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OPTIMUM DESIGN OF ROCKING WALL COUPLED WITH BUILDING UNDER STOCHASTIC SEISMIC GROUND MOTION

Michela De Angelis[1], Giuseppe Quaranta[2], Giulia Angelucci[1], Stefano Pampanin[2], and Fabrizio Mollaioli[1]

[1] Department of Structural and Geotechnical Engineering, Sapienza University of Rome
Via Gramsci 53, 00197 Rome, Italy
e-mail: {michela.deangelis,fabrizio.mollaioli}@uniroma1.it

[2] Department of Structural and Geotechnical Engineering, Sapienza University of Rome
Via Eudossiana 18, 00184 Rome, Italy
e-mail: {giuseppe.quaranta,stefano.pampanin}@uniroma1.it

Abstract. *Coupling with rocking walls is a possible approach to protect buildings against earthquakes. In fact, previous studies have demonstrated that such strategy can mitigate the seismic damage and also prevent soft-story collapse mechanisms due to excessive drifts or displacements. In this regard, the use of special devices connecting the building and the rocking wall can further enhance the dissipation of the input seismic energy. Within this framework, the present work aims at providing some insights about the optimum design of rocking walls for seismic protection of building by means of a semi-analytical formulation. To this end, in a first stage the dynamics of the building is reduced to a linear-elastic and viscously damped single-degree-of-freedom system. A linear elastic spring and a linear viscous device provide the coupling between the main system and the rocking wall, which is connected at the base mid-width through a linear elastic rotational spring and a rotational dashpot. The dynamics of such coupled system under earthquake is analyzed by simulating the seismic ground motion as time-modulated filtered white Gaussian noise. Once the differential equations governing the dynamics of the resulting coupled system are derived, the optimum design problem is formulated. The numerical results highlight the performance of this seismic protection strategy and provide useful information for its preliminary optimum design.*

Keywords: Optimum design, Random vibrations, Rocking wall, Seismic Protection.

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1 INTRODUCTION

The concept of coupling a moment resisting frame with a (more) rigid system in order to reduce its lateral response goes back to the '70s [1, 2]. In the same period, Kelly et al. [3] first proposed the use of rocking shear walls together with energy dissipation devices for the seismic protection of moment-resisting frames. Next, the PRESSS program [4] had the merit of further developing and spreading the concept of uplifting and controlled rocking of un-bonded post-tensioned shear wall system as effective seismic protection strategy [5–7]. Advanced rocking wall solutions have been presented by Marriott et al. [8, 9], Iqbal et al. [10] and Sarti et al. [11].

Rocking walls are commonly implemented as either stepping or pinned systems. Differently from a stepping rocking wall, a pinned rocking wall does not alternate pivot points at the contact interfaces given that it is pinned at mid-width [12]. Within this framework, the use of reduced-order models for the analysis of a rocking wall system is especially attractive because it can provide valuable information about its seismic effectiveness and can serve at supporting its preliminary design. So doing, Makri and Aghagholizadeh [13] investigated an elastic main system rigidly connected to either a stepping or pinned rocking wall. Later on, they extended their study to a inelastic main system rigidly connected to either a stepping or a pinned rocking wall [14] and vertically restrained rocking walls [15]. The analysis of a yielding main structure coupled to rocking walls equipped with supplemental damping devices was also addressed using a reduced-order model by Aghagholizadeh and Makri [16].

This work aims at contributing to the analysis of rocking wall systems for seismic protection. While previous studies in this field have been mostly based on the direct integration of the equations of motion, a semi-analytical approach is herein presented by relying upon the random vibration theory. This study especially deals with a linear elastic and viscously damped main structural system connected to a rigid rocking wall by means of a linear elastic spring and a linear viscous device. The rocking wall, in turn, is constrained at the mid-width through a linear elastic rotational spring and a rotational dashpot. The seismic ground motion is modeled as nonstationary filtered white Gaussian noise. Semi-analytical solutions are obtained for the main system response displacement and absolute acceleration under the hypothesis of small displacements. A convenient parametrization of the connector parameters is adopted to generalize the results of their optimum design. Preliminary results are finally presented.

2 NONSTATIONARY STOCHASTIC SEISMIC GROUND MOTION MODELING

The seismic ground motion $\ddot{x}_g$ is modeled as nonstationary filtered white Gaussian noise acting over a time window $[0, T]$. In the context of earthquake engineering, the Kanai–Tajimi filter and the Clough–Penzien filter are two commonly adopted linear filtering techniques. The Kanai–Tajimi model is the simplest since it employs a single linear second-order filter. The Clough–Penzien filter is more appropriate for modeling an earthquake because an additional linear filter with respect to the Kanai–Tajimi model removes the embedded low-frequency components. Therefore, the Clough–Penzien filter model is here adopted. The assumption of non-stationary seismic ground motion means that both amplitude and frequency content can change throughout the earthquake duration. With these premises, the random seismic ground motion is here defined as follows:

$$\ddot{x}_g = \mathbf{a}_p^\top \mathbf{y}_p, \tag{1a}$$

$$\dot{\mathbf{y}}_p = \mathbf{D}_p \mathbf{y}_p + \mathbf{v}_p W, \tag{1b}$$

where

$$\mathbf{a}_p = \left\{-\omega_p^2 \quad -2\xi_p\omega_p \quad \omega_k^2 \quad 2\xi_k\omega_k\right\}^\top, \tag{2a}$$

$$\mathbf{y}_p = \left\{x_p \quad \dot{x}_p \quad x_k \quad \dot{x}_k\right\}^\top, \tag{2b}$$

$$\mathbf{D}_p = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -\omega_p^2 & -2\xi_p\omega_p & \omega_k^2 & 2\xi_k\omega_k \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -\omega_k^2 & -2\xi_k\omega_k \end{bmatrix}, \tag{2c}$$

$$\mathbf{v}_p = \left\{0 \quad 0 \quad 0 \quad -\varphi\right\}^\top. \tag{2d}$$

