Preliminary numerical analysis of the Vibro-Impact Isolation systems under seismic excitations

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Abstract

The problem of large displacements in isolated structures can cause undesirable effects, such as damage to isolation systems or increases in superstructure accelerations. In order to limit these undesirable effects, the authors propose a new integrated design methodology of vibro-impact isolation systems that aims to control large displacements while limiting the increase in accelerations due to the impact phenomenon. Therefore, this paper shows numerical results obtained on single-degree-of-freedom systems isolated at the base subjected to seismic excitations and constrained by two deformable and dissipative devices.

Introduction

Seismic isolation is a widely used passive control methodology for mitigating the dynamic response of structures. However, significant seismic actions can induce considerable displacements in these structures, which in turn can cause damage to the isolation system or impacts against adjacent structures in the case that the seismic gap is insufficient [1]. Vibration-impacted isolation systems (V-IIS) have been studied by the authors through the definition of a single-degree-of-freedom system isolated at the base, whose displacements are limited by deformable and dissipative devices, called bumpers [2-4]. There are three parameters that define V-IIS: the initial seismic gap, the stiffness and the damping of the bumper. In order to mitigate the detrimental effects of large displacements, an optimal design methodology for base action of harmonic type was defined, which produced an optimality relation and an optimal curve, minimizing the maximum accelerations due to impacts. The optimality relation and the optimal curve reduce the design of V-IISs to the initial seismic gap parameter only. The objective of this paper is to apply the proposed methodology in the case of harmonic action for the optimal design of the parameters that characterize V-IISs subjected to seismic actions.

Results and discussion

The numerical response of V-IIS subjected to known seismic actions was studied. The results shown in Figures 1a, 1b and 1c refer to the Irpinia earthquake. Figures 1a and 1b represent, respectively, the maximum relative displacement and maximum absolute acceleration of the system, appropriately normalized, as a function of its natural period and for different initial seismic gaps. In the zone between 1.5 sec and 4 sec, of interest for isolation, there are greater reductions in displacement, compared with the no-impact (FF) case, as the initial gap decreases; from the acceleration point of view, slight increases are obtained for the various gaps investigated except for the null gap case, which even reports reductions, again compared with the FF case. Finally, Figure 1c shows a force-displacement cycle for a particular case. This graph well summarizes the strong displacement reduction and good control of the total system force, compared to the FF case, obtained by the proposed V-IIS optimal design methodology.

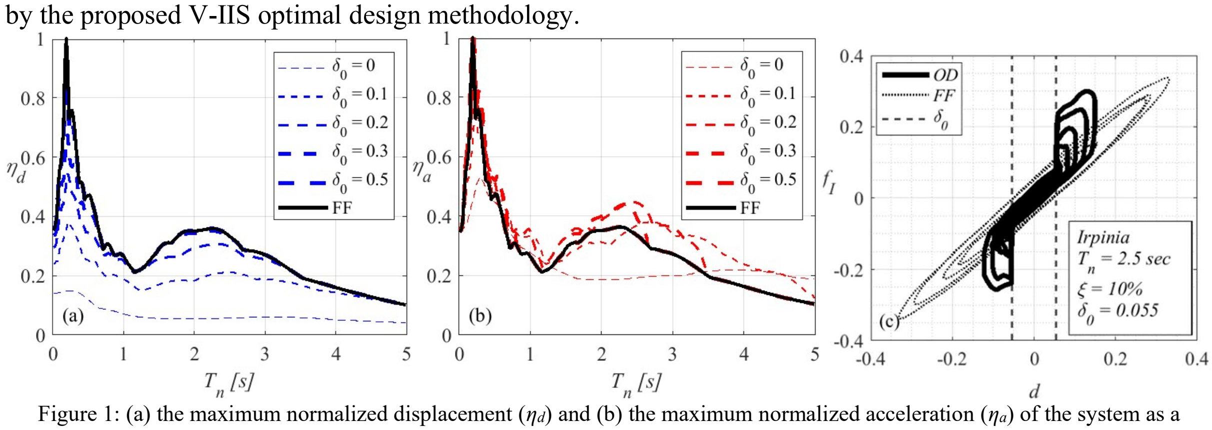

Figure 1: (a) the maximum normalized displacement (η_d) and (b) the maximum normalized acceleration (η_a) of the system as a function of its natural period (T_n), for different initial seismic gap (δ_0); (c) the force-displacement cycle.

References

[1] Polycarpou, P.C., Komodromos, P., "On poundings of a seismically isolated building with adjacent structures during strong earthquakes", Earthq Eng Struct Dyn, 39(8), 2010.

[2] Andreaus, U., De Angelis, M., "Influence of the characteristics of isolation and mitigation devices on the response of single-degree-of-freedom vibro-impact systems with two-sided bumpers and gaps via shaking table test", Struct Control Health Monit, 27(5), 2020.

[3] Stefani, G., De Angelis, M. Andreaus, U., "Influence of the gap size on the response of a single-degree-of-freedom vibro-impact system with two-sided constraints: Experimental test and numerical modelling", Int J Mech Sci, 206, 2021.

[4] Stefani, G., De Angelis, M. Andreaus, U., "The effect of the presence of obstacles on the dynamic response of single-degree-of-freedom systems: Study of the scenarios aimed at vibration control", J Sound Vib 531, 2022.