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Original Research Article

Architectural Heritage at Risk: Historical Churches of East Azerbaijan*,**

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Abstract

Problem statement: Iran, with its valuable architectural heritage, is situated in one of the most seismically active regions of the world; therefore, special attention is required to ensure the protection of its historical buildings. East Azerbaijan Province, in the northwest of the country, with its prominent historical churches, represents a clear example of this necessity. Studies indicate that out of forty-nine identified churches in this province, only thirteen remain standing, while the majority have been damaged or destroyed due to natural and human-induced factors.

Research objective: This study aims to assess the safety and analyze the seismic vulnerability of eight selected historical churches in the province and to develop a prioritized list for their conservation.

Research method: The research adopts a comparative mixed-methods approach, combining qualitative and quantitative methods to ensure the accuracy of the results. Qualitative assessment was conducted on-site using Italian conservation guidelines, while quantitative evaluation was carried out using the 3Muri software to simulate the behavior of masonry walls.

Conclusion: The findings indicate that the seismic safety index of the churches is less than one, demonstrating the vulnerability of these historical structures to seismic events and highlighting the urgent need for intervention and the implementation of appropriate conservation measures. A comparison of qualitative and quantitative assessment outputs revealed that the qualitative approach is more conservative than the quantitative method. Therefore, this study emphasizes the importance of integrating both qualitative and quantitative approaches in a comprehensive assessment process to guide sustainable conservation strategies for national architectural heritage.

Keywords: *Church, Eastern Azerbaijan, Seismic Assessment, Italian Conservation Guidelines.*

Introduction and Problem Statement

In Iran, Christian religious buildings are a prominent example of cultural diversity and the peaceful coexistence of different ethnic and religious groups. Historic churches, especially in the northwestern region, are among the most important manifestations of this coexistence and reflect multifaceted cultural, social, and religious interactions over time. These valuable structures, built using unique architectural techniques and local materials, serve as clear evidence of the historical and cultural richness of the Christian community in Iran. They reflect the creativity and dynamism of diverse Christian traditions within this millennia-old geographical expanse, which has been a crossroads of

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civilizations, and provide valuable information about the technological and technical advancements of the society, as well as their beliefs and symbolic expressions.

According to research data, in the past there were a total of 223 churches in the Azerbaijan region, including the areas of Tabriz, Maragheh, Marand, Julfa, and Arasbaran in East Azerbaijan, as well as Urmia, Maku, Khoy, and Salmas (Fig. 1), but today only 42 of them remain (Malekmian, 2001). This region hosts a significant number of historic churches belonging to various Christian denominations, including Armenian Gregorian, Armenian Catholic, Chaldean Catholic, Roman Catholic, Assyrian Evangelical, and Adventist churches; among these, Armenian Gregorian churches are more numerous than the others (Karang, 1972; Hoviyan 2003; Catholic Church ..., 2026). Studies show that only 13 out of the 49 identified churches in East Azerbaijan Province (Table 1) have survived to the present day, while many others have been destroyed over time due to neglect or natural hazards.

This issue further underscores the necessity of paying attention to the conservation and restoration of these structures, especially in seismically active regions. Iran, located on the Alpine–Himalayan seismic belt, is considered one of the countries with a high seismic hazard in the world (Abdollahzadeh et al., 2014), and East Azerbaijan Province, as one of the most seismically active regions of the country, has experienced numerous earthquakes

Fig. 1. Map of the distribution of churches in northwest Iran. Source: Authors based on Google Earth.

throughout its history (Permanent Committee …, 2014). Under such conditions, seismic and structural assessment of historic buildings, aimed at identifying vulnerabilities and proposing effective conservation strategies, is of particular importance. Understanding the structural behavior of these buildings is the first step in developing sustainable strategies for the preservation of cultural heritage.

In this regard, the Italian Guidelines for the Evaluation and Mitigation of Seismic Risk for Cultural Heritage (Presidente del ..., 2011), as one of the valid international references, provide a systematic framework for assessing the seismic vulnerability of historic structures. These guidelines include both qualitative and quantitative methods for various types of historic buildings, including religious structures with large halls, towers, bell towers, masonry bridges, and vaulted structures, and can serve as a suitable scientific basis for analyzing the condition of historic churches in Iran.

Given the lack of comprehensive studies on the seismic and structural assessment of historic churches in Iran, the present research has been conducted to fill this scientific gap. The main objective of this paper is to evaluate the seismic vulnerability of historic churches in East Azerbaijan Province using a combined approach, including qualitative assessment based on the Italian conservation guidelines and quantitative assessment utilizing 3Muri software. The churches studied belong to various historical periods, ranging from the 10th to the 20th centuries, and represent Armenian Gregorian and Adventist denominations. The results of this study can, in addition to identifying structural weaknesses of these buildings, provide a basis for developing optimal seismic protection strategies and enhancing the resilience of the country's religious heritage.

Literature Review

Since the mid-20th century, the International Council on Monuments and Sites (ICOMOS) has developed various charters aimed at safeguarding cultural heritage. Among these, the Venice Charter (1964), emphasizing principles such as minimal intervention, preservation of the historical fabric, the use of valid restoration

Table 1. Churches of East Azerbaijan Province. Source: Karang, 1972; Shojadel, 2005.