Herein, ω_k and ξ_k are the dominant circular frequency and dominant damping of the soil, respectively. On the other hand, ω_p and ξ_p denote the parameters of the filter hindering the low-frequency components of the dynamic excitation. In general, all these parameters are allowed to vary in time. However, the dominant circular frequency ω_k only will be possibly considered as time-dependent parameter in the present study. Moreover, W is a zero-mean white Gaussian noise having constant power spectral density S_0 whereas φ is a modulation function that changes the amplitude of the seismic ground motion over time.

3 STRUCTURAL MODELING OF FRAME CONNECTED TO ROCKING WALL

3.1 Structural system, reduced-order modeling and motion equations

A linear elastic and viscously damped main structural system is here considered. In order to protect such system against the seismic ground acceleration $\ddot{x}_g$, it is connected to a rocking wall. The frame dynamics is reduced to single-degree-of-freedom (SDOF) system. A linear elastic spring and a linear viscous device ensure the connection between the main system and the wall, which is constrained at the base mid-width through a linear elastic rotational spring and a rotational dashpot. The coupled dynamical system is illustrated in Fig. 1. It is assumed that such dual system is designed to undergo small displacements under the seismic ground motion. The equations of motion in the state-space read:

$$\dot{\mathbf{y}}_s = \mathbf{A}_s\mathbf{y}_s + \mathbf{H}_p\mathbf{y}_p, \tag{3}$$

where $\dot{\mathbf{y}}_s$ is the state-space $N \times 1$ vector whereas $\mathbf{A}_s$ and $\mathbf{H}_p$ are state-space matrices. Mass, stiffness and viscous damping of the main system are denoted as m_s, k_s and c_s, respectively. On the one hand, stiffness and viscous damping of the connectors that link the rocking wall with the main system are $k_\delta = \kappa_\delta k_s$ and $c_\delta = \gamma_\delta c_s$, respectively. On the other hand, stiffness and viscous damping of the connectors that underpin the rocking wall are $k_\theta = \kappa_\theta k_s$ and $c_\theta = \gamma_\theta c_s$, respectively. The rocking wall mass is denoted as $m_w = \mu_w m_s$.

The dynamic moments equilibrium condition allows to derive the following equations of motion:

$$\begin{aligned} m_s H\ddot{x} + (1+\gamma_\delta)\, c_s H\dot{x} - \gamma_\delta c_s H^2\dot{\theta} \\ + (1+\kappa_\delta)\, k_s Hx - \kappa_\delta k_s H^2\theta = -m_s H\ddot{x}_g, \end{aligned} \tag{4a}$$

$$\begin{aligned} \mu_w m_s H^2\ddot{\theta} - \gamma_\delta c_s H\dot{x} + (\gamma_\theta+\gamma_\delta)\, c_s H^2\dot{\theta} \\ - \kappa_\delta k_s Hx + (\kappa_\theta+\kappa_\delta)\, k_s H^2\theta - \mu_w m_s g\frac{H}{2}\theta = -\mu_w m_s H\ddot{x}_g. \end{aligned} \tag{4b}$$

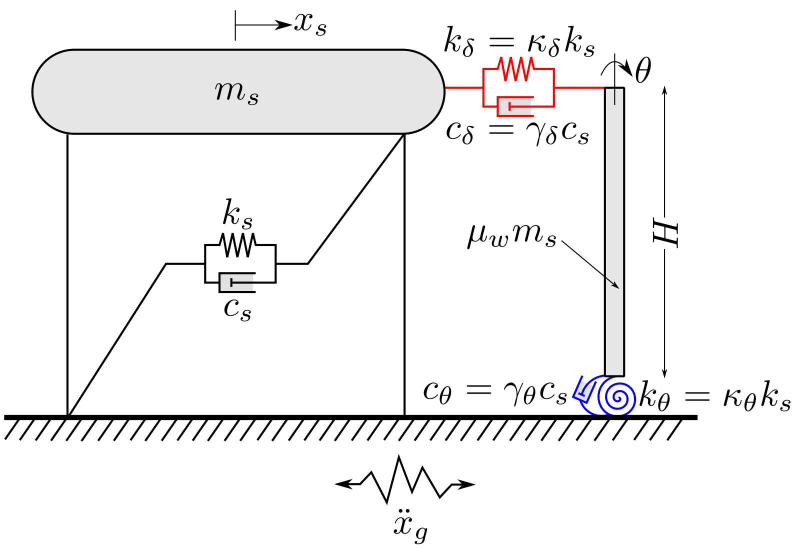

Figure 1: Reduced-order model of linear elastic frame connected to a rocking wall subjected to seismic ground motion: relevant system parameters and degrees-of-freedom of the dual system.

