
Horizontal and vertical base isolation for the seismic protection of non-symmetric rigid blocks

Lorenzo Amoroso^{*1}, Manuel Ferretti^{†1}, and Angelo Di Egidio²

¹University of LÁquila [Italy] – Italy

²University of LÁquila [Italy] – Italy

Abstract

In modern society, there is an increasing need to address the impact of catastrophic natural hazards. Among these, earthquakes and their economic and societal effects have been extensively studied. The devastation caused by numerous earthquakes has significantly deepened and expanded the understanding of the seismic vulnerability of structures, leading to the development of various seismic risk assessment methods.

Particular attention has been given to mitigating the seismic vulnerability of various objects within buildings. Many of these elements can be modeled as rigid blocks. The growing need to reduce seismic risk for these rigid block-like objects has spurred numerous studies proposing different protection methods. This diversity stems both from the distinct characteristics of rigid block structures, which impose specific constraints on protection strategies, and from the rapid technological advancements in protective devices, which offer new possibilities for more effective solutions. For example, objects such as artworks, storage racks, electrical cabinets, and certain hospital equipment can all be modeled as rigid blocks.

Base isolation is one of the most effective protection methods against earthquakes. In recent years, numerous studies have investigated the application of this technique to rigid block-like structures representing artworks. For example, studies (1) and (2) analyzed the effectiveness of horizontal base isolation in detail, focusing on moderately slender and highly slender rigid blocks, respectively. Most studies use a symmetric rigid block model to describe the seismic response of artworks. However, in reality, nearly all artworks are asymmetrical and require a non-symmetric rigid block model for accurate representation. Very few studies have examined the use of base isolation to protect non-symmetric rigid blocks from earthquakes, such as in (3). More recently, in (4), the effectiveness of base isolation acting in both horizontal and vertical directions was examined as a seismic protection method for symmetric rigid blocks. To the best of the authors' knowledge, horizontal and vertical base isolation has never been applied to non-symmetric rigid blocks. This paper aims to address this gap.

A mathematical model of a non-symmetric rigid block on a horizontally and vertically oscillating base was developed. The equations of motion were derived using a Lagrangian approach. Particular attention was given to formulating the impact conditions, which provide the velocities of both the oscillating base and the block after impact, based on their velocities before impact. The non-symmetric block was initially subjected to a horizontal impulsive one-sine excitation to generate classical overturning spectra and maps. The

*Speaker

†Corresponding author: manuel.ferretti@univaq.it

findings revealed several intriguing aspects of the behavior of the isolated non-symmetric block. Notably, unlike symmetric blocks, which exhibit only two overturning modes, non-symmetric blocks display additional distinct overturning modes. Additionally, the response of the isolated system under various recorded horizontal and vertical earthquake excitations was analyzed, highlighting the influence of block eccentricity.

The results demonstrated the effectiveness of horizontal and vertical seismic isolation in protecting non-symmetric rigid blocks, even when subjected to seismic excitations with very high vertical PGA (Peak Ground Acceleration).

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