Region	Church Name	Historical Period	Current Condition
Tabriz	St. Mary (Qala Neighborhood)	18th century	Standing
	St. Mary (Maralan Neighborhood)	18th–19th century	Standing
	St. Sarkis (Leylava Neighborhood)	19th century	Standing
	Holy Shoghagat	19th century	Standing
	Adventist Church	–	Standing
	Catholic Church	–	Standing
	Assyrian (Evangelical) Church	20th century	Standing
Villages near Tabriz	St. Hovhannes – Darvazeh Taq	–	Destroyed
	Varvara – Mojombar	18th century	–
	St. Hripsimeh – Mojombar	17th century	Standing
	Surp Anruyt – Mojombar	19th century	Almost completely destroyed
	St. Hovhannes – Sohrol	19th century	Standing
	Grigor Aljamak	18th century	Converted to a mosque
	Pir – Minavar	–	–
	Surp Sarkis – Dehkharaqan	16th century	Destroyed
Maragheh	St. Hovhannes	18th century	Standing
	Boghos	18th century	Destroyed
	Sarkis	18th century	Destroyed
	St. Mary (Pehrawa)	18th century	Partially destroyed
	St. Sarkis Aghajari	18th century	Partially destroyed
	St. Mary	16th century	–
Jolfa	St. Gevorg	19th century	Partially destroyed
	St. Sarkis	16th–17th century	Partially destroyed
	Andreas	–	Destroyed
	Chupan (Andre Vordi)	19th century	Standing
	Shrines of St. Hovhannes	18th century	–
	St. Mary of Old Jolfa	19th century	Standing
	Vank Amnaprgich	14th century	Destroyed
	St. Stepanos	10th–12th century	Standing
Arasbaran	Aghakhan Village Church	–	–
	Khanqah Village Church	18th century	–
	Qashvaq Village Church	18th century	–
	Gholudi Village Church	18th century	–
	Garmanav Village Church	–	–
	Gazmimat Village Church	–	–
	Milkidi Village Church	–	–
	Nepsht Village Church	–	–
	Kalala Village Church	–	–
	Oghan Village Church	–	–
	Amreh Dul Village Church	20th century	–
	Sava Hovkh Village Church	–	–
	Vartanash Village Church	–	–
	Vineh Village Church	17th century	Converted to a mosque
	Karaglukh Village Church	18th century	–
	Qasemushan Village Church	17th century	–
	Tazeh Kand Village Church	18th century	–
	Luma Village Church	–	–
	Hoj’aliha Village Church	–	–
	Okuton Village Church	–	–

techniques, and the distinguishability of restored parts from the original structure, is considered the most fundamental document in this field. Despite the global recognition of these principles, Forsyth (2008) argues that their application in seismic regions is faced with serious challenges due to potential conflicts with structural safety requirements. Consequently, the Lima Charter (2010) was adopted to guide local policymaking in high-risk areas and to emphasize educational and conservation aspects; however, it did not provide precise operational solutions for the physical assessment of historic buildings.

In response to this need, the ISCARSAH committee in 1996 issued recommendations proposing a multidisciplinary approach distinct from the regulations applied to new constructions. This approach is based on three levels of analysis: historical, qualitative, and quantitative (including laboratory testing and modeling). The code warns against aggressive interventions resulting from the direct application of conventional seismic codes and offers a more precise path for structural conservation. In this context, the direct use of general building codes (such as conventional seismic regulations), due to their strict nature, may lead to severe interventions and the loss of a building's authenticity. Therefore, the use of specialized guidelines for the assessment of historic structures becomes essential. The "Italian Guidelines for the Evaluation and Mitigation of Seismic Risk to Cultural Heritage," developed based on the NTC technical standards, is one of the most valid references in this field. These guidelines provide a framework for accurate cognition of buildings, evaluation of seismic stability, and seismic improvement and strengthening interventions, while maintaining a balance between engineering requirements and the preservation of historical characteristics and architectural authenticity (Presidente del ..., 2011)

In recent years, several studies in Iran have been conducted based on these guidelines. For instance, Gholami & Akhoundi (2023), in a study titled "Seismic Safety Assessment of Historic Houses in Tabriz Based on the Italian DPCM Guidelines," evaluated the safety condition of the Ali Monsieur historic house under both ultimate limit state and damage limit state. The findings, obtained through manual calculations (qualitative method) and numerical analysis using 3Muri software, indicated that the building lacks sufficient safety in the ultimate limit state but shows acceptable stability in the damage limit state. The study also highlighted that the manual calculations based on the Italian guidelines are more conservative compared to numerical modeling and tend to underestimate the seismic safety index of the structure.

Additionally, in 2025, Gharehayaghi et al. (2025) conducted a seismic evaluation of the historic Saint Sarkis Church in Tabriz using Italian conservation guidelines. In this study, employing a combined qualitative–quantitative approach, the seismic vulnerability of the building was first assessed based on qualitative methods and the analysis of failure mechanisms of the main structural components. Subsequently, its seismic behavior was quantitatively evaluated using 3Muri software and nonlinear pushover analysis. The results showed that the seismic safety index of the building was less than one in both methods, indicating insufficient seismic safety. The findings also confirmed the conservative nature of qualitative assessments compared to the higher accuracy of quantitative methods.

Given the lack of accurate technical and structural studies on the seismic conservation of historic churches in East Azerbaijan, the aim of this research is to fill this gap by providing a comprehensive (qualitative and quantitative) assessment to effectively enhance natural hazard risk management and the preservation of this architectural heritage.