Hence, the state-space $N \times 1$ vector, with $N = 4$, is introduced as follows:

$$\mathbf{y}_s = \left\{x \quad H\theta \quad \dot{x} \quad H\dot{\theta}\right\}^\top . \tag{5}$$

Once natural circular frequency and viscous damping ratio of the main system have been introduced as $\omega_s = \sqrt{k_s/m_s}$ (being T_s the period) and $\xi_s = c_s/\left(2\sqrt{k_s m_s}\right)$, respectively, it is thus obtained:

$$\mathbf{A}_s = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -\omega_s^2\left(1+\kappa_\delta\right) & \omega_s^2\kappa_\delta & -2\xi_s\omega_s\left(1+\gamma_\delta\right) & 2\xi_s\omega_s\gamma_\delta \\ \dfrac{\omega_s^2\kappa_\delta}{\mu_w} & -\dfrac{\omega_s^2\left(\kappa_\theta+\kappa_\delta\right)}{\mu_w}+\dfrac{g}{2H} & \dfrac{2\xi_s\omega_s\gamma_\delta}{\mu_w} & -\dfrac{2\xi_s\omega_s\left(\gamma_\delta+\gamma_\theta\right)}{\mu_w} \end{bmatrix}, \tag{6}$$

$$\mathbf{H}_p = \left[\mathbf{0}_{1\times 4} \quad \mathbf{0}_{1\times 4} \quad -\mathbf{a}_p^\top \quad -\mathbf{a}_p^\top\right]^\top . \tag{7}$$

4 STOCHASTIC ANALYSIS OF THE STRUCTURAL RESPONSE

4.1 Covariance analysis

The state-space representation of the overall dynamics is obtained by assembling the filter equation in Eq. (1) and the equations of motion in Eq. (3) as follows:

$$\underbrace{\begin{Bmatrix} \dot{\mathbf{y}}_s \\ \dot{\mathbf{y}}_p \end{Bmatrix}}_{\dot{\mathbf{y}}} = \underbrace{\begin{bmatrix} \mathbf{A}_s & \mathbf{H}_p \\ \mathbf{0}_{4\times N} & \mathbf{D}_p \end{bmatrix}}_{\mathbf{A}} \underbrace{\begin{Bmatrix} \mathbf{y}_s \\ \mathbf{y}_p \end{Bmatrix}}_{\mathbf{y}} + \underbrace{\begin{Bmatrix} \mathbf{0}_{N\times 1} \\ \mathbf{v}_p W \end{Bmatrix}}_{\mathbf{f}} . \tag{8}$$

The covariance matrix of the state-space system is:

$$\mathbf{R} = \mathrm{E}\left[\mathbf{y}\mathbf{y}^\top\right] = \mathrm{E}\left[\begin{Bmatrix} \mathbf{y}_s \\ \mathbf{y}_p \end{Bmatrix}\left\{\mathbf{y}_s \quad \mathbf{y}_p\right\}\right] = \begin{bmatrix} \mathbf{R}_{\mathbf{y}_s\mathbf{y}_s} & \mathbf{R}_{\mathbf{y}_s\mathbf{y}_p} \\ \mathbf{R}_{\mathbf{y}_p\mathbf{y}_s} & \mathbf{R}_{\mathbf{y}_p\mathbf{y}_p} \end{bmatrix} . \tag{9}$$

The matrix $\mathbf{R}$, in turn, is the solution of the Lyapunov equation in nonstationary conditions, which reads:

$$\mathbf{AR} + \mathbf{RA}^\top + \mathbf{B} = \dot{\mathbf{R}}, \tag{10}$$

where $\mathbf{B}$ is a matrix whose elements are equal to zero expect that the element whose index is $(N+4, N+4)$, which is equal to $2\pi S_0 \varphi^2$.

A discrete set of N_t time instants labeled as $1, \ldots, i, i+1, \ldots$ is considered within the time window $[0, T]$ of the seismic ground motion, and evenly spaced assuming a constant time step Δt. A linear variation of $\dot{\mathbf{R}}$ within each time interval Δt is considered, and thus:

$$^{i+1}\mathbf{R} = {}^{i}\mathbf{R} + \frac{1}{2}\Delta t \left(^{i+1}\dot{\mathbf{R}} + {}^{i}\dot{\mathbf{R}} \right), \tag{11}$$

under the assumption that $^{1}\mathbf{R} = \mathbf{0}_{N+4}$.

