Optimal Design and Assessment of a Nonlinear Rooftop Isolated Tuned Mass Damper Inerter System for Seismic Protection of Buildings

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Abstract. This paper pursues the optimal design of a passive nonlinear dynamic vibration absorber for the seismic protection of buildings, which combines a limber seismically isolated rooftop (IR) equipped with a tuned mass damper inerter (TMDI), termed IR-TMDI. A three degree of freedom dynamical system is used to study the potential of the IR-TMDI in which the isolation bearings are modelled through the Bouc-Wen model. A comprehensive parametric investigation is undertaken to appraise the seismic performance trade-off established by the considered objective functions. The investigation is further complemented by nonlinear response history analyses using recorded ground motions. Numerical results establish the good potential of the studied absorber for retrofitting existing buildings and for achieving high-performing new buildings.

Introduction

In recent years, the passive tuned mass damper inerter (TMDI), introduced in [1], was demonstrated to improve significantly the potential of the conventional top-floor tuned mass damper for seismic protection of non-isolated buildings [2], by leveraging the mass amplification effect of an inerter [3]. The latter is a device resisting relative acceleration and in the TMDI configuration it links the secondary mass to a different (lower) floor from the top floor that the mass is attached to the building (typically using a viscoelastic link). Recently, it was established [4] that installing a TMDI within a single flexible top-floor enhances the TMDI vibration suppression potential. With this in mind, this paper investigates the seismic response mitigation potential of a TMDI installed within an isolated rooftop, IR-TMDI. This is pursued by considering the three degree of freedom dynamical system shown in Fig.1(a) whereby the isolation layer is modelled through the Bouc-Wen model, representing standard lead-bearing isolation bearings. Statistical linearization is applied to expedite optimal TMDI tuning given structure, isolator, and TMDI inertia properties. Three different objective functions (OFs) are investigated, aiming to minimize structural displacement or acceleration, or maximizing energy dissipated by the TMDI under white noise excitation. A comprehensive parametric investigation is undertaken to appraise the seismic performance trade-off established by the considered objective functions. The investigation is further complemented by nonlinear response history analyses using recorded ground motions.

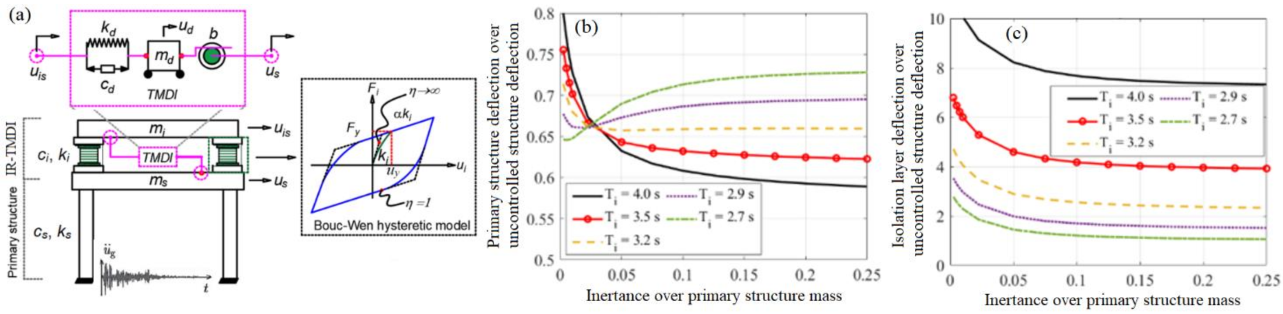

Figure 1: (a) IR-TMDI model, (b) Primary structure displacement versus inertance for different effective natural periods of the isolation layer, (c) Isolation layer deflection versus inertance for different effective natural periods of the isolation layer.

Results and Discussion

The overarching finding from the obtained numerical results is that there is a trade-off between the seismic structural displacement demand and deflection of the isolators, as shown in Figs.1(b) and 1(c). Specifically, the IR-TMDI lowers the primary structure deflection as the effective flexibility (natural period T_i) of the isolators increases, provided that the TMDI has sufficiently high inertance. However, this improvement comes at the cost of increased deflection of the isolators. Still, by increasing the inertance structural and isolator deflections are reduced. Overall, the reported numerical results demonstrate the good potential of IR-TDMI for seismic retrofitting of existing buildings as well as for improving the seismic performance of new buildings.

References

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