Rocking of rigid blocks on flexible foundations: modeling and experimental assessment

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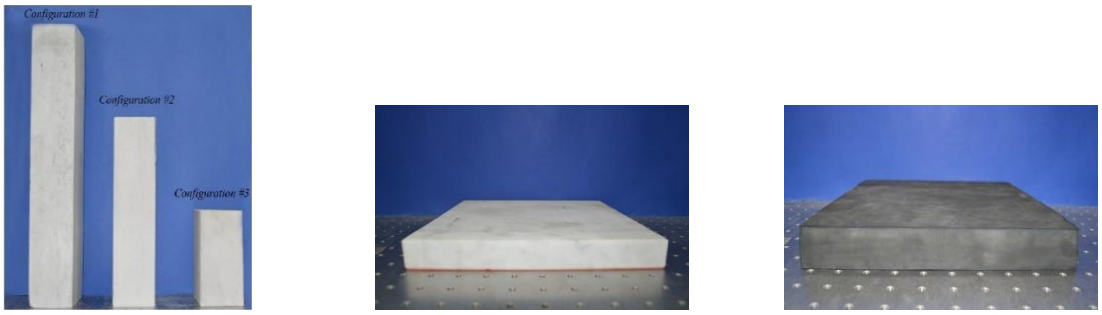
Abstract. In this paper harmonic rocking responses of a rigid block subjected to foundation shaking is examined. Several foundation models are considered comprising the classical rigid one, as well as linear and nonlinear flexible foundation models which account for the possibility of uplifting in the case of strong excitation. An identification procedure of the appropriate model parameters is developed based on the associated steady state response amplitude determined through an averaging procedure in case of harmonic base excitation. The analytical study is supplemented by experimental tests for several marble-block geometries on both rigid and flexible foundations. Numerical vis-à-vis experimental data are presented, assessing the accuracy of the different models in capturing certain salient features of the phenomenon even for quite soft foundation materials.

Introduction

The behaviour of block-like structures allowed to rock due to base excitation has been a longstanding problem of technical interest and still attracts the attention of a significant number of researchers. Several alternative analytical models have been proposed, among which the Housner model (HM), and the Winkler foundation model (WFM) are primarily used. The first deals with the motion of a rigid block rocking about its base corners on a rigid foundation [1]. The second deals with the motion of a rigid block rocking and bouncing on a flexible foundation of distributed linear springs and dashpots (Winkler foundation) [2].

Recently, to further study the complex behaviour which may arise during the rocking motion of rigid blocks on flexible foundations, additional aspects of the problem have been captured by an enhanced nonlinear model for the base-foundation interaction. In this regard, the Hunt-Crossley's nonlinear impact force model commonly used in the literature to represent the nonlinear nature of impact and contact phenomena has been adopted. Thus, the foundation is treated as a bed of continuously distributed tensionless springs in parallel with nonlinear dampers, with stiffness coefficient k and damping coefficient λ, respectively [3].



(a) (b) (c)

Figure 3: Blocks and base foundation: (a) Marble block configurations; (b) Rigid base (marble material); (c) Soft base (Aerstop CN20 material).

Results and discussion

The rocking phenomenon has been extensively studied. However, most of the previous studies have been analytical in nature. Further , many experiments on rocking blocks have considered the behavior of rigid blocks on rigid foundations, while the problem of rigid blocks on flexible foundation has less been investigated [3]. In this regard, in this paper an approximate analytical method has been developed for studying the rocking responses in case of harmonic base excitations. Specifically, a combination of static condensation and the method averaging has been employed to derive the rocking response amplitude for harmonic excitations. These results have been then used to derive a novel identification procedure for the model parameters. Further, an extensive experimental study has been conducted in the Laboratory of Experimental Dynamics at the University of Palermo, Italy. In this context, and due to their obvious relevance for historical monuments, tests are presented for several marble-block geometries on both rigid (marble) and flexible foundations (Fig. 1). The results have shown the reliability of the proposed identification procedure and the accuracy of the considered models in the various situations and configurations.

References

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