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DETERMINATION OF THE APPLICABILITY OF SEISMIC CONTROL METHODS TO THE HISTORICAL BUILDINGS OF ELAZIĞ-PALU DISTRICT

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Abstract

Historical buildings need to be preserved, shedding light on the history and culture of societies that have survived from the past to the present. These buildings may face the threat of extinction for various reasons. It is important to minimize these threats and transfer the building to future generations healthily. In this regard, traditional techniques or current technologies come to the fore. This study aims to investigate the use of "seismic control methods" in historical buildings, which have emerged as an important method of earthquake conservation in recent years. This study consists of two stages. In the first stage of the study, the legislation related to the conservation of cultural heritage was examined and the important parameters related to the consolidation and restoration of historical buildings were determined. Then, "seismic control methods" related to the strengthening of historical buildings against disasters were examined and the use of these methods in historical buildings was evaluated in terms of international legislation. In the second part of the study, fieldwork was carried out. 3 historical masonry buildings in the Palu district of Elazığ were selected as the study area. These historical masonry buildings are Palu Grand Mosque, Historical Palu Bridge and Cemsit Bey Kulliye. The applicability of seismic control methods in these historical buildings has been investigated in terms of legislation. In the evaluation stage of the study, to minimize the disaster risk of these historical buildings, other examples in the literature were examined and seismic control methods that can be used in historical buildings were determined. As a result of the study, it has been seen that seismic strengthening can be applied using seismic control systems in different historical buildings in Elazığ Palu in accordance with international legislation.

***Keywords**: Historical Buildings; Seismic Risk; Seismic Control Methods; Architectural Conservation*

Introduction

Historical buildings as cultural heritage needs to be preserved, shedding light on the history and culture of societies that have survived from the past to the present. These buildings may face the threat of extinction for various reasons. It is important to minimize these threats and to transfer the historical buildings to future generations in a healthy way.

There is an important historical building stock in Türkiye, which has been home to many civilizations over the years. However, natural disasters that occur frequently in Türkiye and threat these historical buildings. Since Türkiye is located on active fault lines, the earthquake factor appears as an important issue. According to the statement made by the Ministry of Environment, Urbanization and Climate Change of Türkiye in 2020, there are 24500 kilometres

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of live fault lines in Türkiye and 71 percent of the population and 66 percent of the country's territory are at risk of earthquakes. In Türkiye, these historical buildings, which are mostly built with a masonry system, are under threat of earthquakes. These masonry buildings lack the "ductile" behaviour, which is very important in earthquake-resistant building design.

In this study, the Palu district of Elazığ Province, which is located on the Eastern Anatolian Fault Line, was selected as fieldwork. The disaster risk maps of the district were obtained from the Elazığ Provincial Risk Reduction Plan of the Disaster and Emergency Management Presidency (AFAD) affiliated with the Ministry of Internal Affairs of Türkiye. There are findings that the history of the Elazığ-Palu dates to 5000BC. For this reason, there are many architectural monuments and historical buildings belonging to different periods.

In the study, the disaster risks of 3 historical buildings located in Elazığ-Palu were determined. These historical masonry buildings are Palu Grand Mosque, Historical Palu Bridge and Cemsit Bey Kulliye. In the study, seismic control methods for strengthening historical buildings against earthquake risk were investigated. Turkish legislation and international legislation on the restoration and strengthening of historical buildings were analysed in detail. As a result of this analysis, the principles to be considered during the restoration determined in these legislations are listed in a table. In the next stage of the study, a literature review on seismic control methods was carried out and seismic control methods applied to historical buildings around the world were examined. Although there are many examples of the use of seismic control methods, which are frequently used in seismic retrofitting of today's buildings, they are relatively new in historical buildings. There are some principles and international legislation that should be considered when intervening in historical buildings. In the examinations, the construction date, location, construction system of the building, the location of the isolator and detailed technical drawings of the historical buildings where the seismic control method was applied were given.

In the last stage, the applicability of seismic control methods to the historical masonry structures of Elazığ-Palu was discussed.

Case Study

In the case study, 3 different historical buildings have been selected from Elazığ-Palu. Elazığ is located on Eastern Anatolia Region of Türkiye. Elazığ has high seismicity. In this study, Palu district of Elazığ has been selected as the case study area. Palu has located on Palu-Bingöl active fault line. The district has great historical building stock. Therefore, these historical buildings under risk of earthquakes. There are different disaster risks for these three historical buildings due to the factors such as the state of preservation, construction technique and the characteristics of their locations etc.

In the study, seismic control methods, which are the newest technologies in terms of earthquake resistance, are discussed in terms of the limitations of the protection regulations for these three historical buildings with different functions. The constraints to be observed in terms of architecture have been selected as follows according to the regulations, uniqueness, integrity, consistency, minimum intervention, reversibility and preservation of historical aesthetic artistic and cultural value. In the study, these historical buildings were evaluated from a broad perspective in terms of the determined criteria.

Palu has located on the side of the Murat River and it is 844 meters above sea level (Fig. 1). Palu has been an important settlement area of the region since early times. Findings are dating back to 5000BC in the district. Throughout history, the district has been home to various cultures such as Sumerians, Hurrians, Hittites, Assyrians, Urartians, Persians, Romans, Sasanians, Byzantines, Umayyads and Abbasids.

Various architectural monuments belonging to these cultures have survived to the present day in the district. Some of these historical buildings have been restored and are still in use today, while others face extinction threats. The region is an area that is highly affected by natural disasters, these historical buildings are also affected by these natural disasters.

