



## کاهش خطر لرزه‌ای اشیاء هنری داخل موزه‌ها علی تارمیغ

### چکیده

دستاوردهای فرهنگی که از تاریخ باستان تا عصر معاصر کشیده شده‌اند، بیانگر تلاش جمعی گروه‌های قومی متنوع است. همانند کلماتی که معانی را از طریق صدا منتقل می‌کنند، اشیاء موزه سمبل و مفاهیم فرهنگ‌های مختلف هستند. تهدید ناشی از زلزله فراتر از زیرساخت تخریب موزه برای به خطر انداختن ویتترین و اشیاء داخل موزه‌ها در نظر گرفته شده است. حفاظت از میراث فرهنگی یک کشور نیازمند اقدامات ویژه‌ای برای کاهش خطرات ناشی از زلزله است.

برای ارزیابی آسیب‌پذیری لرزه‌ای اشیاء داخل موزه‌ها، یک رویکرد منطقی شامل اتصال آن‌ها به اجسام صلب و تحلیل دینامیکی شبیه به دینامیک خطی مورد مطالعه گسترده بلوک‌های صلب است. با شناخت ماهیت پویای اشیاء موزه و ضرورت حفاظت لرزه‌ای در مدیریت بحران موزه، محدود کردن پاسخ لرزه‌ای این اشیاء به منظور جلوگیری از آسیب به آثار باستانی و دیگر ارقام ارزشمند ضروری است. در این مقاله به بررسی رویکرد افزایش مقاومت لرزه‌ای اشیاء داخل موزه‌ها پرداخته می‌شود که به آن‌ها اجازه می‌دهد تا در معرض نمایش عمومی باقی بمانند و آسیب بالقوه را به حداقل برسانند.

واژگان کلیدی: اشیاء هنری، مکانیسم فروپاشی، میراث، شی موزه، مدیریت ریسک، کاهش لرزه‌ای.

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## Seismic Risk Mitigation of Art Objects in Museums

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### Abstract

Cultural achievements, such as art, architecture, and historical artifacts, represent the collective efforts of various civilizations and ethnic groups throughout history. These achievements are preserved and displayed in museums, where they symbolize and communicate cultural values and historical knowledge. Museums face multiple threats, including the risk of natural disasters like earthquakes, which not only damage museum infrastructure but also jeopardize the safety of exhibits and stored artifacts.

Protecting a nation's cultural heritage within museum settings requires targeted measures to mitigate earthquake-induced risks. To assess the seismic vulnerability of museum artifacts, they can be modeled as rigid bodies, with their seismic response analyzed similarly to rigid block dynamics, a well-established method in structural engineering. By understanding the dynamic behavior of museum objects and integrating earthquake protection strategies into museum crisis management, it is possible to limit the seismic response of these objects, reducing the risk of damage both to the artifacts and surrounding exhibits.

This paper introduces methods to enhance the earthquake resistance of museum artifacts, enabling them to remain safely on public display while minimizing potential damage during seismic events.

**Keywords:** Artifact, Collapse mechanism, Heritage, Museum object, Risk management, Seismic mitigation.

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## Introduction

Iran indeed has a rich and diverse history that has contributed significantly to world civilization. The country is home to a wide array of historical artifacts and remnants from various dynasties, showcasing the cultural, artistic, and scientific achievements of different periods. Museums in Iran play a crucial role in preserving and displaying these valuable historical items, offering a glimpse into the nation's fascinating past.

The presence of numerous museums across Iran reflects the commitment to safeguarding the cultural heritage of the region. These institutions serve as repositories of knowledge and contribute to the education and appreciation of both locals and visitors. Museums in Iran cover a wide range of topics, including archaeology, art, history, and science, providing a comprehensive overview of the country's multifaceted cultural legacy.

However, the susceptibility to earthquakes in Iran, particularly in cities like Tehran, poses a significant challenge to the preservation of these

historical artifacts. The seismic activity in the region can potentially lead to the destruction of valuable items and cultural landmarks. It is imperative for museum authorities and the government to implement robust measures to protect these artifacts from the impact of earthquakes.

This may involve employing advanced seismic retrofitting techniques, designing earthquake-resistant museum structures, and establishing emergency response plans to mitigate potential damage during seismic events. Additionally, raising awareness about the importance of preserving cultural heritage and the role of museums in achieving this goal is crucial.

Despite the challenges posed by the seismic activity, the efforts to maintain and showcase Iran's rich history through its museums remain essential. By combining effective preservation strategies with public awareness and engagement, Iran can continue to celebrate and share its cultural heritage with the world, even in the face of natural hazards. Tehran is one of the cities with high earthquake hazard and according to Fig. 1, the earthquake hazard in Tehran is very high.

