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Original article

Assessment of seismic vulnerability of art objects: The "Galleria dei Prigioni" sculptures at the Accademia Gallery in Florence

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ABSTRACT

The seismic assessment of art objects requires a multidisciplinary approach and the definition of a specific methodology for evaluating the level of safety and the possible interventions necessary for seismic risk prevention, finding a compromise between safety and conservation. This paper describes a first step in this direction, in which the different aspects of the procedure, from knowledge path of the art object to the structural analysis, were studied in the six Michelangelo's statues located in the "Galleria dei Prigioni" (Slaves' Gallery) at the Accademia Gallery of Florence. We showed that the general principles and criteria expressed in the "Italian Guidelines for evaluation and mitigation of seismic-risk to cultural heritage", which are specifically devoted to masonry constructions, could be profitably extended to other artworks, like statues, starting from historical research, geometrical survey and material characterization, up to the developing of specific methods of analysis. This research could be the base for future studies to be performed concerning the prevention of seismic damage of art objects, including both bare minimum interventions and specific devices, such as isolation systems.

1. Research aims

The aim of the research was to perform a study of seismic assessment of art objects on display in museums. In particular, a multidisciplinary methodology was proposed and the six sculptures located in the "Galleria dei Prigioni" (Slaves' Gallery) at the Accademia Gallery of Florence were analysed. We hypothesized that the general principles and criteria expressed in the "*Italian Guidelines for evaluation and mitigation of seismic-risk to cultural heritage*" (DPCM2007, [1]), which are specifically devoted to masonry constructions, could be extended to other cultural objects, like statues.

In order to develop this methodology aimed to evaluate the seismic safety level of the art objects, we took the following steps:

- the knowledge path, which involves historical research, geometrical survey and material characterization;
- the characterization of the seismic action of the site;
- the development of specific methods of analysis, according to the characteristics of the objects and to the required level of accuracy.

This research could be the base for future studies to be performed concerning the prevention of seismic damage of art objects, including both bare minimum interventions and specific devices, such as isolation systems.

2. Introduction

The protection of museum collections against seismic hazard is increasingly gaining the interest of governments and scientists, as their damage could irreparably affect the cultural heritage. Relevant experience in studying and promoting seismic mitigation programs for museum collections has been developed for example at the J. Paul Getty Museum in California [2]. Important efforts to protect art objects have also been carried out in some countries of the Mediterranean area, which is a zone prone to earthquakes and famous for its artistic heritage, such as Greece [3,4], Turkey [5,6] and Italy [7,8]).

Dealing with this issue requires a multidisciplinary approach in order to formulate a global judgement on the level of risk and to evaluate effective protection strategies, trying to find a compromise between the requisite for safety and the principles of conservation.

An essential step in the assessment of the vulnerability of art objects is to control their global stability condition. To this aim different methods may be applied within the framework of rigid block mechanics, such as dynamic analysis with the integration of the non linear equations of motion [9], or approximated relationships which control sliding and rocking by the seismic Peak Ground Acceleration (PGA) and the overturning by the Peak Ground Velocity (PGV) [10,11].

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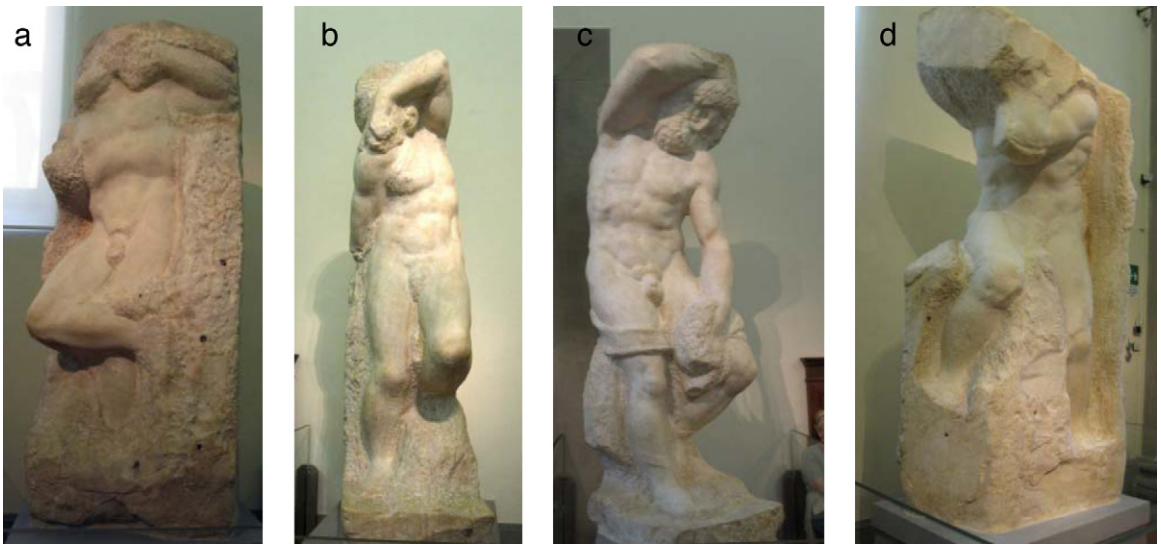

Fig. 1. (a) *"Prigione Che Si Sveglia"*; (b) *"Prigione il Giovane"*; (c) *"Prigione Barbuto"*; (d) *"Prigione Atlante"* (Florence, Accademia Gallery).