Fig. 1. Palu District [1]

Evaluation of Elazığ-Palu District in Terms of Disaster Risks

When the Türkiye Earthquake Risk Map is analysed, it is seen that Elazığ is in the 2nd degree earthquake risk zone (Fig. 2). According to historical earthquake records, there have been many destructive earthquakes in Palu district, which was determined as the sample area for this study. According to Türkiye Active Fault Map, the destructive East Anatolian Fault Zone (EAFZ) passes just south of Palu (Fig. 3). Türkiye has experienced significant loss of life and property, in devastating earthquakes that took place in recent years. The most destructive of these earthquakes in recent years are the 6.9 mW Izmir Earthquake on 30 October 2020, the 6.5 mW Elazığ-Sivrice Earthquake on 24 January 2020 and the 7.2 mW Van Earthquake on 23 October 2011[2].

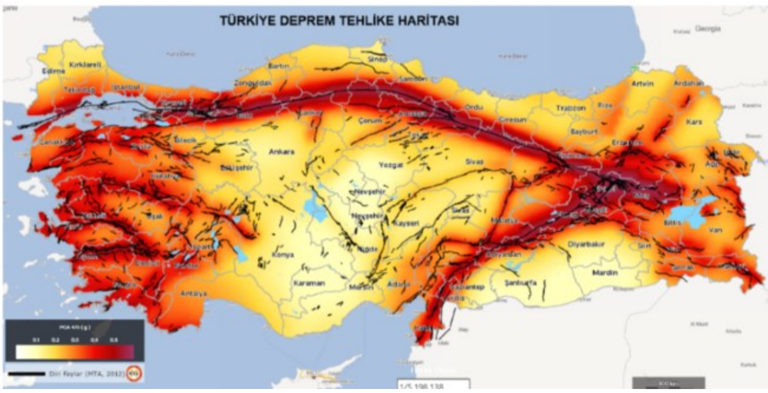
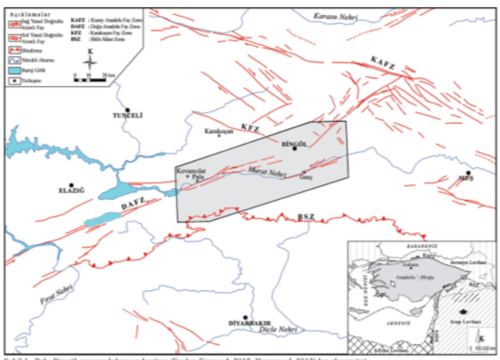


Fig. 2. Earthquake Risk Map of Türkiye [3]



Şekil 1- Palu-Bingöl arasının lokasyon haritası (Faylar, Emre vd. 2012; Duman vd. 2012'den alınmıştır).

Fig. 3. Location map of Palu-Bingöl Fault [4]

Historical Buildings Selected as Examples

Cemşid Bey Kulliye

Cemşit Bey Kulliye was built in the 16th century at an altitude of approximately 500 meters above the Murat River (Fig. 4). The Kulliye consists of four parts. These are the mosque, the tomb, the madrasah and the graveyard. The current domes of the mosque are not original and were rebuilt after they collapsed. The General Directorate of Foundations completed the restoration of Cemşid Bey Kulliye in 2017. Kulliye has been restorated and strengthened in 2017. Therefore, risks have been eliminated.

Fig. 4. Cemşit Bey Kulliye

Palu Grand Mosque

The Grand Mosque, located in the Çarşıbaşı Neighborhood of Old Palu, is understood to have been built in 1852 to its inscription (Fig. 5). The Grand Mosque has a rectangular plan, the upper part of which is domeless and has the shape of a terrace roof. The roof of the mosque completely collapsed and has been repaired today after the restoration works started in 2014. The minaret has a square plan. The upper part of the mosque was also destroyed and has been restorated today. Black-and-white cut stone was used in the arch of the building. The building was built with rubble stone.

Fig. 5. Palu Grand Mosque before and after Restoration

Historical Palu Bridge

The Historical Palu Bridge, located on the Murat River, was built during the Roman Period according to the rumour and was restored during the Byzantine and Artuqid Periods. the bridge, which is 156.50 meters long and 3.5 meters wide, was restored in accordance with the original by the General Directorate of Highways in 2010 (Fig. 6). The bridge, which was the only transportation and crossing point that provided the south-north connection at the time, was passed as the bridge connecting Istanbul to Baghdad in historical sources. This bridge also has great importance in the development of Palu and the formation of a commercial centre.

Fig. 6. Historical Palu Bridge

Legislation on Conservation, Restoration and Strengthening of Historic Buildings

The legislation related to the conservation, repair and strengthening of historical structures can be divided into international and national legislation. In the study, the Athens Charter (1931) [5], Venice Charter (1964) [6], Convention for the Conservation of the World Natural and Cultural Heritage (1972) [7], Amsterdam Declaration (1975) [8], Convention for the Conservation of the European Architectural Heritage (1985) [9], Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage (2003) [10], Declaration for the Conservation of the Architectural Heritage of Türkiye (2013) [11], Grouping of Immovable Cultural Assets in Türkiye, Maintenance and The Principle Decision No. 660 [12] have been examined. In the examined legislation related to the conservation of architectural heritage etc. information is given about the substances that are thought to affect the relationship between the structural system and architectural design.