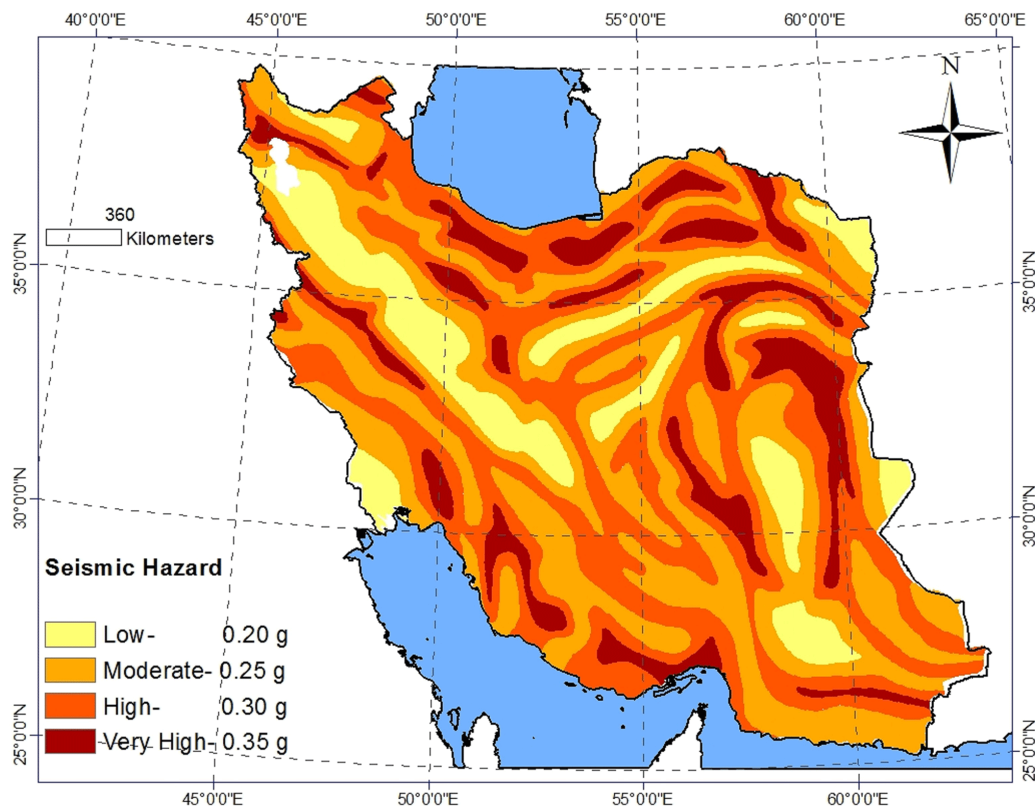


Fig. 1. Seismic hazard map of Iran (BHRC, 2015).

Earthquakes are an integral part of the course of natural disasters and basic planning is needed to mitigate earthquake damage. Strengthening the building and strengthening its foundation structures is one of the key steps to reduce damage. Earthquake is a natural and historical fact for us that it constantly targets some parts of the earth at short and long-term intervals with high and moderate intensity, and the only way to deal with it is the rational acceptance and application of this fact. Program is planned and responsible according to Fig 2. for three phases: pre-earthquake, when the earthquake occurs, and post-earthquake (rescue phase and reconstruction phase). In such cases, one of the sensitive areas is definitely the cultural and historical heritage of each country.

Without reinforcement, even a low-magnitude earthquake can have devastating effects. If the structure survives the earthquake, the facilities and objects inside the museum may be damaged. For this reason, ensuring the safety of objects inside the museum should be taken as seriously as the building. To this end, Getty Museum has made good progress in protecting museums and monuments of historical value.

The protection of cultural and historical heritage is particularly sensitive during seismic

events. Museums, which house invaluable artifacts, are especially vulnerable, and the damage to these artifacts can result not only in a loss of cultural heritage but also in the destruction of irreplaceable historical items.

The mention of the Getty Museum's efforts is pertinent. The Getty Museum, located in Los Angeles, California, is known for its proactive approach to earthquake preparedness. The museum has implemented advanced seismic retrofitting techniques and technologies to protect its collections and buildings. These measures include base isolators, structural reinforcements, and other engineering solutions to minimize the impact of seismic activity.

Museums worldwide can learn from such examples and invest in advanced technologies and strategies to enhance the seismic resilience of their structures. This includes not only strengthening the physical buildings but also implementing measures to secure and protect the artifacts within.