Therefore, after some mathematical manipulations, the time discretization of Eq. (10) in case of fully nonstationary seismic ground motion leads to the following stationary Lyapunov equation at each time step [17, 18]:

$$^{i+1}\bar{\mathbf{A}}\,^{i+1}\mathbf{R} + {}^{i+1}\mathbf{R}\,^{i+1}\bar{\mathbf{A}}^\top + {}^{i+1}\bar{\mathbf{B}} = \mathbf{0}_{N+4}, \tag{12}$$

where

$$^{i+1}\bar{\mathbf{A}} = \frac{1}{2}\left[-\mathbf{I}_{N+4} + \Delta t\,^{i+1}\mathbf{A} \right], \tag{13}$$

$$^{i+1}\bar{\mathbf{B}} = \left(\mathbf{I}_{N+4} + \frac{1}{2}\Delta t\,^{i}\mathbf{A} \right) {}^{i}\mathbf{R} + \frac{1}{2}\Delta t\,^{i}\mathbf{R}\,^{i}\mathbf{A}^\top + \frac{1}{2}\Delta t \left(^{i+1}\mathbf{B} + {}^{i}\mathbf{B} \right). \tag{14}$$

4.2 Response statistics

The time-dependent statistics of the dynamic response can be obtained from Eq. (9) accounting for the time discretization as per Eq. (11) and Eq. (12). They mainly consist of variance $^{i+1}\sigma^2_{\blacksquare}$ and covariance $^{i+1}\sigma_{\blacksquare\blacksquare}$ terms involving the system response variables.

Particularly, the variance of the main system response at the ith time instant is determined as follows:

$$^{i+1}\sigma^2_x = {}^{i+1}\mathbf{R}_{\mathbf{y}_s\mathbf{y}_s}(1,1). \tag{15}$$

For a linear coupled system whose dynamics is ruled by Eq. (4), the variance of the total acceleration of the main system is given by:

$$\begin{aligned}
^{i+1}\sigma^2_{\ddot{x},tot} &= \mathrm{E}\left[(\ddot{x} + \ddot{x}_g)^2 \right] \\
&= \mathrm{E}\left[\left(-2\xi_s\omega_s (1+\gamma_\delta)\dot{x} + 2\xi_s\omega_s\gamma_\delta H\dot{\theta} - \omega_s^2 (1+\kappa_\delta) x + \omega_s^2 \kappa_\delta H\theta \right)^2 \right] \\
&= {}^{i+1}\sigma^2_x \left(\omega_s^4 + 2\kappa_\delta\omega_s^4 + \kappa_\delta^2\omega_s^4 \right) + {}^{i+1}\sigma^2_{\dot{x}} \left(4\xi_s^2\omega_s^2 + 8\gamma_\delta\xi_s^2\omega_s^2 + 4\gamma_\delta^2\xi_s^2\omega_s^2 \right) \\
&+ {}^{i+1}\sigma_{x\dot{x}} \left(4\xi_s\omega_s^3 + 4\gamma_\delta\xi_s\omega_s^3 + 4\kappa_\delta\xi_s\omega_s^3 + 4\gamma_\delta\kappa_\delta\xi_s\omega_s^3 \right) \\
&+ {}^{i+1}\sigma_{x\theta} \left(-2H\kappa_\delta\omega_s^4 - 2H\kappa_\delta^2\omega_s^4 \right) + {}^{i+1}\sigma_{x\dot{\theta}} \left(-4H\gamma_\delta\xi_s\omega_s^3 - 4H\gamma_\delta\kappa_\delta\xi_s\omega_s^3 \right) \\
&+ 4\,^{i+1}\sigma^2_{\dot{\theta}} H^2\gamma_\delta^2\xi_s^2\omega_s^2 + 4\,^{i+1}\sigma_{\theta\dot{\theta}} H^2\gamma_\delta\kappa_\delta\xi_s\omega_s^3 + {}^{i+1}\sigma^2_\theta H^2\kappa_\delta^2\omega_s^4 \\
&+ {}^{i+1}\sigma_{\dot{x}\theta} \left(-4H\kappa_\delta\xi_s\omega_s^3 - 4H\gamma_\delta\kappa_\delta\xi_s\omega_s^3 \right) \\
&+ {}^{i+1}\sigma_{\dot{x}\dot{\theta}} \left(-8H\gamma_\delta\xi_s^2\omega_s^2 - 8H\gamma_\delta^2\xi_s^2\omega_s^2 \right).
\end{aligned} \tag{16}$$

5 OPTIMUM DESIGN PROBLEM

The optimization problem is meant at determining the optimal value of some design variables $\mathbf{d}$ such that the manufacturing cost of the protection system is minimized while achieving the required performance levels in terms of displacement and absolute acceleration of the main system. The following performance index can be considered to mitigate displacement-induced damage in structural components:

$$F_{dis}(\mathbf{d}) = \int_0^T \sigma_x \mathrm{d}t. \tag{17}$$

Another important performance index accounts for the absolute acceleration of the main system, which is critical for the protection of high-frequency sensitive equipment and some non-structural components subject to earthquake excitation:

$$F_{acc}(\mathbf{d}) = \int_0^T \sigma_{\ddot{x},tot} \mathrm{d}t. \tag{18}$$

It is understood that the integrals in Eq. (17) and Eq. (18) must be computed numerically through a suitable quadrature technique because of the time discretization in Eq. (11) and Eq. (12). In order to quantify the performance of the rocking wall system, it is convenient to cast both performance indicators in dimensionless form as follows:

$$I_{dis}(\mathbf{d}) = \frac{F_{dis}(\mathbf{d})}{F_{dis,0}}, \tag{19a}$$

$$I_{acc}(\mathbf{d}) = \frac{F_{acc}(\mathbf{d})}{F_{acc,0}}, \tag{19b}$$

where $F_{dis,0}$ and $F_{acc,0}$ are computed according to Eq. (17) and Eq. (18), respectively, for the main system only (i.e., without the connection with the rocking wall system).