The Athens Charter (1931) [4] is characterized as the first serious international initiative on conservation. The 1st article of the charter states "First of all, the monument should be given importance to continuous maintenance and consolidation efforts aimed at restoring the durability and time-resisting power that it has lost due to collapse and abrasion". It has been stated that the existing monuments can be given a new use that is not very different from the original function and that the necessary arrangements can be made in the building in such a way as not to cause significant damage. According to the 7th article of the Charter; when historical structures need to be made for various purposes such as reinforcement, integration and reuse, the most basic condition is that the new interventions should be minimal, should be simple and reflect the structural layout and that the additions made can be read to be different from the original. In addition, it has been stated that modern techniques can also be used in cases where the old construction methods are not sufficient to strengthen the structural system or to integrate the structure.

In the 2nd article of the Venice Charter (1964) [5], it is stated "For the conservation and repair of monuments, all sciences and techniques that can help the study and conservation of the architectural heritage should be used". It is also stated in the Venice Charter that in cases where traditional techniques are insufficient, the monument can be strengthened by using any modern technique.

According to the Convention for the Conservation of the World Natural and Cultural Heritage (1972) [6], each country should strive by its conditions to develop scientific and technical studies and research for the conservation of the heritage and to perfect methods of intervention against hazards that threaten the natural and cultural heritage.

In the Declaration of Amsterdam (1975) [7], it is stated that the structures can be used with functions that are appropriate to their character and comply with the requirements of modern life, which will contribute positively to conservation. It is proposed to carry out regular maintenance of the architectural heritage, to carry out a comprehensive document collection and archiving work related to materials and techniques at the same time as maintenance and improvement is carried out.

According to the Convention for the Conservation of the European Architectural Heritage (1985) [8], states parties are obliged to prevent “the deterioration, damage or destruction of all protected assets”.

With the “Principles for the Analysis, Preservation and Structural Restoration of Architectural Heritage” adopted by ICOMOS in 2003 [10], the issue of repairing structural systems belonging to architectural heritage has been formalized and recognized for the first time. In this document, it was emphasized that the fact that the architectural heritage has been preserved to reflect the characteristics of the construction technology of the period is also important for the value of the architectural heritage. It has been recommended that the main goal in the restoration of the architectural heritage is the preservation of the entire structure, the restoration of the structural system alone is not enough and an interdisciplinary approach should be taken in the interventions to be made in the structural system of the architectural heritage. Considering the function of each structure, the safety and durability required by it should be evaluated and a choice should be made between traditional and modern methods that bring minimal intervention and are compatible with cultural values. It is important that the intervention made is reversible and that the intervention can be removed and/or changed without harming the work. On the other hand, besides the cultural authenticity of the structure, it was recommended to avoid interventions that would damage its structural authenticity, to respect the “initial design, construction technique and historical value of the structure” and to preserve the traces that will enable understanding in the future, to repair the structure as much as possible instead of completely renovating it. Regarding this issue, the ICOMOS Turkish Architectural Heritage Conservation Declaration was published in Türkiye in 2013 [11], information was given about the principles of intervention in architectural heritage, intervention approaches and forms in the declaration and the importance of originality and integrity concepts in conservation was emphasized. In the declaration, technical and technological value is defined as “all of the documentary qualities related to the technical knowledge, skills, construction, materials and workmanship of the period to which the cultural entity belongs”. In the declaration stating what needs to be done in terms of architectural features and structural system research at the documentation stage, the importance of operations such as determining the building foundations and floor properties is emphasized.

In the Decision of the High Council for the Conservation of Cultural and Natural Assets dated 05.11.1999 and Numbered 660 on the Grouping, Maintenance and Repair of Immovable Cultural Assets in Türkiye [12], it was decided that “the spatial, formal and structural characteristics that constitute the socio-cultural and historical identity of the structure, its original location in the environment, the conservation of its original mass and size, the form and qualities of intervention in these operations according to the current physical condition of the structure will be determined by the regional conservation boards” related to the principles of basic repair, with the same decision, it was stated that it is essential to protect the structures from demolition.

The principles emphasized in the legislation examined within the scope of the study on the conservation of historical structures are classified as indicated in Table 1.

Table 1. Principles of Conservation

Principles	Activities and processes
Function	Re-Function of the Building; Using the Same Function
Uniqueness	Structural Authenticity; Architectural Authenticity; Location; Material Construction Technique
Integrity	Structural Integrity; Architectural Integrity; Continuity with its Environment
Consistency	Structural Adaptation of Material; Aesthetic Harmony of the Material; Harmony of the Building with the Environment; Adaptation of the Structural System to Functional Change
Minimum Intervention	Minimal Intervention in terms of Architectural, Structural, Material and Construction Techniques; Functional, Aesthetic and Economical Dimensions of the Intervention; The Intervention is in a Visible or Invisible Position in the Building; Effect on Architectural Form
Reversible and/or Renewable Feature	Reversibility; Being Detachable; Being Renewable
Preservation of Historical, Aesthetic, Artistic and Cultural Value	Intervention; Ornamentation and Embellishment Effect etc.; The Effect of the Intervention on the Aesthetic, Artistic, Cultural and Technological Features of the Construction Period; Impact of Intervention on Historical Value
Documentation	Documentation at the Stage of Determination of the Foundation line; Documentation of Repair Stages; Post Repair Documentation; Architectural Documentation; Analysis and Detection of Structural System Problems; Creating a Future-Looking Archive