Research Method / Materials and Methods

The present study investigates the seismic behavior of historical churches in East Azerbaijan Province using an integrated approach combining qualitative and quantitative methods. In the qualitative section, the Italian conservation guideline was used as the main framework. This guideline is a reliable tool for assessing the seismic vulnerability of historical buildings with diverse geometries and structural systems, enabling qualitative analysis of different building components in terms of stability, connections, and damage.

In the first stage, data collection was carried out based on historical sources and architectural documentation. Historical records, architectural plans, archival images, and previous restoration reports were reviewed to identify the history, structural system, and past damages of the churches. Subsequently, detailed field surveys of the selected churches were conducted to document the current condition of each structure in terms of structural cracks, settlements, deformations, material deterioration, and surrounding environmental conditions. At this stage, visual documentation, including photography and video recording of different parts of the structures, was performed to enable more accurate analysis and comparison with historical evidence.

In the next step, quantitative analysis was conducted using 3Muri software. This software enables the modeling of masonry components and performs static and nonlinear pushover analyses, allowing the simulation of the actual behavior of historical structures under seismic forces. The three-dimensional modeling of the churches in this software was carried out based on collected geometric data, mechanical properties of materials, and the observed damage patterns.

In the final stage, the results obtained from qualitative and quantitative analyses were compared and integrated to identify the strengths and limitations of each method and to determine the level of agreement between the findings. This comparison provided a basis for validating the qualitative assessment results and for more accurately determining the seismic vulnerability of the churches. Overall, the combined approach used in this research provides an effective tool for decision-making in the conservation, restoration, and strengthening of historical masonry structures, particularly in seismic-prone regions.

- **Qualitative assessment method**

The assessment of the seismic vulnerability of historical buildings, particularly churches, is one of the key stages prior to restoration and strengthening. This process is carried out to evaluate the structural safety of buildings against earthquakes and to determine the required level of intervention. Such an assessment represents an important prerequisite for decision-making regarding structural strengthening and has been widely addressed within various international frameworks. The present study employs the Italian Guidelines for Cultural Heritage Conservation (DPCM), which were developed in 2005 with the aim of reducing seismic risk and protecting historical buildings. Unlike general standards such as FEMA, ASCE 41, Eurocode 8, or the Iranian Guideline No. 360, this guideline has been specifically designed for historical masonry structures. Based on practical experiences following destructive earthquakes in Italy, the DPCM comprehensively addresses qualitative and quantitative assessment methods, considerations related to traditional materials, and minimum intervention requirements. It is applicable to various types of historical buildings, including churches, villas, and towers.

- **Quantitative assessment method**

In this study, the software 3Muri was used to analyze the seismic performance of historical churches. This software, through nonlinear static pushover analysis, enables detailed analysis of the behavior of masonry structures. Its high computational speed, absence of convergence issues, and ability to run multiple models within a short time are among its key advantages. In large-scale strengthening projects, 3Muri is considered a suitable choice due to its simplicity in modeling and its capability to evaluate different retrofitting schemes.

The software employs the Equivalent Frame Method (EFM) for modeling masonry walls. This method enables the transformation of masonry walls into bending frames exhibiting shear behavior. In this model, each pier and beam is analyzed using a nonlinear shear force–displacement curve that includes both elastic and plastic behavior with limited ductility. In modeling based on the equivalent frame method, masonry components are converted into frame elements, and meshing in this software is performed such that openings are defined as piers, while the beams above openings are defined as spandrel beams.

Historical and Architectural Overview of the Studied Churches

With a history of nearly two thousand years, church architecture in Iran is largely concentrated in three principal regions, Azerbaijan, Isfahan, and Tehran, and may be broadly grouped into four categories: monastic complexes, urban churches, rural churches, and small chapels. Within this context, East Azerbaijan stands out for both the quantity and variety of its churches, with over two hundred examples documented across its cities and villages.

These churches belong to different Christian denominations, including Armenian Gregorian, Assyrian (Evangelical), Adventist, and Roman Catholic traditions. However, most belong to the Armenian Gregorian Church, reflecting the long-standing historical and cultural presence of Armenians in northwestern Iran. Armenian church architecture originated during the early centuries of Christianity in Armenia. Armenia, recognized as the first officially Christian country in the world, developed an authentic church-building tradition from the early fourth century AD based on two principal typologies: linear basilica-type churches and cruciform churches. These two types reflected a deep integration of Christian culture with pre-Christian architectural traditions in Armenia and later influenced Byzantine architecture and subsequently Western church architecture, including that of Italy and France (Simoni & Hojat, 2020).