Additionally, a comprehensive disaster management plan for museums should encompass preventive measures, such as secure display mounts, storage solutions, and emergency evacuation plans for both staff and visitors. Training staff on emergency response proce-

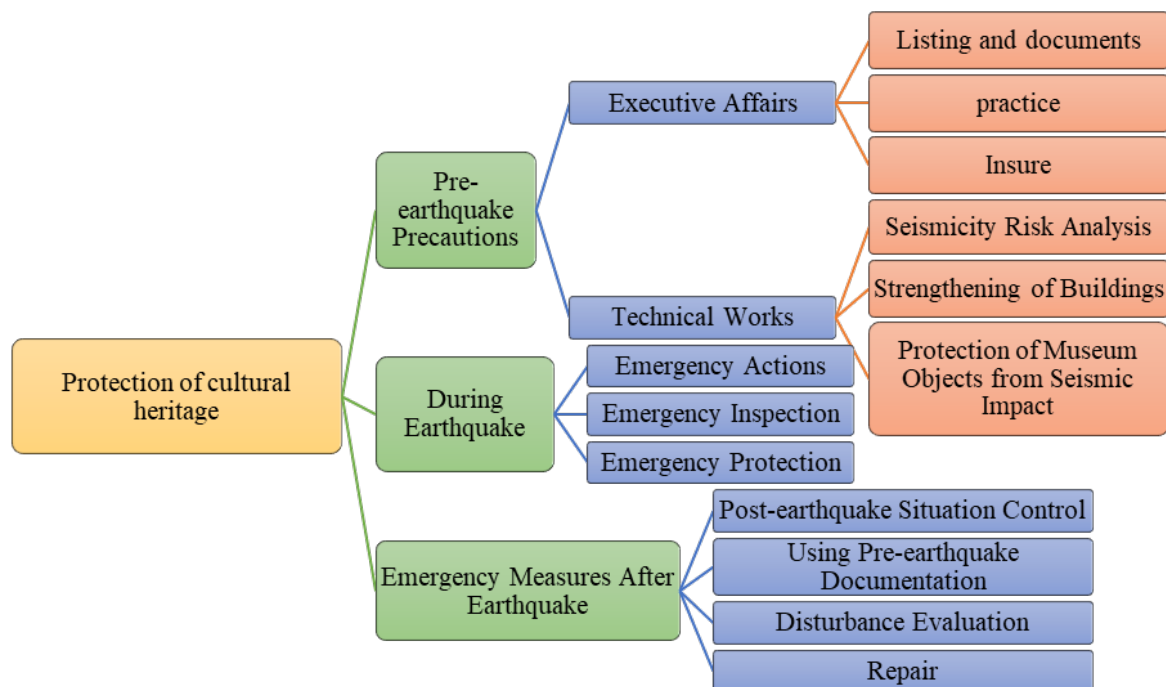


Fig. 2. Risk management in protection of cultural heritage.

dures and conducting regular drills can further enhance the readiness of museums to handle seismic events.

The rational acceptance of the seismic risk and the application of well-thought-out strategies are crucial for minimizing the impact of earthquakes on cultural and historical heritage. As technology and knowledge in this field continue to advance, ongoing efforts to strengthen structures, protect artifacts, and refine disaster management plans will contribute to preserving our shared cultural legacy.

Earthquakes threaten not only museum buildings, but also exhibits and all objects kept in storage. As shown in Figures 3 and 4, when an earthquake occurs for a museum, even if the museum is structurally the strongest possible, seismic waves are transmitted to the floors via structural elements. This will cause the artworks inside the museum to vibrate. These objects, which may include chandeliers, frames, showcases and other art objects, may fall or collide with other objects due to the vibration created by earthquake waves. Every work of art kept in museums is related to the history and heritage of a nation, and if it is destroyed, a country's heritage is destroyed. For this reason, it is very important to protect the national heritage of our country against the dangers caused by earthquakes and special precautions should be taken in this regard.

Seismic waves, even in well-constructed and earthquake-resistant buildings, can lead to the shaking and displacement of objects inside museums. This poses a risk to delicate and valuable items such as sculptures, paintings, artifacts, chandeliers, frames, and other art objects. The potential for these items to fall or collide during an earthquake can result in irreparable damage, causing the loss of a country's cultural heritage.

To address these challenges, museums implement various measures to secure and protect exhibits:

**Seismic Isolation Systems:** Some museums use advanced seismic isolation systems that decouple the building structure from ground motion, reducing the transmission of seismic forces to the contents inside.