Seismic Control Methods

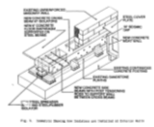
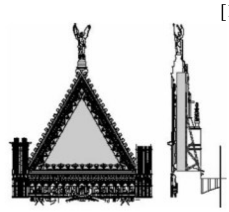
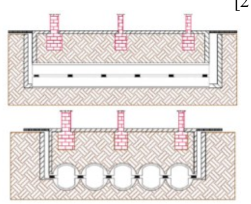
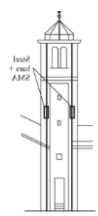
The seismic control method, which is based on the working principle of “dynamic characteristics of buildings using seismic isolators by changing to ensure safety against earthquakes” [13] the use of seismic isolators “instead of increasing the capacity of earthquake resistance of the building, the building is extended by the period of building is intended to reduce the seismic forces [14]. Seismic control methods are classified in various ways in the studies carried out on the subject. *N. Mora et al.* [15], divide seismic control methods into four main groups: passive systems, semi-active systems, active systems and hybrid systems. Passive control methods work without the need for any external energy [16]. For the operation of other systems, sensors, a control centre (computer) and an external power supply are required. Semi-active systems can be considered controllable passive devices since the data provided by the sensors are used only to readjust their mechanical properties. Active systems generate a real-time force applied to the building through electromechanical or electrohydraulic actuators to dampen external stimulation. Systems in which passive systems are used together with a semi-active or active system are hybrid systems [15] these techniques initially, new buildings (mainly steel and concrete framed buildings and bridges) are designed for, although these historic masonry buildings and other similar buildings that have low ductility are applied to [15].

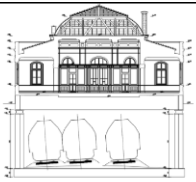
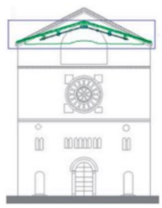
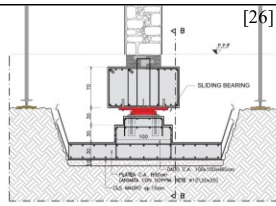
Shape Memory Alloys (SMA Devices), for their peculiar properties, have great potential in the field of passive seismic protection of buildings.

Examples of Historical Buildings Strengthened Using Seismic Control Methods

The most prominent examples of strengthening existing historical buildings with seismic control methods are mostly found in the United States (USA) and Italy [15]. On the other hand, there are also studies in which the devices are being tested in laboratories and are at the experimental verification stage. In this section, numerical analysis and experimental studies were performed and the suggestions in the models created were examined through applications and applied examples. The sample buildings examined are information about the construction system, the seismic control method used, the location of the isolator in the building and the details formed are shown in Table 2.

Table 2. Examples of Historical Buildings Strengthened Using Seismic Control Methods

Name of the Historical Building	Country/ Construction Date	Construction System of the Building/ Architectural Features/ Seismic Control Method Used	The Position of the Isolator in the Historical Building	Detail	Source
The Salt Lake City and Country Building	ABD/1891-1893	It is the first building in the world to be strengthened using seismic isolation. The building is a five-storey stone masonry building. There is a clock tower with a height of 76m. The building has a rectangular plan. The second and third floors are made of steel beams with brick arches. Other floors and roof are made of wood. /Reinforced using elastic friction and **lead core bearing**.	**The Foundation Level**/Isolators were made above the foundation and below the ground floor, so the first-floor slab had to rise 36 cm up.		[14-18]
San Serafino Church in Montegranaro	Italy/ 1503	The original church and additional cloister were rebuilt in 1603 on an old 13th-century building that was destroyed in 1431. Due to the earthquake in 1997, its roof was partially destroyed and the main facade was separated by 8cm displacement. The building, which was built with masonry walls, was strengthened with the **SMA** system by improving the connection between the traditional steel bars placed at a height of 15m.	**Between roof construction and walls, in a diagonal position, indoors**		[19, 20]
Cathedral of Siena	Italy/1125-1263	Siena Cathedral is one of the examples of Italian Gothic architecture. Its facade has golden mosaics and stained-glass windows. There are valuable works of art inside the building, which was built with masonry stones and bricks./ Strengthened with **Viscous Liquid Absorber**.	**On the façade/To prevent the façade from falling in order to improve the Dome**		[16-20]
Margherita Palace and the Civic Tower	Italy/1254-1374	The 2-storey palace building, made of masonry stone and brick, is a 40mx60m rectangular building with a courtyard. It was severely damaged in the 1703 earthquake and was rebuilt at a lower level. In 1937, the tower was reinforced by placing iron T-beams on the floors. It has been suggested that the horizontal pipes be placed and the isolation devices positioned in the horizontal diameter plane and reinforced with the **base isolation system** so that a discontinuity is created between the foundations and the ground.	**It is proposed to create an isolated platform under the foundation of the building without direct interference with the building.**		[21]
The Bell Tower of The Church of San Giorgio in Trignano	Italy/ 1302	The Bell Tower is 18.5 m high and has a square foundation with 3 m sides. It is surrounded by other buildings up to 11 m high on three sides. The masonry walls are 0.42 m thick near the corners and 0.3 m thick in the middle. The first three floors are made of wood, the fourth floor has been replaced by a floor made of two brick small vaults separated by a central steel I-beam. Powered by **SMA** device.	**It is made at the level of the wall in the facade/ interior.**		[20-22]
Göztepe Train Station	Türkiye/1915	It has been proposed to strengthen the building with isolation units to be placed on reinforced concrete carriers to be constructed in accordance with the new train line	**Foundation level/ Isolators were built on top of the existing foundation, under new columns**		[23]