In Iran, particularly in the Azerbaijan region, this architectural heritage continued in a localized form, representing a synthesis of Armenian traditions with Iran's historical and cultural context. The case studies selected for this research consist of a number of churches located in urban and rural areas of East Azerbaijan Province, most of which possess significant historical, architectural, and structural value. All of these churches belong to the Armenian community of the region, except for the Adventist Church, which belongs to a non-Armenian Christian denomination. Followers of this denomination believe in the Second Coming of Jesus Christ and the sanctity of Saturday as the Sabbath, and their population in Tabriz has historically been very small (Karang, 1972). Among the selected cases, the Holy Shoghagat Church, located in the Akhar Shahnaz neighborhood of Tabriz, is a small ritual stone structure built for conducting religious ceremonies within the Armenian cemetery (Karang 1972; Hoviyan, 2003). The St. Mary Church of Tabriz is considered the oldest church in the city; it was reconstructed after the earthquake of 1193 AH and holds a special place in the religious memory of the Armenian community (Shojadel, 2005). The St. Hovhannes Church in Sohrol village, characterized by three distinct domes, demonstrates a combination of Armenian architecture and Russian influences and is regarded as one of the notable brick structures of the region. The St. Hripsimeh Church of Mojombar, designed as a three-aisled basilica, is one of the earliest Armenian churches located north of Tabriz. It was constructed in the 12th century AD on the site of a former Mithraic temple (Arakelyan, 1996). The St. Mary Church of Jolfa (1518 AD), featuring four central columns and a dome with twelve light openings, is considered one of the most prominent religious structures along the Aras River. The St. Hovhannes Church of Maragheh, constructed with cylindrical wooden columns, represents a unique example of Safavid-period architecture in the southern part of the province. Among the most distinguished churches, the St. Stepanos Church of Jolfa holds a particularly prominent position; this stone-built structure, enriched with elaborate decorative elements, is located near the Aras River border zone and is regarded as one of the most significant elements of Armenian ecclesiastical heritage. The Adventist Church, located on South Shahnaz Street in Tabriz, belongs to the Adventist Christian denomination. This brick church is the only Adventist church in East Azerbaijan Province and is currently semi-abandoned and not registered on the national heritage list (Karang 1972; Hoviyan, 2003). Figs. 2 & 3 present images and architectural plans of the studied churches, respectively, providing a comparative illustration of their architectural similarities and differences.

- **Material properties**

Masonry materials, as composite materials, consist of components with different mechanical properties. Therefore, determining their mechanical characteristics solely based on the properties of their constituent materials is not feasible and typically requires laboratory and field testing. In historical structures, sampling must be carried out with minimal damage to the building; consequently, the use of non-destructive or semi-destructive methods, such as flat-jack testing and core sampling, is recommended (Betti & Galano, 2012).

Due to the impossibility of conducting direct tests on the studied historical churches, the mechanical properties of the masonry materials were derived from the

Fig. 2. Images of the studied churches: (a) Shoghagat, (b) St. Mary Church of Tabriz, (c) St. Hovhannes Church of Sohrol, (d) St. Hripsimeh Church of Mojombar, (e) St. Mary Church of Jolfa, (f) St. Hovhannes Church of Maragheh, (g) Adventist Church, (h) St. Stepanos Church. Source: Author's archive..

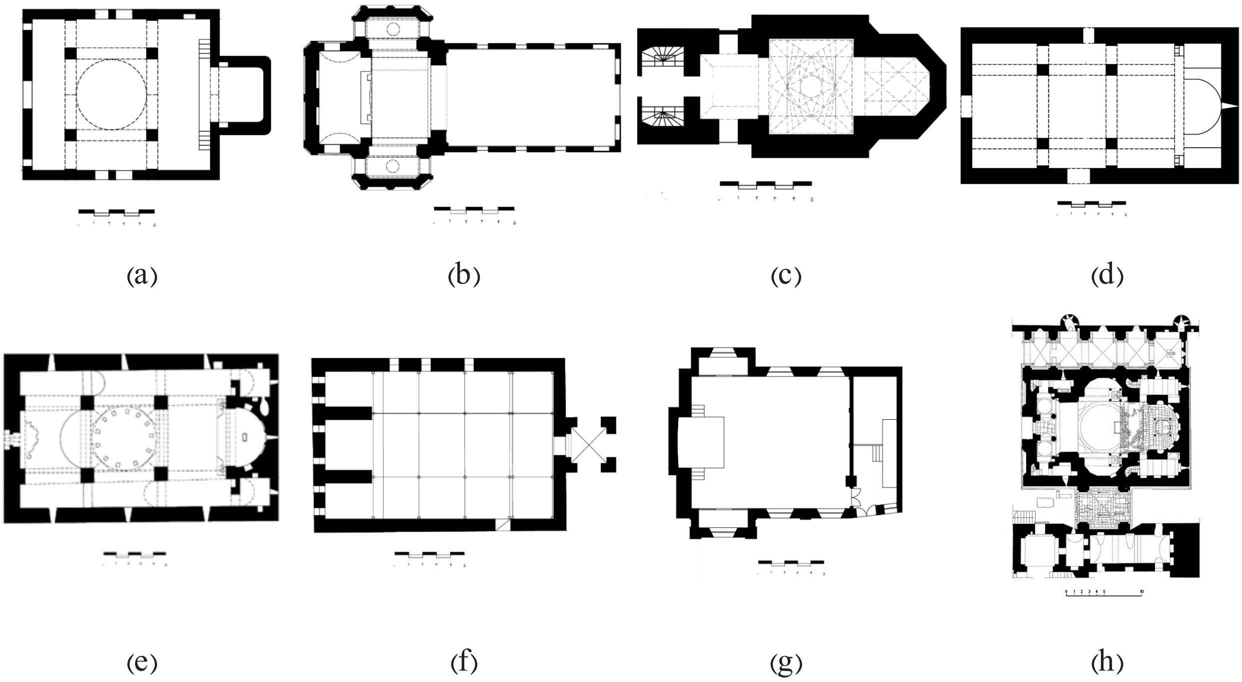

Fig. 3. Plans of the studied churches: (a) Shoghagat, (b) St. Mary Church of Tabriz, (c) St. Hovhannes Church of Sohrol, (d) St. Hripsimeh Church of Mojombar, (e) St. Mary Church of Jolfa, (f) St. Hovhannes Church of Maragheh, (g) Adventist Church, (h) St. Stepanos Church. Source: Authors.

recommended values provided in the NTC code. These values, developed based on an extensive set of tests on various types of masonry materials, were assigned to mechanical parameters, including compressive strength, modulus of elasticity, and shear strength, using Table C8.5.1 of the NTC2018-Cir code, according to the material type of each church.