When rocking and tilting phenomena are predicted by the stability analyses a possible solution may be to fix firmly the object to the base; this solution avoids triggering of every motion phenomenon, but it opens up two important questions: the first, which focuses more on the procedure and the philosophy of intervention, concerns the choice of fixing the object to the pedestal – the restraining procedure is not always feasible with low impact techniques and sometimes it requires non reversible interventions such as drilling and piercing the contact areas of the object in order to get the best fitting between it and the plane. The second aspect goes deeper into the technical aspects of the problem: actually, as long as the art object is fixed to the ground, it will move together with the ground, hence the amount of forces transmitted to the artefact can be very high. In this condition the art object is forced to bend and deform, instead of oscillating rigidly, so requiring an accurate evaluation of the stress level: the mechanical limit state of the material must not be reached at any instant of the earthquake. To this aim detailed finite element analyses, which account for the deformability of the object, may be applied.

2.1. Seismic action and reference limit state

The safety and protection of art objects against seismic risk could be guaranteed by defining two specific limit states which are respectively referred to the necessity of safeguarding people (Life-Safeguard Limit State, which is a Ultimate Limit State, ULS) and to the loss or damage of the artistic assets themselves (Artistic Limit State, ALS), according to the suggestions of the DPCM2007, [1].

For an art object, the fulfilment of ALS could be guaranteed with respect to the reference seismic event used for ULS, since it considers a global loss of equilibrium, which irreparably compromises the conservation of the art object itself. As for the difference of such limit states, by considering for example the analysis of equilibrium of a statue, if the reference seismic action implies the oscillation but not the overturning, we can assert that ALS is not verified (the triggering of oscillations could lead to uncontrollable damage for the object), while the ULS is satisfied, since no overturning occurs, so guaranteeing the safety of the persons which are near the object.

3. "Galleria dei Prigioni" sculptures

The "Galleria dei Prigioni", located at the ground floor of the Accademia Gallery in Florence, houses six important Michelangelo's sculptures thus creating a suggestive path leading the visitor to the centre of the Tribune where the famous David stands.

The Gallery takes its name from the four big unfinished sculptures showing male nudes known as the Slaves or Prisoners: *"Prigione Che Si Sveglia"* (Awakening Slave), *"Prigione il Giovane"* (Young Slave), *"Prigione Barbuto"* (Bearded Slave) and *"Prigione Atlante"* (Atlas Slave), Fig. 1; besides them in the room the sculptures of *"San Matteo"* (Saint-Matthew) and *"Pietà da Palestrina"* (Pietà Group) are displayed, Fig. 2.

3.1. Historical research

The Slaves were carved by Michelangelo between 1530 and 1536 and were intended for the tomb of Pope Julius II. After the death of Michelangelo they were given as a gift to Cosimo I, the Grand Duke of Tuscany, and then placed in the "*Grotta del Buontalenti*" in the Boboli Gardens in Florence, where they remained up to 1909 when they were moved to the Accademia Gallery.

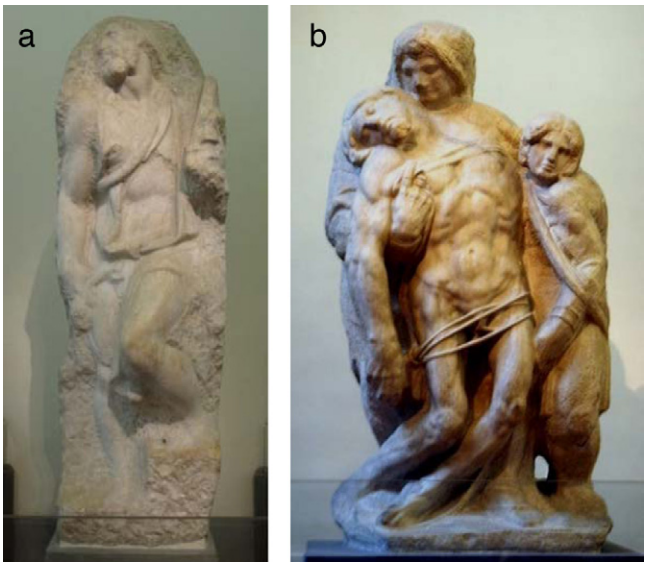

Fig. 2. (a) *"San Matteo"* and (b) *"Pietà da Palestrina"* (Florence, Accademia Gallery).