With these premises, the optimum design problem is formulated as follows:

$$\begin{aligned} \min_{\mathbf{d}} \quad & C(\mathbf{d}) \\ \text{s. t.} \quad & I_{dis}(\mathbf{d}) \leq \Gamma_{dis} \\ & I_{acc}(\mathbf{d}) \leq \Gamma_{acc} \\ & \mathbf{d}_{\text{min}} \leq \mathbf{d} \leq \mathbf{d}_{\text{max}}, \end{aligned} \quad , \tag{20}$$

where $C(\mathbf{d})$ is a suitable manufacturing cost function of the protection system whereas Γ_{dis} and Γ_{acc} quantify to what extent displacement and absolute acceleration of the main system must be reduced by means of the rocking wall system. Moreover, $\mathbf{d}_{\text{min}}$ and $\mathbf{d}_{\text{max}}$ are lower and upper bound of the design variables in $\mathbf{d}$, respectively.

It is here assumed that $\mathbf{d} = \begin{Bmatrix} \kappa_\delta & \gamma_\delta & \kappa_\theta & \gamma_\theta \end{Bmatrix}$, while the other parameters are considered as design data. For the sake of simplicity, it is also supposed that the cost is proportional to the mechanical characteristics of the devices, with identical unitary costs for springs and dashpots. Hence, the cost function $C(\mathbf{d})$ is readily formulated as:

$$C(\mathbf{d}) = \kappa_\delta + \gamma_\delta + \kappa_\theta + \gamma_\theta. \tag{21}$$

It is noted that the optimization problem in Eq. (20) should also take into account proper constraints able to ensure that the assumption of small displacements is fulfilled. It might also include manufacturing details and constraints. Furthermore, the cost function in Eq. (21) might be revised, for instance, to consider expected annual loss. Further refinements of the optimization problem in Eq. (20), however, are left to future studies.

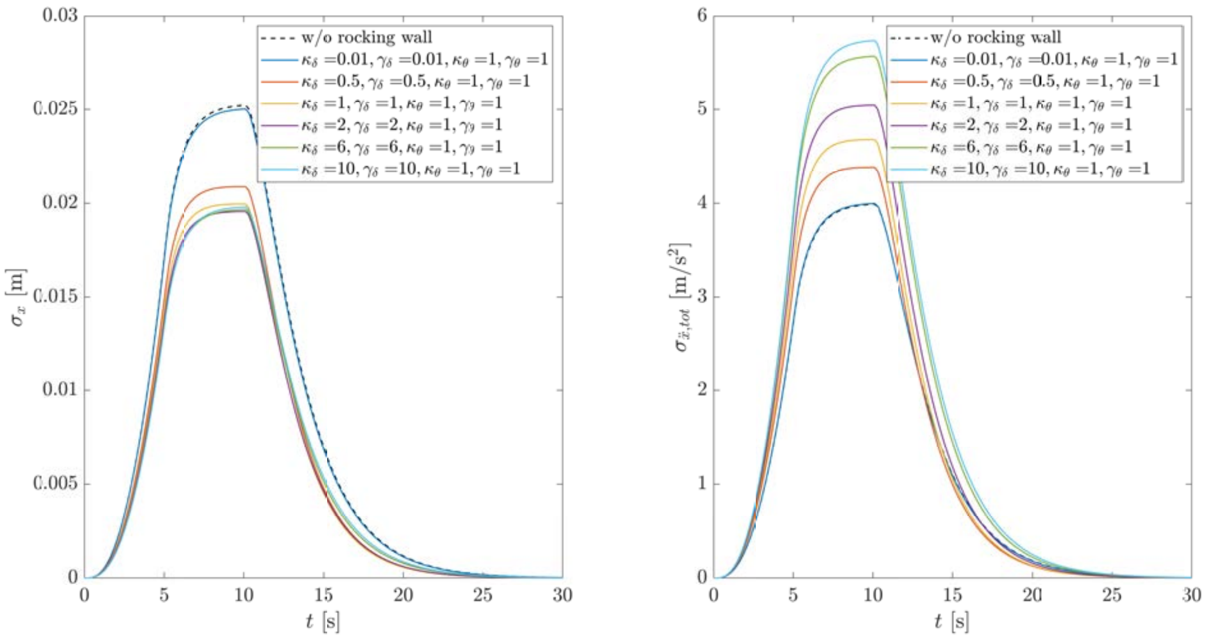

Figure 2: Variation of the standard deviation of the main system displacement σ_x (left) and total acceleration $\sigma_{\ddot{x},tot}$ (right) for different values of κ_δ and γ_δ given $\kappa_\theta = 1$ and $\gamma_\theta = 1$.