Compressive strength refers to the maximum compressive stress that a material can withstand before failure and is one of the most important indicators of the load-bearing capacity of masonry materials. The modulus of elasticity represents the ratio of stress to strain within the elastic range and is considered a measure of material stiffness. Shear strength is defined as the maximum shear stress that a material can sustain before sliding or failure occurs along a shear plane, which plays a decisive role in analyzing the behavior of masonry structures under lateral loads, particularly earthquakes (Gere & Timoshenko, 1997; Lourenço, 2002).

The mechanical properties of the materials used in these churches, which form the basis of the quantitative assessment in this research, are presented in Table 2.

Findings and Discussion

• Qualitative assessment of the studied churches

The Italian conservation guideline provides a three-level framework for building assessment: Level 1 (LV1), based on simple geometric and mechanical analysis; Level 2 (LV2), based on local analysis of collapse mechanisms; and Level 3 (LV3), based on detailed numerical modeling. In addition, three seismic hazard levels with different return periods are defined and considered in performance-based design. In this guideline, structural performance levels include three limit states: Near Collapse (NC), Significant Damage (SD), and Damage Limitation (DL). At the near-collapse state, the structure experiences severe damage, and non-load-bearing elements collapse. At the Significant Damage state, moderate damage occurs in the structure, and non-load-bearing elements fail. At the Damage Limitation state, the damage is minor, and the structure maintains its functionality. In the present study, the selected case studies were analyzed at Level 1 (LV1) and Level 3 (LV3), referred to respectively as qualitative and quantitative assessments.

In this method, vulnerability indicators, including geometric characteristics, materials, site conditions, and foundation properties, are evaluated, and the confidence factor of the analytical model is determined based on the level of knowledge available about the structure. Furthermore, the importance of the building is classified according to its function and the probability of earthquake exceedance, and all these parameters are calculated in accordance with the Italian conservation guideline. Coefficients related to soil type and topography are also incorporated into the final analysis based on the NTC18 code.

In the assessment of churches, standardized damage survey forms are used, which consider 28 damage mechanisms, enabling statistical analysis and objective comparison among the churches. Table 3 presents the results of the qualitative assessment of the churches at the Near Collapse and Damage Limitation limit states. Since qualitative assessment is based on the expert judgment of the inspector, the results are significantly influenced by the inspector's analysis and individual perspective. For this reason, in addition to the analysis conducted by the author as the principal inspector, a sensitivity analysis was also performed to determine the range of variations resulting from different inspectors' viewpoints. The results of the sensitivity analysis for these two limit states are also included in Table 3.

• Quantitative assessment of the studied churches

As mentioned in Material properties, Level 3 assessment in the Italian conservation guideline (LV3) is dedicated

Table 2. Mechanical properties and structural materials of the studied churches. Source: Consiglio Superiore ..., 2019.

Church	Type of Masonry Materials	f[2] (N/mm2)	τ_0[3] (N/mm2	E[4] (N/mm2)
Shoghagat	Split stones	3.2	0.065	1740
St. Mary Church of Tabriz	Solid brick with lime mortar (original section)	3.4	0.09	1200
	Semi-solid brick with cement mortar (extended section)	6.5	0.125	4550
	Concrete (extended section)	43	35	34000
St. Hovhannes Church of Sohrol	Solid brick with lime mortar	3.4	0.09	1200
St. Hripsimeh Church of Mojombar	Uneven stonework	2.0	0.043	1230
St. Mary Church of Jolfa	Uneven stonework	2.0	0.043	1230
	Solid brick with lime mortar	3.4	0.09	1200
St. Hovhannes Church of Maragheh	Solid brick with lime mortar	3.4	0.09	1200
	Wood	57	40	14000
Adventist Church	Solid brick with lime mortar	3.4	0.09	1200
	Wood	57	40	14000
St. Stepanos Church.	Split stones	3.2	0.065	1740
	Solid brick with lime mortar	3.4	0.09	1200
	Uneven stonework	2.0	0.043	1230

to detailed numerical modeling of structures. In this study, 3Muri software was used to analyze the seismic performance of the historical churches. After completing accurate geometric modeling, the mechanical properties of materials were assigned to each structural component based on the data presented in Table 2. Subsequently, after defining the seismic characteristics of the region and parameters related to soil conditions, a nonlinear pushover analysis was performed for each of the studied churches. Fig. 4 presents examples of the numerical models developed for the historical churches under investigation.

In the analysis stage, the nonlinear pushover method was applied, in which gradually increasing lateral loads are imposed to evaluate the structural behavior until the target displacement is reached. This method operates based on the assumption of a single-degree-of-freedom system and derives the capacity curve of the structure from the relationship between base shear and the displacement of the control node (Nortman, 2019). The capacity curve represents the ability of the structure to resist seismic forces in terms of deformation and strength. Fig. 5 illustrates the capacity curves of the studied churches obtained from the pushover analyses conducted in the

Table 3. Safety index obtained from qualitative assessment. Source: Authors.

