Engineering Structures 167 (2018) 272–286

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Vulnerability assessment and seismic mitigation intervention for artistic assets: from theory to practice

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ARTICLE INFO

Keywords:
Seismic assessment
Risk mitigation technique
Isolation devices
Numerical analysis
Cultural heritage
Art objects

ABSTRACT

This paper deals with the vulnerability assessment of artistic assets, aiming at exploiting the potential of specifically designed seismic-isolation strategy to mitigate their seismic risk. In detail, starting from a review of the multidisciplinary procedure proposed by some of the authors for evaluating the safety level of art objects, this paper focuses on the required steps necessary to effectively design proper seismic mitigation intervention. For this purpose, the case study of the bust of Francesco I d'Este is investigated. This sculpture is housed at the second floor of Palazzo dei Musei in Modena, one of the cities hit by the seismic events occurred in May 2012 in Italy, which brought up to date the need of preserving this valuable object from seismic risk. After a preliminary vulnerability analysis carried out to assess the safety of the bust, a specific intervention of seismic isolation is conceived and realized by adopting Double Concave Curved Surface Sliders (DCCSS), which combine a strong flexibility to different museum contexts, with the possibility of standardizing the production process. To this aim, some operative charts are proposed as useful tool for the design phase of the seismic devices. Then special attention is devoted to an accurate evaluation of the seismic action, considering the location of the artistic asset at upper floors, also by means of different strategies for numerical modeling of the host masonry building. Finally, a series of non linear dynamic analyses are carried out to assess the effectiveness of the whole isolated system.

1. Introduction

The damage caused by recent and past earthquakes in Italy and in the Mediterranean area has shown the high seismic vulnerability of the cultural heritage comprising both historic constructions and artistic assets, such as statues, paintings and in general museum collection. It is therefore mandatory to invest research efforts and financial resources in the emerging field of the conservation engineering, which pays attention to art objects, representing inestimable heritage of the whole community that must be safeguarded.

The J. P. Getty Museum, which is located in the seismically active area of Los Angeles, was the first, to the authors' knowledge, to recognize this problem. In 1983 it started its effort to study measures for seismic mitigation and protection of its collections, underlying the necessity of an effective cooperation between seismic engineers, conservators and other members of the museum staff and encouraging the research in implementing efficient solutions for mitigation of seismic risk to artistic assets.

Since then, the research has continued by studying, for the different art object categories, both vulnerability assessment methods and seismic mitigation strategies, which range from simple and low cost systems, such as securing and restraining objects with mount making techniques, to more complex and costly approaches, such as decoupling the motion of the object from that of the ground, (e.g. [1–5]).

In particular, dealing with this type of objects, a fundamental role is played by the application of an interdisciplinary methodology, like the one proposed in Berto et al. [6] which comprehends: knowledge path, involving historical research; geometrical survey and material characterization; accurate definition of seismic demand; development of specific methods of analysis, according to the characteristics of the artefact and to the required level of accuracy; design of suitable intervention for seismic protection of art objects.

It is worth noting that, in case of art objects located in upper floors, the characterization of seismic action becomes a challenging task due to the need of considering that the host building filters the seismic signal, modifying, with its response, the frequency content and the amplification of the strong motion applied to the base. In this work, such an interaction is analyzed through cascading approach, i.e. according to floor response spectra formulations both by using simplified and more refined approaches (e.g. [7,8]).

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https://doi.org/10.1016/j.engstruct.2018.03.093
Received 18 May 2017; Received in revised form 19 February 2018; Accepted 30 March 2018