6 NUMERICAL INVESTIGATION

6.1 Parametric study

A stochastic seismic ground motion with time-variant amplitude and frequency is considered. To this end, a peak ground motion PGA $= 0.25g$ is assumed whereas filter parameters that simulate a stiff soil condition (soil type A) are adopted. The following parametric study has been performed for a reference linear elastic frame where $T_s = 0.5$ s and $\xi_s = 0.03$. Moreover, it is assumed $H = 12$ m and $\mu_w = 0.05$. Particularly, Fig. 2 shows the standard deviation of the main system displacement σ_x and absolute acceleration $\sigma_{\ddot{x},tot}$ for different values of κ_δ and γ_δ given κ_θ and γ_θ. A more comprehensive parametric study is reported in Figs. 3-6. On the one hand, these results demonstrates that the rocking wall is able to mitigate the main system displacement (i.e., $I_{dis} < 1$). On the other hand, these results also highlight that the total acceleration of the main system can be significantly amplified for certain combination of the connector parameters. This is in agreement with previous evidences about the seismic protection of frame systems coupled with walls [19]. It is however worth noting that the re-centering behavior of a controlled rocking system should be more accurately modeled through a nonlinear elastic [20, 21] rather than linear elastic behavior as assumed at this stage for the sake of simplicity, significantly reducing and limiting the acceleration amplifications.

6.2 Optimization

The results of the parametric investigation confirms that the optimum design of the rocking wall system must be performed by taking into account, both, displacement and absolute acceleration of the main system. Otherwise, the main system displacement is reduced at the expense of amplifying its total acceleration. As an example, the optimum values of the connector parameters (i.e., κ^*_δ, γ^*_δ, κ^*_θ, γ^*_θ) are estimated for the reference linear elastic frame and two other frames. Specifically, a stiffer structure with $T_s = 0.4$ s and $H = 8$ m as well as a more flexible

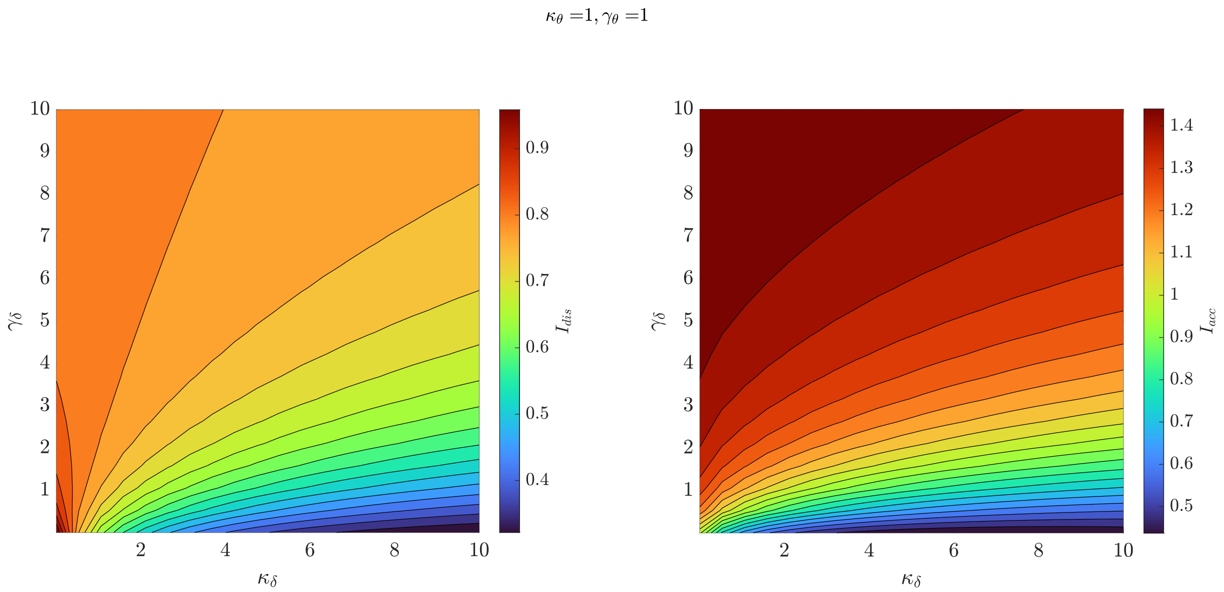

Figure 3: Variation of displacement I_{dis} (left) and acceleration I_{acc} (right) performance indicators for different values of κ_δ and γ_δ given $\kappa_\theta = 1$ and $\gamma_\theta = 1$.