Church	Safety index obtained from qualitative assessment			
	Near-Collapse state		Damage Limitation state	
	Sensitivity Analysis	Inspector Analysis	Sensitivity Analysis	Inspector Analysis
Shoghagat	$0.239<I_s<0.166$	0.195	$0.225<I_s<0.156$	0.184
St. Mary Church of Tabriz	$0.268<I_s<0.198$	0.232	$0.253<I_s< 0.186$	0.218
St. Hovhannes Church of Sohrol	$0.263<I_s<0.225$	0.243	$0.248<I_s< 0.212$	0.229
St. Hripsimeh Church of Mojombar	$0.307<I_s< 0.236$	0.258	$0.290<I_s< 0.202$	0.243
St. Mary Church of Jolfa	$0.285<I_s< 0.229$	0.250	$0.268<I_s<0.216$	0.235
St. Hovhannes Church of Maragheh	$0.478<I_s< 0.331$	0.380	$0.451<I_s<0.312$	0.358
Adventist Church	$0.349<I_s< 0.303$	0.303	$0.329<I_s< 0.285$	0.285
St. Stepanos Church	$0.302<I_s< 0.194$	0.267	$0.284<I_s< 0.182$	0.247

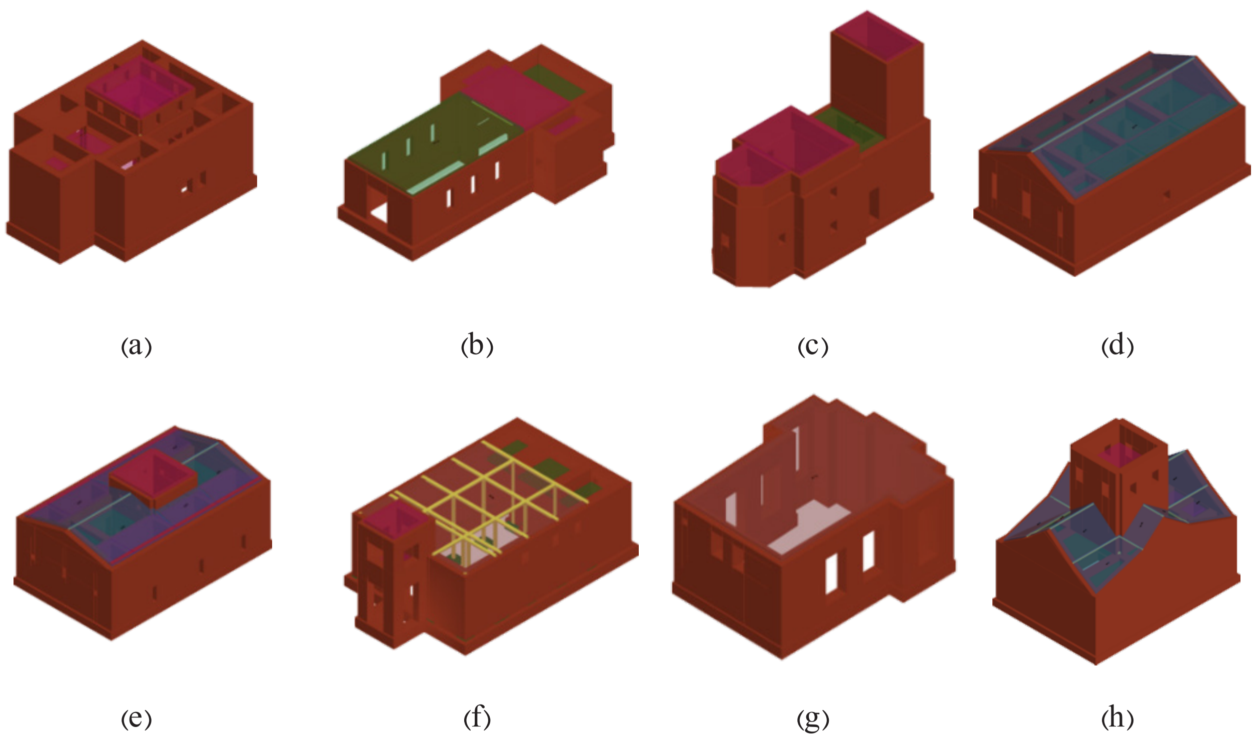

Fig. 4. 3D Modeling of the churches in 3Muri software: ((a) Shoghagat, (b) St. Mary Church of Tabriz, (c) St. Hovhannes Church of Sohrol, (d) St. Hripsimeh Church of Mojombar, (e) St. Mary Church of Jolfa, (f) St. Hovhannes Church of Maragheh, (g) Adventist Church, (h) St. Stepanos Church. Source: Authors.