**Display Mounts and Casework:** Artifacts and objects are often secured with specially designed mounts and casework that can absorb shocks and prevent movement during seismic events.

**Storage Solutions:** Proper storage is crucial. Objects in storage should be securely housed in cabinets or shelving designed to withstand seismic activity. Secure storage can prevent objects from falling or shifting.

**Securing Hanging Objects:** Chandeliers, frames, and other hanging objects are secured using appropriate hanging systems that can absorb shocks and prevent swinging.

**Training and Emergency Procedures:** Museum staff should be trained in emergency response procedures, including protocols for securing and protecting artifacts during earthquakes. Regular drills can ensure that staff are well-prepared.

Collaboration with engineers, conservators, and experts in museum studies is vital for developing and implementing effective strategies to protect cultural heritage during seismic events. As you rightly pointed out, the destruction of cultural heritage is a loss not just to the museum but to the entire nation, emphasizing the need for special precautions and ongoing efforts to enhance the resilience of museums and their collections against earthquake-related risks.

### **Dynamic analysis and method**

The earthquake resistance of irreplaceable art objects in seismically active regions is of paramount importance because of the possibility of damage to historical and cultural art objects in museums and other public institutions. The development of methods to increase the earthquake resistance of art objects, while at the same time allowing them to remain on public display, is a complex problem. The earthquake resistance of an art object depends upon both the object's characteristics and the methods used for its support. To increase earthquake resistance, both the object itself and the support system can be modified. Examples of modification of the object include adding mass to

lower the center of gravity, and introducing internal damping devices. Examples of support system modification include suspension devices, viscoelastic mounts, and base isolators. In any case, an important and difficult requirement is that these modifications interfere as little as possible with the appearance of the art object to the viewer.

The seismic action is transmitted to the art object by its support or restraint. These introductory considerations make it evident that the development of guidelines of general validity for the seismic protection of art objects requires some preliminary broad classification with respect to the main features of their seismic response and possible causes of damages: the most important division is between objects supported on a horizontal plane (on a floor of the building, within an exhibition case, etc.) and suspended or hanging objects. Such a classification, a revised version of the one first presented by Agbabian *et al.* (1990) and already modified by Augusti *et al.* (1992), is reported in Tables 1 and 2, respectively with regard to the main types of art objects and their form of support or restraint.

The choice of the most convenient anti-seismic intervention is related to the dynamic behavior of the artifact, and to the expected collapse mechanism, which is, in turn, strictly related to the assumed restraint.

Statues, indeed, are usually represented, both as fixed at the soil/pedestal, through a two-way restraint, or as simply supported, through a one-way restraint. These two restraint assumptions are expected to determine different mechanical responses of the artifact to seismic excitation, suggesting, in turn, the opportunity of different choices regarding the structural modeling and the type of analysis. In case of fixed restraints, the seismic acceleration arising from the earthquake affects the artifact, inducing high stress levels, which can lead to damages or rupture. The amount of damage is related to the mechanical properties of the material, which play an important role in the seismic reliability of the artifact. In case of simply supported restraints, the seismic action induces mainly displacements and rotations between the artifact and its support, with a consequent sliding and rocking or overturning, depending on the friction (Monaco *et al.* 2014) assumed



Fig. 3. Failures caused by overturning at the National Museum of Athens during the 1999 Athens (Parnitha) earthquake (Spyrakos *et al.*, 2008).



Fig. 4. Failures caused by overturning and impact at the Archaeological Museum of Argostoli during the Kefalonia 2007 earthquake (Spyrakos et al., 2008).

Type	Objects
A1	Small Flat-bottom Ed Objects (Vases, Cups, Dishes, Flat-bottom Ed Busts, Etc.)
A2	Small Objects Without Flat Bases
A3	Statues
A4	Paintings On Canvas or Wood Panels
A5	Clocks
A6	Objects Supported By 4 Legs (Commodes, Tables, Chairs, Etc.)
A7	Objects Supported by Fewer Than 4 Legs (Consoles, Tables, Etc.)
A8	Objects Displayed at An Angle (Plates, Bowls, Etc.)
A9	Hanging Panels (Boiserie)
A10	Candelabra Or Chandeliers
A11	Display Cases or Wall Supports
A12	Art Objects Not Described in Above

Table 1. Art objects typological categories (Agbabian et al., 1990).

between the artifact and its support (soil or pedestal).

As a result of these observations, the type of analysis should be related to the restraints assumptions. The assumption of simply supported restraint should be related with a Finite Element Model with interface friction between the sculpture and the support, or—for high friction levels—with a rigid blocks analysis. The assumption of fixed support, instead, should be related to a Finite Element Analysis where the material is described through a

careful representation. Figure 5 shows the relationship between the restraint assumptions, the consequent collapse mechanisms and the most suitable types of analysis.