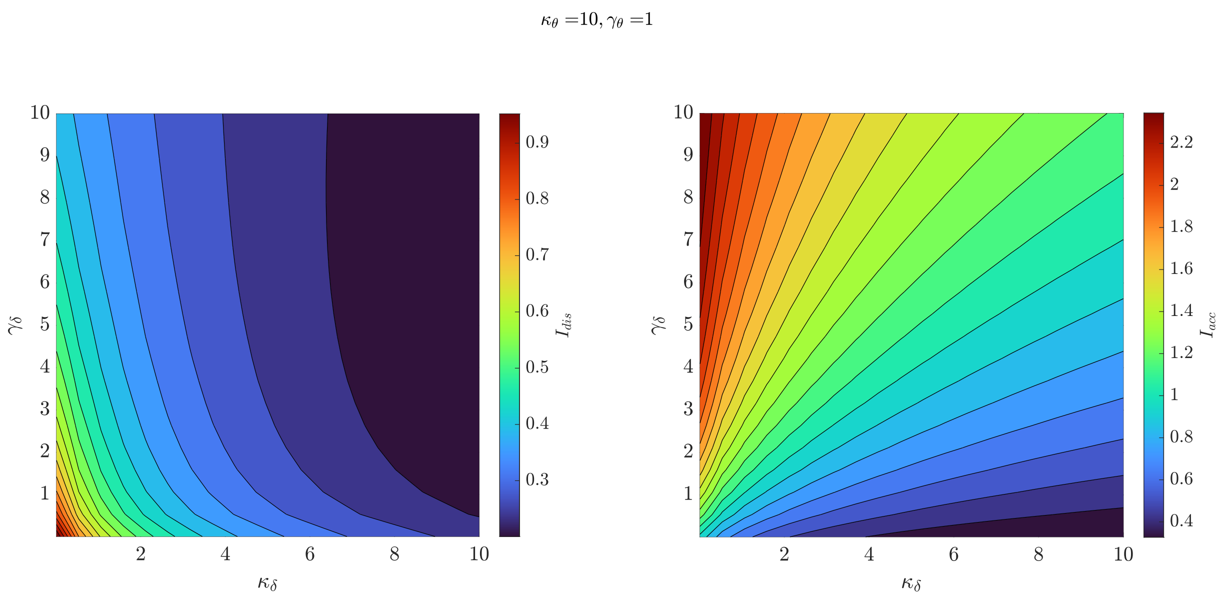

Figure 4: Variation of displacement I_{dis} (left) and acceleration I_{acc} (right) performance indicators for different values of κ_δ and γ_δ given $\kappa_\theta = 10$ and $\gamma_\theta = 1$.

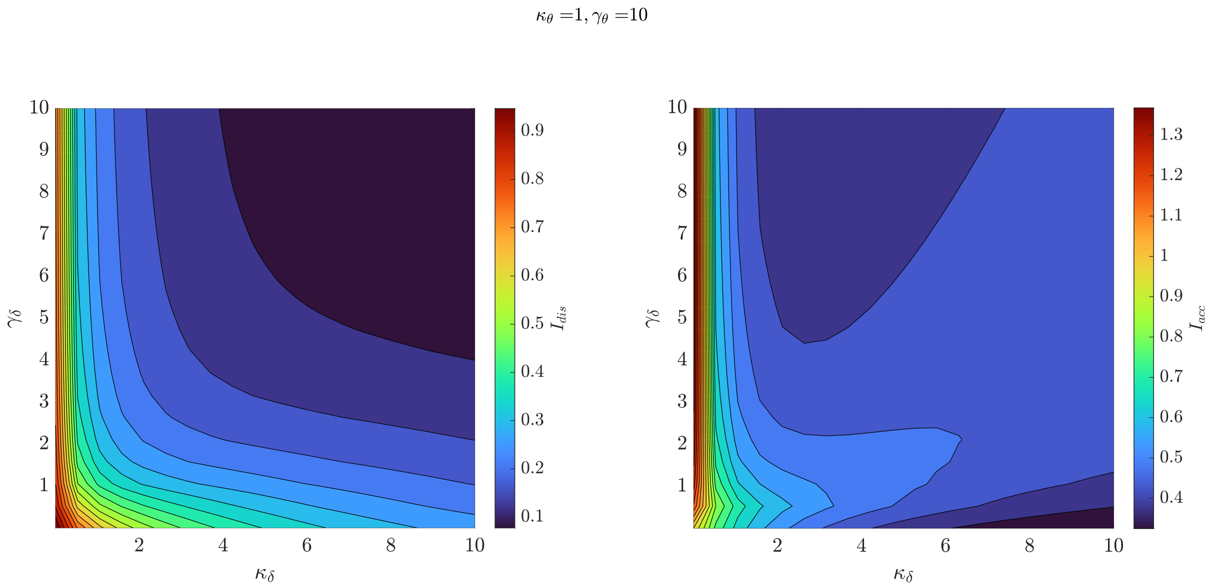

Figure 5: Variation of displacement I_{dis} (left) and acceleration I_{acc} (right) performance indicators for different values of κ_δ and γ_δ given $\kappa_\theta = 1$ and $\gamma_\theta = 10$.