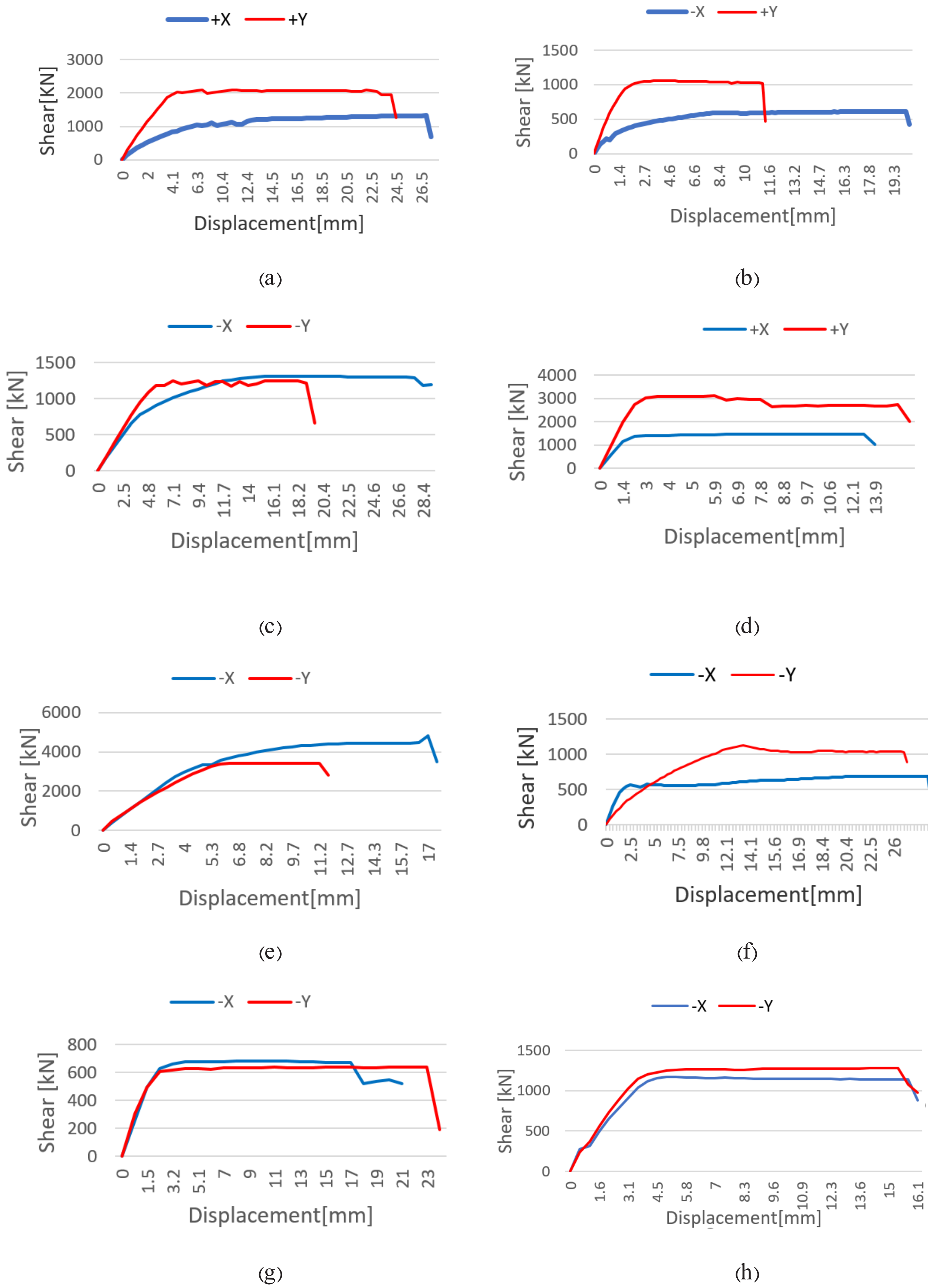

Fig. 5. Force-displacement diagram (capacity curve) of the studied churches: (a) Shoghagat, (b) St. Mary Church of Tabriz, (c) St. Hovhannes Church of Sohrol, (d) St. Hripsimeh Church of Mojombar, (e) St. Mary Church of Jolfa, (f) St. Hovhannes Church of Maragheh, (g) Adventist Church, (h) St. Stepanos Church. Source: Authors.

3Muri software. In addition, Table 4 presents the seismic safety indices derived from this analysis for each church.

Discussion

According to the results obtained from the qualitative assessment presented in Table 3, in both limit states, the safety index of the Shoghagat Church was calculated as 0.184 in the Damage Limitation state and 0.195 in the Near Collapse state. In contrast, the St. Mary Church of Jolfa, with safety indices of 0.358 and 0.380, respectively, shows a better condition compared to the other structures. Overall, the values obtained from the qualitative assessment range between 0.18 and 0.38, indicating the general structural vulnerability of the buildings. This implies that all the studied structures fall within an unsafe range against earthquakes and are at risk of damage or collapse.

Based on Table 4, the safety indices obtained from the quantitative assessment are higher than those derived from the qualitative method, ranging between 0.278 and 0.752. The highest safety index corresponds to the St. Hovhannes Church of Maragheh (0.752 in the Damage Limitation state and 0.591 in the Near Collapse state), while the lowest value corresponds to the St. Stepanos Church (0.278 and 0.307, respectively). Overall, the results of the quantitative assessment confirm the safety indices obtained from the qualitative evaluation and reinforce the conclusion that the studied churches are generally unsafe under potential seismic events.

Since qualitative assessment is based on the expert judgment of the inspector, the results are significantly influenced by the inspector's analysis and personal perspective. In practice, variations in the inspector's judgment and evaluation can lead to changes in the final safety index. For this reason, in addition to the analysis conducted by the author as the principal inspector, a sensitivity analysis was also performed to determine the range of variations resulting from different inspectors' viewpoints. The results of this analysis showed that the safety index of the St. Hovhannes Church of Sohrol, in the Damage Limitation state, changes from 0.290 to 0.202, and in the Near Collapse state from 0.307 to 0.236, depending on the evaluator. This range of variation (Table 3) indicates the high sensitivity of the qualitative method to the inspector's judgment and confirms the necessity of performing sensitivity analysis to improve the accuracy and reliability of the evaluation results.