Name of the Historical Building	Country/ Construction Date	Construction System of the Building/ Architectural Features/ Seismic Control Method Used	The Position of the Isolator in the Historical Building	Detail	Source
		elevation and route, by cutting the feet carrying the masonry structural system. /Reinforced with **Pendulum Type Friction Isolator.**	**and masonry walls.**	 	
Nusretiye Clock Tower	Türkiye/19.yy	Nusretiye (Tophane) Clock Tower, built in the second half of the 19th century, is the first clock tower in Istanbul. It is reinforced with **Pendulum Type Friction Isolator.**	**It is reinforced with the base isolator used at the foundation level.**		[24]
San Francisco Basilica, Assissi	Italy/1253	The building, which was built with a stone masonry system, was strengthened with **SMA**.			[25]
San Feliciano Cathedral, Foligno	Italy/1201-1133	The building, which was built with a stone masonry system, was strengthened with **SMA**.	**Under roof construction/on existing steel beams and walls**		[15-19]
Villa Ciccozzi La Silvestrella", L'Aquilla	Italy/1915	The masonry building was built in the early years of the twentieth century and has been preserved in its original configuration without any alterations or excesses. For this reason, it is thought to represent a rare example of eclectic, fantastic, grotesque architecture. It has been strengthened by insulating the base with **a highly damped rubber support system.**	**At the foundation level/Isolators are made above the foundation and under the ground floor walls.**		[26]
San Giovanni Battista Church	Italy/1340	Building made of masonry/Reinforced with metal roof and **viscous liquid absorber.**	**Between roof construction and walls**		[27]

The fact that these countries are located on active fault lines can be shown as a reason for using seismic control methods in historical buildings. In addition, there are regulations on earthquake risk management for historical buildings only in Türkiye, Italy and the USA in the world. In the year of 2017, which was enacted in Türkiye, "the English historical buildings for earthquake risk management guideline (2017)", which took effect in Italy in 2017 "Guidelines for the seismic risk Classification of Constructions" and prepared in the United States in 1992, updated in 2006, "FEMA 547: Techniques for the seismic Rehabilitation of existing buildings" in the regulations [17].

It is seen that different architectural details are formed according to the type of seismic isolation method used and the location where it is used in the building. In the strengthening of historical buildings against earthquakes using the seismic isolation method; the location of each building, its function, floor characteristics, structural damage status, decoration, decoration etc. it is understood that a special design should be made for the building by considering its aesthetic properties and the application process should be determined. While determining the isolation method and type at the design stage, it is possible to determine the effects of isolators placed in different positions of the building on the structural system with various analyses and simulations and to determine their effects from an architectural point of view. While determining the isolation method and type to be used; analysing electrical and mechanical solutions as well as static and architectural details enables more efficient applications.

In the examples examined, it is seen that seismic isolators can be placed at the foundation level, under the foundation level, under the roof construction, between the roof construction and the walls, on the facade, between the foundation and the floor columns. It is seen that in historical buildings built with the masonry construction system, base isolation systems, SMA devices and viscous liquid absorbers are generally used. Of these, it has been observed that the base insulation systems are located at the foundation level and SMA devices and viscous liquid absorbers can be positioned under the roof construction, between the columns. It is seen that if the base isolation systems are used at the foundation level, they can be in an invisible position indoors, while SMA devices and viscous liquid absorbers (if they are not hidden in any way) can be detected on the interior walls or exterior. If isolators are intended to be used on the façade, the existing façade setup/material must be resolved in a way that does not prevent the movement of the building after the isolation and does not create an additional danger to the users during a concussion. On the other hand, the function and interior features of the building are also effective in determining the method to be used and the position of the Isolator in the building. For example, the fact that the viscous liquid damping device used in the Siena Cathedral, which has Gothic features, is not perceived from the interior and is solved on the exterior, can provide a positive solution in terms of the density and aesthetic properties of the ornaments and decorations in the interior.

As can be seen from the examined examples; seismic isolation methods can be used alone or in combination with traditional reinforcement methods in masonry buildings. In the general evaluation, it is seen that isolator gaps and trenches should be built around the historical buildings strengthened by using base isolators and the reinforcement processes of the stairs and elevator shafts in these buildings should be examined in more detail.

Table 3. Evaluation of Seismic Control Methods According to Legislation

Seismic Control	**Position of the Isolator in the Building**	**Its Effect in Terms of Conservation Principles**
Method Used		Function; Uniqueness; Integrity; Consistency; Minimum Intervention; Reversible and/or Renewable Feature; Preservation of Historical, Aesthetic, Artistic and Cultural Value.
Base Isolator System	At foundation level between columns on the floor (in the foundation and ground floor columns)	• Does not affect the re-functioning of the building; • It negatively affects structural originality in terms of construction technique and material; • The floor height can indirectly affect architectural