### Conclusion

The rich cultural and historical heritage of Iran, as reflected in its museums and artifacts, faces a significant challenge due to the country's susceptibility to earthquakes. While museums serve as invaluable repositories of knowledge, preserving and showcasing Iran's multifaceted

Type of Support	Support
S1	Free-standing
S2	Fixed-base
S3	Rod-supported
S4	Suspended. 1 Dof
S5	Suspended, 2 Dof
S6	On Pedestal
S7	In Floor Case
S8	In Wall Case
S9	Composite System
S10	Braced From Side

Table 2. Support of objects typical categories (Augusti et al., 1992).

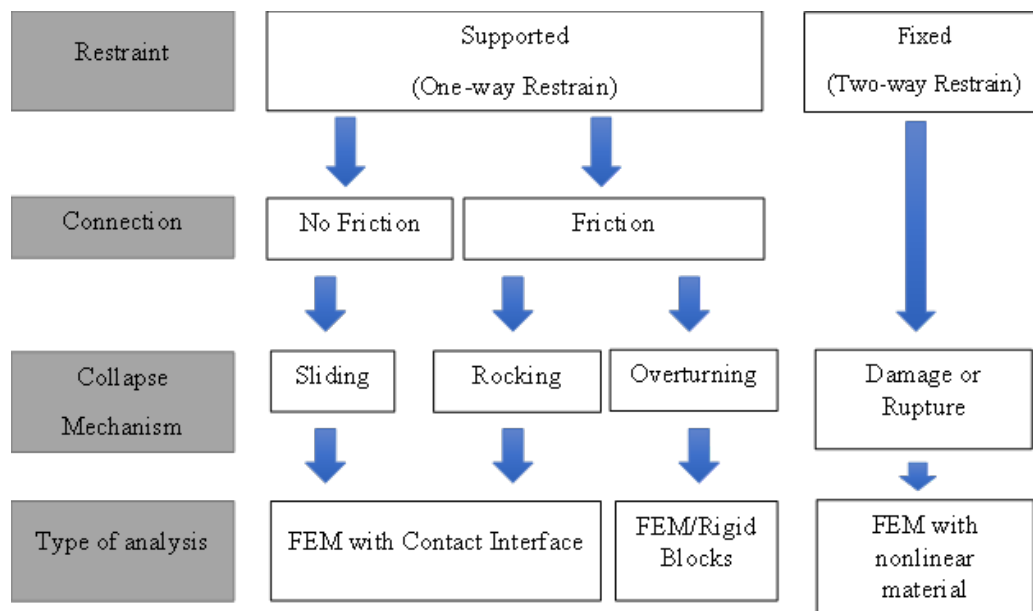


Fig. 5. Relationship between type of analysis and restraint assumptions (Viti et al., 2020).

cultural legacy, the seismic activity in regions like Tehran poses a threat to the preservation of these treasures.

Efforts to protect cultural heritage during earthquakes involve a multi-faceted approach. The structural reinforcement of museum buildings is a key element, encompassing advanced seismic retrofitting techniques and earthquake-resistant designs. The Getty Museum's proactive measures in earthquake preparedness serve as a noteworthy example for museums worldwide.

However, the focus extends beyond building resilience. The protection of exhibits and

artifacts within museums is equally critical. Seismic waves can transmit vibrations to objects, potentially leading to their displacement or damage. Implementing measures such as seismic isolation systems, secure display mounts, and storage solutions are essential to safeguarding the irreplaceable artworks and artifacts.

The dynamic analysis and methods discussed further underscore the complexity of ensuring earthquake resistance for art objects. Modifications to both the objects and their support systems, while minimizing interference with their visual appearance, require careful

consideration. The classification of art objects based on their seismic response and restraint types guides the choice of anti-seismic interventions, emphasizing the importance of tailored strategies for different artifacts.

In the face of seismic threats, ongoing collaboration between museum authorities, engineers, conservators, and experts in museum studies is crucial. A comprehensive disaster management plan, including training for museum staff in emergency response procedures, adds an extra layer of preparedness.

As technology and knowledge in seismic protection continue to advance, it is imperative for nations, including Iran, to adapt and implement evolving strategies. The rational acceptance of seismic risks, coupled with the application of well-thought-out measures, ensures the continued preservation and celebration of cultural heritage, even in the face of natural hazards. By combining effective preservation strategies with public awareness and engagement, Iran and other earthquake-prone regions can strive to protect their national heritage for future generations.

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