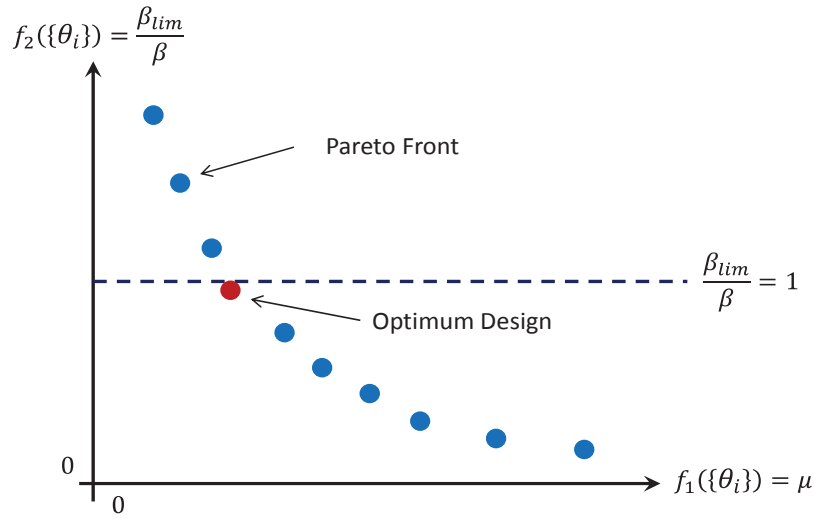


Figure 3: Additional condition considered to solve the decision-making problem.

#### 4 APPLICATION EXAMPLE: MOTION-BASED DESIGN OF AN ATMD FOR A VIBRATING FOOTBRIDGE UNDER UNCERTAINTY CONDITIONS

In order to illustrate the performance of the motion-based design method, when it is implemented to design ATMDs for vibrating footbridges under uncertainty conditions, the following numerical case-study is presented. Thus, the compliance of the VSLs of a numerical footbridge is guaranteed via the installation of an ATMD. A detailed description of this numerical footbridge can be found in the French guidelines [2]. The structural behavior of the structure has been simulated via the finite element (FE) method. The FE package Ansys [15] has been used for this purpose. A numerical model using 646 beam elements and 540 shell elements (BEAM188 and SHELL181 respectively) has been built (Figure 4). A structural damping ratio of  $\zeta_f = 0.6\%$  has been considered [2]. The numerical modal parameters of the footbridge have been obtained via a numerical modal analysis. As result of this analysis, it was checked that the first vertical vibration mode ( $f_f = 2.14$  Hz) is prone to vibrate under pedestrian action (Figure 4). The modal mass,  $m_f$ , of this vertical vibration mode is about 34706 kg.

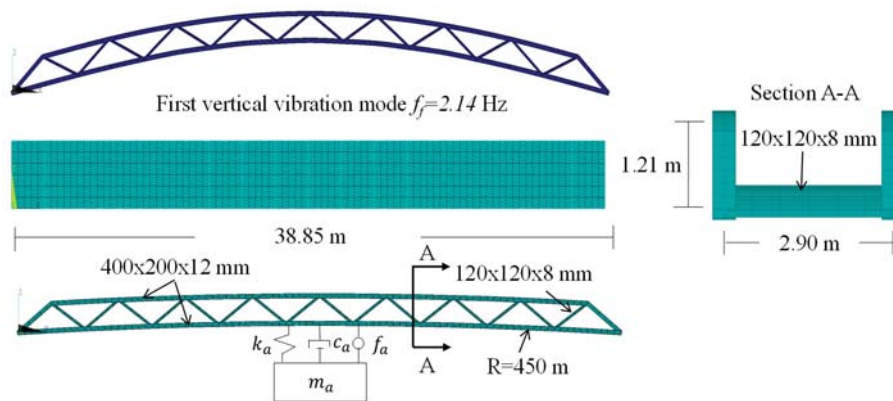


Figure 4: FE model of the benchmark footbridge and first vertical vibration mode.

In order to check the VSLS of this footbridge, the recommendations of the French guidelines [2] have been considered herein. Thus, one design scenario has been taken into account with the following design parameters: (i) a pedestrian traffic of  $1 \text{ P/m}^2$  [2]; (ii) an allowable vertical acceleration,  $\ddot{x}_{lim}$ , of  $1.00 \text{ m/s}^2$  [2]; and (iii) an allowable reliability index,  $\beta_{lim}$ , of 1.5 [14]. If this requirement is not met, an ATMD must be installed to reduce the amplitude of the human-induced vibrations according to the mentioned thresholds. According to the results provided by several researchers [3], a range of variation of  $\pm 10\%$  has been considered for both the first vertical natural frequency of the footbridge and its associated damping ratio. Consequently, it has been checked that the VSLS term of the multi-objective function is a random variable which follows a log-normal probability distribution. In order to obtain the reliability index,  $\beta$ , associated with the VSLS of the footbridge, a Monte Carlo simulation has been performed [10]. For the selection of the sample size (50000 simulations), a convergence analysis has been carried out. The mathematical package Matlab [12] has been employed for this study.

As result of this study, Table 1 shows the reliability index,  $\beta$ , associated with the VSLS without and with the ATMD. As Table 1 shows, the motion-based design method allows control the dynamic response of the footbridge under uncertainty conditions without compromising the cost of the control system. Additionally, the parameters of the ATMD designed according to this method have been included in Table 1.

ATMD	$\ddot{x}_f$ [m/s <sup>2</sup> ]	$\beta$ [-]	$\alpha_d$ [-]	$\beta_d \times 10^{-8}$ [-]	$m_a$ [kg]	$c_a$ [sN/m]	$k_a \times 10^5$ [N/m]	$f_a$ [N]
No	---	-0.53	---	---	---	---	---	---
Yes	1.00	1.50	511.30	344.19	625	1343	1.09	286

Table 1: Reliability index,  $\beta$ , of the VSLS of the footbridge (without and with ATMD)..

## 5 CONCLUSIONS

In this manuscript, the motion-based design method has been presented and further implemented for the design of ATMDs when they are used to mitigate the human-induced vibrations in footbridges under uncertainty conditions. According to this method, the design problem may be formulated via two coupled sub-problems: (i) a multi-objective optimization sub-problem; and (ii) a reliability analysis sub-problem. Thus, the multi-objective function is defined in terms of two aspects: (i) the parameters of the ATMD which are needed to be determined; and (ii) a reliability index, which establishes the probability of compliance of the VSLS of the structure. Sampling techniques, as the Monte Carlos simulation method, can be employed to estimate numerically this reliability index. As application example, a steel footbridge, which is prone to vibrate due to walking pedestrian action, has been selected. In order to mitigate the pedestrian-induced vibrations, an ATMD has been installed at its mid-span. The ATMD parameters have been obtained via the implementation of the aforementioned method. As result of this study, the performance of the proposed method has been shown up. In spite of its good performance, further studies are needed, both to better characterize the probabilistic distribution function of the different modal properties of the structure; and to assess experimentally the performance of structures controlled by active damping devices designed according to this proposal.

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