Seismic Control	Position of the Isolator in the Building	Its Effect in Terms of Conservation Principles
		originality negatively; • Structural integrity may be disrupted; • It does not affect the continuity of the building with its environment; • Structural compatibility of the material can be achieved; • Negative details may occur in terms of the aesthetic harmony of the material; • The harmony of the building with the environment is not adversely affected; • It is positive that flexible solutions can be provided for the adaptation of the structural system to the change in function. • It requires great intervention due to the reasons such as providing an isolator gap around the building and needing to construct a trench, suspending the building; • The economic dimension of the intervention should be considered; • It is a permanent application that cannot be reversed; • Not removable; • Traceable and repairable; • It is thought that the application at the foundation level does not adversely affect the aesthetic and artistic value; • It is thought that the application at the foundation level does not adversely affect the cultural and historical value; • The application between the columns on the floor can negatively affect the aesthetic and artistic value.
Viscous Liquid Absorber	On the facade under roof construction	• Does not affect the re-functioning of the building; • The function of the building is a decisive element in the positioning of the isolator in the building; • It negatively affects structural originality in terms of construction technique and material; • When positioned on the façade, it can negatively affect architectural originality; • Structural integrity is relatively less disrupted; • It does not affect the continuity of the building with its environment; • Structural compatibility of the material can be achieved. • Negative details may occur in terms of the aesthetic harmony of the material; • The harmony of the building with the environment is not adversely affected; • It is positive that flexible solutions can be provided for the adaptation of the structural system to the change in function. • Requires major intervention; • The economic dimension of the intervention should be considered; • Contains less intervention than base isolation systems. • It is a permanent application that cannot be reversed; • Not removable; • Traceable and repairable; • When placed in a visible position, it negatively affects aesthetic and artistic value; • When placed in an invisible position, positive solutions can be produced in terms of preserving aesthetic and artistic value.
SMA Devices	On the façade under roof construction between roof construction and walls	• Does not affect the re-functioning of the building; • The function of the building is a decisive element in the positioning of the isolator in the building; • It negatively affects structural originality in terms of construction technique and material;

Seismic Control	Position of the Isolator in the Building	Its Effect in Terms of Conservation Principles
		• It can negatively affect the original architectural details in the interior; • Structural integrity is relatively less disrupted; • As facade details may occur, it may adversely affect the architectural integrity; • It does not affect the continuity of the building with its environment; • Structural compatibility of the material can be achieved; • Negative details may occur in terms of the aesthetic harmony of the material; • The harmony of the building with the environment is not adversely affected; • It is positive that flexible solutions can be provided for the adaptation of the structural system to the change in function; • Requires major intervention; • The economic dimension of the intervention should be considered; • May include more complex solutions specific to the building; • Contains less intervention than base isolation systems; • It is a permanent application that cannot be reversed; • Not removable; • Traceable and repairable; • When placed in a visible position, it negatively affects aesthetic and artistic value; • When placed in an invisible position, positive solutions can be produced in terms of preserving aesthetic and artistic value.

Evaluation

As a result of disaster risk assessments made on the historical buildings of Palu district of Elazığ province and literature studies conducted, it is observed that the greatest disaster risk in the region is "earthquake". The historical buildings that are intended to be conserved should be primarily structurally protected and strengthened against the effects of earthquakes. To bring the earthquake resistance of historical buildings to an adequate level, approaches are adopted that reduce the earthquake load on the building elements or increase the capacities of the building elements. The techniques used in strengthening practices for this purpose are generally divided into two groups, traditional and non-traditional methods [28]. In traditional strengthening methods, in order to increase the earthquake resistance of the structural system, it is necessary to use materials with high strength and/or structural elements (column, beam etc.) it is necessary to increase their dimensions, add new load-bearing elements such as curtains, frames, supporting steel crosses to the system [16-28]. This situation causes an increase in costs but affects the buildings architecturally and can be restrictive. It is obvious that these buildings, which have been built with traditional masonry construction techniques, should be intervened with different and specialized methods and materials compared to the interventions to be made in today's architectural works. In the 2nd article of the Venice Charter, it is stated that "For the conservation and repair of monuments, all sciences and techniques that can help study and preserve the architectural heritage should be used" [5]. In the Venice Charter, it is also stated that in cases where traditional techniques are insufficient, the monument can be strengthened using any modern technique. With the development of technology, it is seen that seismic control methods have started to be used in the seismic strengthening of historical buildings, as well as traditional methods in earthquake protection. For this reason, interventions that can be made without damaging the construction system and architectural value of the historical building have been examined and seismic control methods have been investigated in strengthening the buildings as a result of the research.

In this study, the use of seismic isolators in historical buildings located in the earthquake zone in different countries of the world has been examined and it was found that the applications are mostly used in the USA and Italy. There are many cultural heritage elements and historical buildings in Türkiye, which are located on active fault lines. Since these buildings need to be passed on to future generations, these historical buildings need to be made earthquake resistant. Throughout the study, seismic control methods have been examined, according to the legislation and international conservation has been compared to the USA, Italy and Türkiye before in historic masonry buildings in seismic base isolation systems applied to control applications, viscous liquid absorber devices and SMA was used.