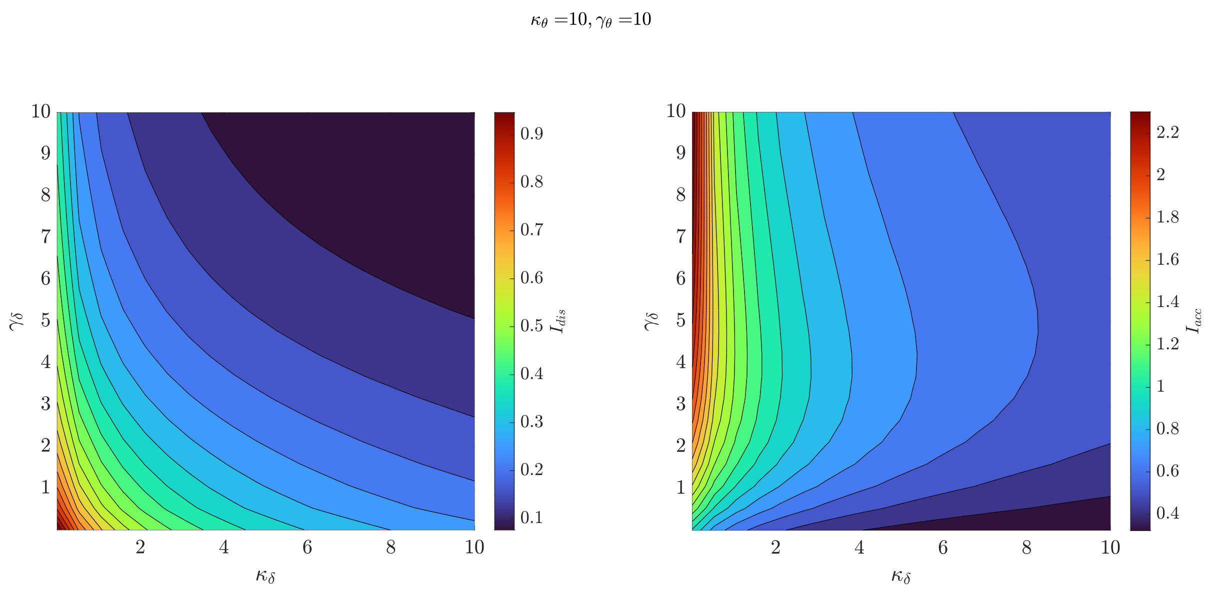

Figure 6: Variation of displacement I_{dis} (left) and acceleration I_{acc} (right) performance indicators for different values of κ_δ and γ_δ given $\kappa_\theta = 10$ and $\gamma_\theta = 10$.

structure with $T_s = 0.6$ s and $H = 16$ m are also considered. The other data as well as the bounds of the design space are those already adopted for the previous parametric study. The optimum design is carried out according to Eq. 20 by assuming $\Gamma_{dis} = \Gamma_{acc} = \Gamma$.

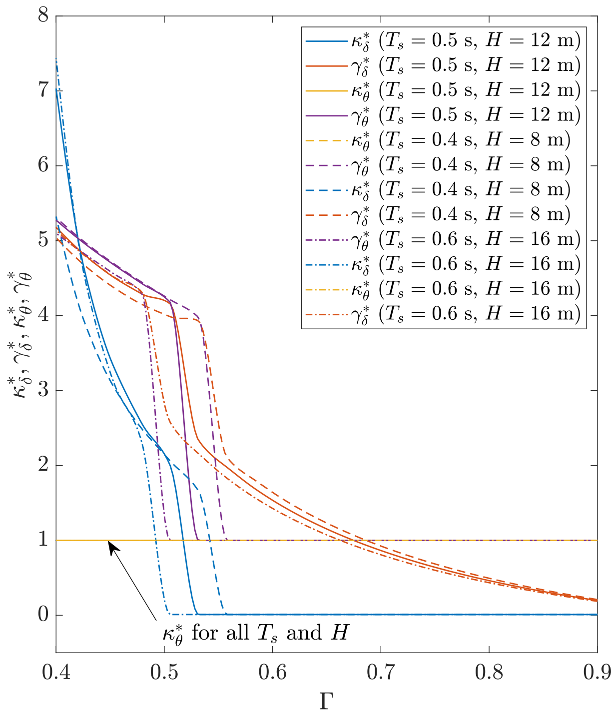

Figure 7: Optimal values of the connector parameters for different values of Γ.

The results in Fig. 7 demonstrate that the optimum design at low-mid value of the target performance level (i.e., $\Gamma > 0.6$) is mainly governed by the dissipation ensured through the dashpot connecting the frame and the rocking wall. For higher values of the target performance level (i.e., $0.4 \leq \Gamma \leq 0.6$), the stiffness of the connection between the frame and the rocking wall as well as the dissipation at the wall base also become relevant. Despite the displacement response of the main system can be further reduced, its total acceleration does not. In fact, with the currently implemented linear elastic model (not yet featuring nonlinear elastic springs to capture the controlled rocking motion), no feasible optimal solution exists for very high target performance levels (i.e., $\Gamma < 0.4$).

7 CONCLUSIONS

This work has presented an initial study about the analysis and design of a rocking wall system coupled with building. The final goal is to provide a simplified approach, and possibly closed-form formulations, for the optimum design of a rocking wall system for the seismic protection of structures subjected to seismic ground motion. A reduced-order model is thus adopted to achieve this goal, and it has been formulated by reducing the dynamics of the building to a linear elastic and viscously damped single-degree-of-freedom system. The coupling between the main system and the rocking wall is ensured by a linear elastic spring and a linear viscous device. The rigid rocking wall is constrained at the mid-width using a linear elastic rotational spring and a rotational dashpot. The seismic ground motion is simulated as nonstationary filtered white Gaussian noise. The preliminary results in the present study have highlighted the need of mitigating the main system displacement and absolute acceleration simultaneously through the optimum design process. This is a preliminary study, and further researches are under way. Particularly, part of the current researches are meant at taking into account the inelastic behavior of both the main system as well as of the controlled rocking wall under seismic ground motion. Moreover, a refined dual building-wall model is going to be prepared and its optimization will be assisted following the semi-analytical approach established in the present work.

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