By comparing the quantitative and qualitative results according to Table 5, it was found that the safety index obtained from the qualitative method is, on average, between 40% and 70% of the value obtained from the quantitative method. The difference between the two methods can be attributed to the way input parameters are defined. In qualitative assessment, the mechanical properties of materials are determined through general and qualitative classification, whereas in the quantitative method, data are entered into the software model in precise numerical form. Moreover, seismic parameters, including design base acceleration, soil type, and characteristics of subsurface layers, are considered with greater accuracy in the quantitative method. Therefore, quantitative results provide a more realistic representation of the seismic performance of structures, while the qualitative method is more suitable for preliminary assessment and prioritization of conservation measures on a large scale.

To facilitate the practical application of the research

Table 4. Safety index obtained from quantitative assessment. Source: Authors.

Church	Safety index obtained from qualitative assessment	
	Near-Collapse state	Damage Limitation state
Shoghagat	0.296	0.382
St. Mary Church of Tabriz	0.380	0.453
St. Hovhannes Church of Sohrol	0.238	0.426
St. Hripsimeh Church of Mojombar	0.437	0.512
St. Mary Church of Jolfa	0.319	0.660
St. Hovhannes Church of Maragheh	0.591	0.714
Adventist Church	0.692	0.752
St. Stepanos Church	0.278	0.307

results, a priority list for the conservation of the studied historical churches was developed in order to identify the structures that are more vulnerable to earthquakes and to place them at the forefront of restoration actions (Table 6).

Based on the results obtained from the qualitative assessment at the Near Collapse limit state, the Shoghagat Church, St. Mary Church of Tabriz, and St. Mary Church of Jolfa show the highest levels of vulnerability, respectively, while the Adventist Church and the St. Hovhannes Church of Maragheh exhibit relatively higher levels of safety.

On the other hand, the results of the quantitative assessment indicate greater vulnerability in the Shoghagat Church, St. Stepanos Church, and St. Mary Church of Jolfa, whereas the St. Hovhannes Church of Maragheh and the Adventist Church demonstrate the highest levels of safety, respectively.

A comparison of the qualitative and quantitative methods shows that although there are minor differences in the ranking order, their overall trends are consistent. This overlap indicates that the integration of the two methods can provide a reliable scientific basis for comprehensive planning in the conservation and seismic strengthening of historical buildings in the province.

Conclusion

Based on the findings of this research, all the studied historical churches in East Azerbaijan Province are at a concerning level in terms of seismic performance, and none of them possess sufficient safety against earthquakes. The comparison between the qualitative and quantitative assessment methods indicates that the qualitative method is a rapid and cost-effective tool for identifying the general condition of structures and prioritizing buildings, whereas the quantitative method offers higher accuracy and is essential for designing conservation and strengthening interventions. Accordingly, qualitative assessment can be used as a preliminary stage in the planning process for more detailed interventions and, at urban or regional scales, serves as an effective tool for preparing priority lists for the conservation of historical buildings. On the other hand, the implementation of strengthening measures requires quantitative analyses based on numerical modeling and precise determination of material properties and geological conditions for each structure.

Table 5. Comparison of qualitative and quantitative evaluation results. Source: Authors.

Church	Qualitative/(quantitative)	
	Near-Collapse state	Damage Limitation state
Shoghagat	0.65	0.48
St. Mary Church of Tabriz	0.61	0.48
St. Hovhannes Church of Sohrol	0.74	0.53
St. Hripsimeh Church of Mojombar	0.59	0.47
St. Mary Church of Jolfa	0.74	0.33
St. Hovhannes Church of Maragheh	0.64	0.50
Adventist Church	0.43	0.39
St. Stepanos Church	0.96	0.80

Table 6. Comparison of the safety index of the studied churches in the near-collapse and damage limitation state . Source: Authors.

	Based on the quantitative method	Based on the qualitative method
conservation priorities in the case studies	Shoghagat	Shoghagat
	St. Stepanos	St. Mary Church of Tabriz
	St. Mary Church of Jolfa	St. Mary Church of Jolfa
	St. Hovhannes- Sohrol	St. Hovhannes- Sohrol
	St. Mary Church of Tabriz	St. Hripsimeh Church of Mojombar
	St. Hripsimeh Church of Mojombar	St. Stepanos
	St. Hovhannes-Maragheh	Adventist
	Adventist	St. Hovhannes-Maragheh

According to the results obtained from both assessment methods, the churches of East Azerbaijan Province are vulnerable to seismic events with high intensity and a 2% probability of exceedance in 50 years, as well as to seismic events with lower intensity and a 20% probability of exceedance in 50 years. Therefore, the protection of historical churches in seismic-prone regions is not only a cultural necessity for preserving architectural heritage but also a vital measure for reducing life-safety risks and ensuring the safety of users and visitors to these spaces.

Based on the findings of this study, preliminary practical recommendations include the installation of digital crack-monitoring sensors at damaged locations, monitoring of structural deformations and seismic vibrations, and the implementation of periodic structural condition assessments. In subsequent stages, conducting more detailed geotechnical investigations around the buildings, performing separate seismic analyses of sensitive structural components such as domes and arches, and developing a comprehensive program for continuous seismic safety monitoring of the province's historical churches are considered essential.

Finally, the findings of this research can serve as a scientific basis for policymaking and conservation planning in the field of religious architectural heritage and may contribute to the development of a systematic approach to reducing seismic risks in historical urban fabrics.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Endnotes

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1. The Italian technical standard of construction (NTC-2018)
2. Compressive strength
3. Shear strength
4. Modulus of elasticity

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