The applicability of these three applications for 3 historical buildings located in the Palu district of Elazığ province has been examined. During the examinations, the compliance of the three applications with the legislation, the current conditions of the buildings and their locations were considered. The biggest priority in the strengthening works to be carried out has been to realize the minimum intervention in the historical building. Base isolation systems require much greater intervention than other systems. The necessity of opening pits in and around the building during the application poses a risk for historical buildings. For this reason, base isolation systems have been determined as the least suitable method for historical buildings. Viscous liquid absorber and SMA devices; although it gives approximately the same result in terms of function, originality, integrity, harmony, minimal intervention, reversibility, historical and aesthetic characteristics, there are differences at some points. Both systems can be positioned on the facade and under the roof construction, SMA devices can also be used between the walls. Neither system affects the function of the historical building. When evaluated in terms of the principle of originality, the fact that both systems can be positioned on the facade will affect the architectural originality of the historical building, therefore, it is necessary to position these seismic control methods in historical buildings in such a way that they are not reflected on the facade. In addition, the fact that some details may occur on the facade when SMA devices are positioned indoors is also an application that should not be preferred for historical buildings. When viscous liquid absorbers and SMA devices are evaluated according to the principle of structural integrity, material compatibility can be achieved with material selection, but aesthetically undesirable results may occur. This aesthetic incompatibility may vary depending on the area where the seismic control elements will be positioned. When seismic control methods are evaluated according to the principle of minimum intervention, it has already been stated that base isolation systems will not be suitable for historical buildings. Although viscous liquid absorbers and SMA devices require relatively less intervention in this regard than base isolation systems, they are still major interventions and it is vital that they are applied with great care. The 3 seismic control methods examined are also not reversible or renewable technologies, but the ongoing material research suggests that these problems can be eliminated in the following processes, especially in SMA devices. Seismic control applications to be carried out at the foundation level in historical buildings will not cause any negative impact on the historical, aesthetic, artistic and cultural value of the buildings. Viscous liquid absorbers and SMA devices can cause a negative impact on the cultural, aesthetic, artistic and cultural value of the building when they are located in a visible place of the building. On the other hand, these seismic control elements will not have any negative impact on these historical, aesthetic, artistic and cultural values when placed in a position where the building is not visible and is not reflected on the facade.

As a result of these assessments, base isolation systems require major intervention. Therefore, it was decided that it would not be appropriate for implementation to historical buildings.

It has been determined that the application of viscous liquid absorbers and SMA devices, which are two other seismic control methods for historical buildings, may have more positive effects compared to base isolation systems when evaluated according to the determined conservation and repair principles in these historical buildings.

According to the evaluation, 3 historical buildings in Elazığ-Palu, can be strengthened against earthquakes with the same seismic control method.

Conclusion

In Türkiye, which has a very rich stock in terms of historical texture and cultural heritage sites, these historical buildings, mostly built with a masonry system, have the threat of earthquakes. Masonry buildings lack the "ductile" behaviour which is crucial in earthquake resistance. In this study, 3 historical masonry buildings in Palu district of Elazığ province, located on active fault lines in Türkiye, were selected as an example. These buildings, which have different functions and architectural forms, have been evaluated in terms of earthquake risk. It has been determined that all these buildings are at risk of earthquakes. In this context, the possible effects of "seismic control methods", which are frequently encountered in recent years, on the strengthening of these historical buildings against earthquakes have been investigated. In the research, basic principles were determined in interventions to historical buildings and 3 different seismic control methods were compared according to these principles. When the national and international legislation and regulations regarding the intervention to historical buildings are examined, some basic principles come to the fore. According to the legislation reviewed, these basic principles were determined as Function, Authenticity, Integrity, Harmony, Minimum Intervention, Reversible and/or Renewable Property and Historical, Aesthetic, Artistic and Cultural Value.

When choosing a seismic control method for historical buildings, a much more sensitive and detailed study is required compared to today's buildings. Within the scope of the study, the seismic control methods used in historical masonry buildings in the world were analysed in detail. As a result of the examinations, it has been seen that the seismic control methods applied in historical masonry buildings in various countries of the world, base insulators, viscous liquid absorbers or SMA devices are used. These three methods are compared within the framework of the legislation in the "Evaluation" section.

The applicability of these 3 different methods was investigated for 3 historical masonry buildings located in the Palu district of Elazığ province, which is located in the earthquake risk zone in Türkiye. The main reason for choosing the historical building with 3 different functions and architectural features in the study is to determine the applicability of these control methods in different buildings. Based on the research, it was decided that base isolation system is not suitable for these 3 historical buildings, as the application of the base isolator requires major intervention to the historical building and will pose a great risk for the historical building during the application phase. Bbase isolation systems provide a positive situation in terms of aesthetics and integrity principles as they are located at the foundation level. Yet, major interventions pose a very important risk for the building according to the "minimum intervention" principle determined in the legislation. In this context, it is thought that other control methods that pose less risk for historical buildings would be more appropriate.

According to the conservation and restoration legislation, it is thought that viscous liquid absorbers and SMA devices will have approximately equal effects. Seismic protection can be provided by both methods. In addition, both methods require less intervention compared to base isolation systems. Both control methods can be positioned hidden under the roof construction or in the columns. This can be considered positive in terms of aesthetics and integrity principles.

In this study, it has been revealed that 3 historical buildings with different functions and forms in different locations in the Palu district of Elazığ can be strengthened against earthquakes with the same seismic control methods. In addition, with this study, a literature including conservation principles and possible risks for decision makers on seismic reinforcement in historical masonry structures has been presented. Table 1, which was prepared based on the conservation and strengthening principles in international legislation, also constitutes an evaluation system that restoration experts can use in seismic strengthening interventions for historical buildings.