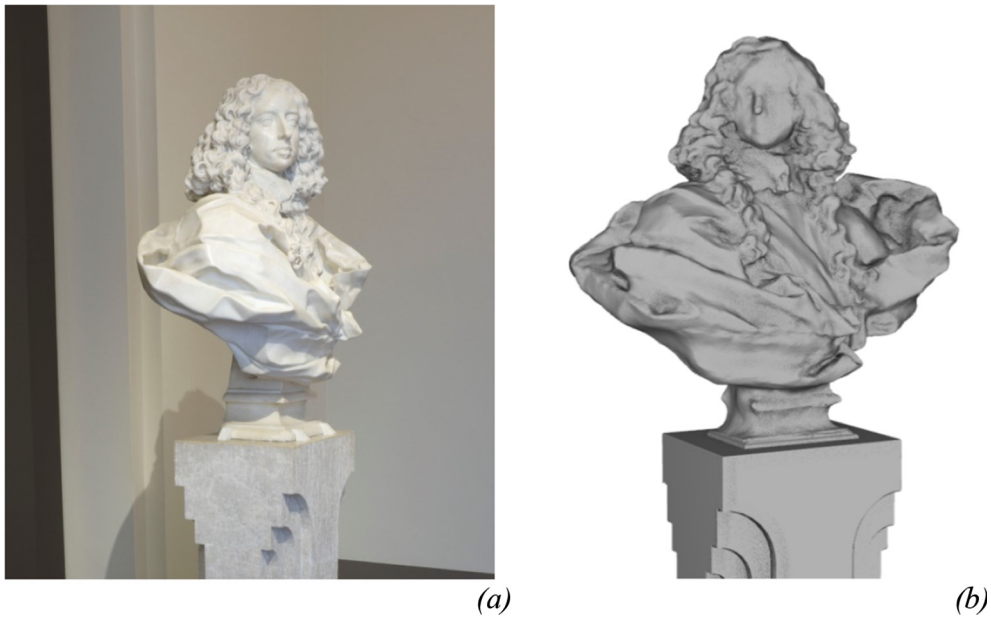

Fig. 1. (a) The bust of Francesco I d'Este by Gian Lorenzo Bernini; (b) View of the 3D model of bust.

As regards methods for vulnerability assessment, focusing on unrestrained objects (such as statues, busts, display cases), their response has been traditionally analyzed within the context of the dynamics of rigid blocks (e.g. [9–14]) and some criteria have been developed for rocking and overturning.

One of the most simple seismic mitigation techniques, suitable if the object has adequate strength to resist to the seismic force without damaging, consists in tightly fixing the object to the base or to the pedestal, as well as stabilizing it with different methods, for instance adjusting the proportion of the display furniture (e.g. [4,15]). On the other hand when the art object does not exhibit enough strength, the most performing solution is reducing the seismic demand by decoupling the motion of the object from that of the ground through base isolation techniques. Actually, the adoption of base-isolation technology to single objects is a practical and suitable alternative to seismically isolate the entire building, which represents often a significantly more complex and expensive activity, especially when the host building belongs to Cultural Heritage. Recently, some studies have also investigated the possibility to adopt a unique floor isolation system for an entire collection [16]; it represents an interesting solution but it implies a significant interaction with the host building and its layout (for instance to sustain the added vertical loads, to keep the safe distance from the perimeter walls, to respect the height of the exhibition halls).

Several applications of seismic isolation of single art objects have been carried out around the world. Among others, the 'Hermes of Praxiteles' at the Archaeological Museum of Olympia [17], which has been isolated by a system of four single concave friction pendulum devices; Rodin's 'The Gates of Hell' at the National Museum of Western Art in Tokyo isolated by friction pendulum devices and dampers [18] and a number of exhibits in the J. Paul Getty Museum in Los Angeles, for which a specific type of isolation system with springs has been adopted [19].

Also in Italy there are important examples of base isolation systems for specific art objects: for instance the statue of the 'Imperatore Germanico' at the National Museum in Perugia and the statue of the 'Satyr of Mazara del Vallo' at the Museo del Satiro near Trapani, which have been isolated by means of laminated rubber bearings; the statues of 'Nettuno and Scilla' at the Museum of Messina, isolated with supports made by steel and Teflon and recently the innovative marble antiseismic basement realized for the 'Bronzes of Riace' at the Archaeological Museum of Reggio Calabria [20].

Recent studies on the behavior of the Double Concave Curved Surface Sliders (DCCSS) have highlighted their effectiveness in seismic risk mitigation of art objects (e.g. [21,22]). This isolation system represents a valid solution for its adaptability to museum context – due to its reduced dimensions – and for the possibility to take advantage of the existing industrial knowhow in this field.

This paper focuses on an enhancement of the design procedure of this type of device for art object and on one actual realization at the Galleria Estense of Modena: the marble bust of 'Francesco I d'Este', which is particularly significant for the low weight, for the requirement of reduced dimensions of the final installation, and for the peculiarity of the host building, which is a complex historical masonry construction.

The development of this case study allows to follow and to carefully understand the above described step-by-step interdisciplinary methodology with the aim to move from theory to practice, bearing in mind the main aims that a modern seismic mitigation intervention should account for: efficiency and safety; compatibility with art object's materials; low invasiveness and reversibility; durability; reasonable costs.

After a brief description of the main results of the knowledge path, the paper deals with the characterization of the seismic demand at the base of the art object exposed at the second floor of the host building, applying approximated formulations according to [7] and to European Standards [23]. Then the assessment of seismic vulnerability of the art object is treated, leading to the choice of adopting a seismic isolation system comprising four double concave curved surface sliders. After a predesign phase, based on the use of specific charts proposed by the authors, the paper focuses on the validation of the seismic intervention, discussing also some issues about the numerical modelling of the complex masonry building and the selection of suitable set of accelerograms for a detailed evaluation of the seismic demand at the base of the art object.

2. Path of knowledge

2.1. The bust of Francesco I d'Este

The bust of Francesco I d'Este by Gian Lorenzo Bernini, Fig. 1a, is exhibited on the second floor of the Palazzo dei Musei of Modena, which contains the art collection of the Galleria Estense. The sculpture is a monolithic piece of Carrara Marble and the stone pedestal was carved in Pietra d'Istria in the 1970s for the renovation of the museum