References

[1] * * *, **Google Earth**. [Accessed on 11.05.2023].
[2] Soyluk, A., Mirnezami, S., & Karakaya, A. G. (2023). *Seismic behavior analysis of the kindergarten projects designed as an alternative to the type project examples in Turkey*. **Alexandria Engineering Journal**, *76*, 237-245.
[3] **AFAD.** [Accessed on 04.11.2022].
[4] V. Avci, M. Sunkar, *Palu (Elazığ)-Bingöl arasında Doğu Anadolu Fay Zonu üzerinde görülen heyelanların litolojik birimler ve fay hatlarıyla ilişkisi*, **MTA Dergisi, 157**, 2018, pp. 23-38.
[5] * * *, **Athens Charter** (1931). [Accessed on 17.06.2022].
[6] * * *, **Venice Charter** (1964). [Accessed on 23.06.2022].
[7] * * *, **Dünya Kültürel ve Doğal Mirasın Korunmasına Dair Sözleşme,** (1972) T.C. Resmî Gazete, (1983, February 14). Ankara, http://www.resmigazete.gov.tr/arsiv/17959.pdf
[8] * * *, **Amsterdam Charter** (1975). [Accessed on 20.07.2022].
[9] * * *, **European Convention for the Protection of the Architectural Heritage** (1985). [Accessed on 07.08.2022].
[10] * * *, **Conservation and Structural Restoration of Architectural Heritage** (2003). [Accessed on 10.07.2022].
[11] * * *, **Türkiye Mimari Mirası Koruma Bildirgesi** (2013). [Accessed on 15.03.2022].
[12] * * *, **Türkiye'de Taşınmaz Kültür Varlıklarının Gruplandırılması**, Bakım ve Onarımları Hakkında Kültür ve Tabiat Varlıklarını Koruma Yüksek Kurulu'nun 05.11.1999 tarihli ve 660 Sayılı İlke Kararı
[13] A. Yücesoy, **Sismik izolatörler ile depreme dayanıklı yapı tasarımı**, Yüksek Lisans Tezi, Mustafa Kemal Üniversitesi Fen Bilimleri Enstitüsü, Antakya, 2005.
[14] A. Soyluk, M.E. Tuna, *Sismik Taban İzolasyonu Uygulaması İçin Tarihi Şehzade Mehmet Camisinin Dinamik Analizi (Dynamic Analysis of Historical Sehzade Mehmet Mosque ForBase Isolation Application)*, **Journal of Faculty Engineering and Architecture, Gazi University**, **26**(3), 2011, pp. 667-675.
[15] N. Mora, E. Mendes, P.B. Lourenço, J.A. Covas, *Vibration control systems: A review of their application to historical unreinforced masonry buildings*, **Journal of Building Engineering**, **44**, 2021, Article Number: 103333. https://doi.org/10.1016/j.jobe.2021.103333.
[16] A. Luca, E. Mele, J. Molina, G. Verzeletti, A.V. Pinto, *Base Isolation for Retrofitting Historic Buildings; Evoluation of Seismic Performance Through Experimental Investigation*, **Earthquake Engineering & Structural Dynamics, 30**, 2001, pp. 1125-1145. DOI: 10.1002/eqe.54.
[17] A.G. Karakaya, A. Soyluk, *Comparison of Technical Intervention Regulations for Historical Buildings*, **The 2nd International Mediterranean Scientific Research and Innovation Congress**, K.K.T.C., 2022.
[18] J.S. Bailey, E.W. Allen, *Seismic isolation retrofitting: Salt Lake City and county building*, **APT Bulletin: The Journal of Preservation Technology**, **20**(2), 1988, pp. 33-44.

[19] M. Indirli, M.G. Castellano, *Shape memory alloy devices for the structural improvement of masonry heritage buildings*, **International Journal of Architectural Heritage**, **2**(2), 2008, pp. 93-119, https://doi.org/10.1080/15583050701636258.
[20] P. Clemente, A. Martelli, *Seismically isolated buildings in Italy: State-of-the-art review and applications*, **Soil Dynamics and Earthquake Engineering**, **119**, 2019, pp. 471-487. https://doi.org/10.1016/j.soildyn.2017.12.029.
[21] P. Clemente, A. De Stefano, *Application of seismic isolation in the retrofit of historical buildings*, **Earth. Resistant Eng. Buildings** (Proc. ERES 2011, Sept. 7–9, Chianciano, Italy), 2011, pp. 41-52.
[22] E. Ferretti, G. Pascale, *Some of the latest active strengthening techniques for Masonry Buildings: A critical analysis*, **Materials**, **12**(7), 2019, Article Number: 1151. https://doi.org/10.3390/ma12071151.
[23] B. Sadan, *State of the Art in Application of Seismic Isolation and Energy Dissipation in Türkiye*, in: **Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures: 17th World Conference on Seismic Isolation (17WCSI)** (Editor: G.P. Cimellaro), 2023, pp. 17-25, https://doi.org/10.1007/978-3-031-21187-4.
[24] * * *, https://www.emke.com.tr/projeler/nusretiye-saat-kulesi/. [Accessed on 07.01.2022].
[25] Croci, G. (2001). *Strengthening the Basilica of St Francis of Assisi after the September 1997 Earthquake.* **Structural Engineering International**, 11(3), 207–210.
[26] R. Vetturini, W. Cecchini, R. Mariani, T. Ciotti, E.M. Agostini, *Intervento di isolamento sismico alla foundation di un edificio in muratura di pregio storico-artistico in L'Aquila*, **Progettazione Sismica**, **4**(1), 2013, pp. 95-111. http://dx.medra.org/10.7414/PS.4.1.95-118.
[26] * * *, https://www.triphobo.com/places/cinque-terre-italy/church-of-san-giovanni-battista. [Accessed on 07.01.2022].
[27] P.S. Dhomane, S.B. Katpelwar, A.M. Chavhan, *"Overview of seismic retrofitting building"*, **IARJSET**, **4**(3), 2017, pp. 11-13.

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