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ICBE 2026

MAY 08th-09th, 2026
POLIS University, Tiranë

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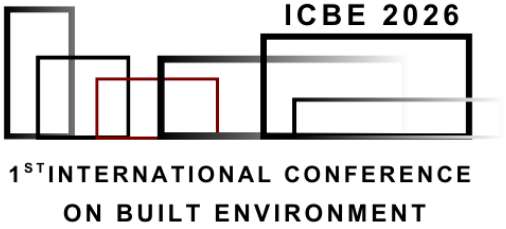
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1st International Conference on Built Environment

ICBE 2026

Conference Theme and Rationale

The 1st International Conference on Built Environment (ICBE 2026) was conceived as an international and interdisciplinary forum for advancing knowledge, critical discussion, and innovation across architecture, urban planning, engineering, construction, materials, design, and the wider built environment. Organized by POLIS University in collaboration with the National Agency for Scientific Research and Innovation in Albania (AKKSHI), the Academy of Sciences of Albania and the University of Ferrara in Italy, the conference brought together academics, researchers, practitioners, students, and industry representatives to exchange research findings, professional experience, and emerging perspectives on the transformation of contemporary cities and territories.

The conference theme reflected the increasingly complex challenges shaping the built environment, with particular attention to sustainability, resilience, technological innovation, heritage preservation, and socially responsive design. Contributions addressed sustainable architecture and green building, innovative construction technologies and materials, climate-responsive and energy-efficient design, disaster risk reduction, circular approaches to construction, and the integration of renewable energy. Equal emphasis was placed on digital transformation through Building Information Modeling, Geographic Information Systems, artificial intelligence, data analytics, automated solutions, digital fabrication, and advanced manufacturing.

ICBE 2026 also recognized that the future of the built environment cannot be approached through technological innovation alone. Urban transformation, cultural heritage, adaptive reuse, inclusive design, ecological thinking, art, and interdisciplinary research were therefore integral to the conference rationale. The scientific sessions examined topics ranging from seismic resilience, geotechnical engineering, and structural safety to urban fragmentation, public space, heritage conservation, adaptive environments, and new relationships between human and non-human systems.

Through keynote lectures, scientific presentations, case studies, and interdisciplinary debate, the conference encouraged connections between research and practice while promoting approaches capable of responding to environmental, social, cultural, and technological change. The breadth of contributions demonstrated the value of bringing engineering, architecture, urbanism, design, heritage, and emerging technologies into a shared academic framework for more resilient, sustainable, adaptive, and human-centered environments.

Held on 8-9 May 2026 at POLIS University in Tirana, with in-person and online participation, ICBE 2026 welcomed guest speakers and participants from Albanian and international universities, research institutions, professional organizations, and industry. Its sessions established a platform for presenting current research, exchanging expertise, strengthening meaningful collaboration, and identifying future directions for the built environment.

The event

The **1st International Conference on Built Environment (ICBE 2026)** is an interdisciplinary academic and professional forum dedicated to exploring contemporary challenges, emerging research, and innovative approaches shaping the future of the built environment. Bringing together researchers, academics, architects, engineers, urban planners, designers, practitioners, and industry professionals, the conference promotes the exchange of knowledge and encourages collaboration across traditionally interconnected disciplines. Its thematic scope encompasses sustainable and resilient construction, technological innovation, advanced building materials, urban transformation, cultural heritage, and interdisciplinary design approaches. Particular attention is given to the growing role of digital technologies, data-driven methodologies, intelligent design processes, and advanced analytical tools in supporting more informed and responsive approaches to architecture, engineering, and urban development. At the same time, ICBE 2026 recognizes the importance of environmental responsibility, cultural identity, social needs, and human-centered design in shaping contemporary cities and territories. Through keynote lectures, scientific sessions, case studies, and interdisciplinary exchange, the conference provides a platform for presenting current research, discussing professional experiences, and developing new perspectives capable of contributing to **safer, more sustainable, adaptive, inclusive, and resilient built environments**.

Objectives

- Promote interdisciplinary collaboration among researchers, academics, practitioners, and professionals in architecture, engineering, urban planning, construction, design, heritage, and related fields of the built environment.
- Advance the use of digital technologies and innovative methodologies, including BIM, GIS, artificial intelligence, data analytics, digital fabrication, and parametric approaches, in research and professional practice.
- Encourage sustainable, resilient, and climate-responsive approaches to architecture, construction, and urban development through innovative materials, energy-efficient strategies, and environmentally responsible design.
- Address contemporary challenges affecting cities, buildings, and infrastructure through scientific research, applied case studies, evidence-based approaches, and innovative design solutions.
- Promote the conservation, transformation, and adaptive reuse of cultural heritage, balancing cultural identity, contemporary needs, structural safety, and responsible urban development.
- Support human-centered and socially responsive urban transformation, considering public space, mobility, ecological systems, community needs, and the wider social and economic impacts of the built environment.
- Provide a platform for knowledge exchange and emerging research, enabling scholars, young researchers, professionals, and students to present innovative ideas, strengthen international collaboration, and contribute to future directions in the built environment.

Main Conference Themes

- Sustainable architecture and green building practices.
- Innovations in construction technologies and materials.
- Heritage preservation and adaptive reuse in the built environment.
- Digital tools and smart technologies in architecture and construction (e.g., BIM, GIS).
- Climate-responsive and energy-efficient design.
- Disaster risk reduction and resilience in the built environment.
- Circular economy approaches in construction and material usage.
- Integration of AI and data analytics in building design.
- Acoustic and thermal performance in building design.
- Renewable energy integration in building systems.
- Advanced manufacturing techniques in construction, such as 3D printing.
- Innovations in construction technologies and materials.
- Heritage preservation and adaptive reuse in the built environment.
- Disaster risk reduction and resilience in the built environment.
- Digital tools and smart technologies in architecture and construction.
- Advanced manufacturing techniques in construction.
- Geotechnical Engineering for Sustainable Development.
- Cartography and Geographic Information System.
- Computer Automated Solutions for Built Environment.
- Reliability in Civil Engineering.
- Urban planning strategies for resilient cities.
- Climate-responsive and energy-efficient design.
- Regulatory frameworks and policies impacting construction and urban development.
- Design in the Era of Anthropocene (Rethinking the Relation between Human and Non-Human Species)
- Speculative Design (with Attention to “Discursive” and “Critical” Design)
- Design and Cross-Disciplinarity (with Emphasis on Processes rather than Design Outputs)
- Inclusive Design
- Art and Urban Regeneration (Focus on Participatory, Collaborative, and Research-Based Practice)
- Relational Art and Architecture
- Monuments and ‘Anti-Monuments’ (Particular Attention to the Process of Designing and Building the City)

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The conference is structured around six thematic sessions, each addressing a specific area of research and practice within the built environment.
Each session is coordinated by experts in the relevant disciplinary field and is open to professors, researchers, PhD candidates, and other scholars and professionals contributing to the conference themes.

SESSION I
Urban Planning and Societal Impact

Chair: Dr. Gent Avdija

This session examines the relationship between urban transformation, spatial development, and their social implications within contemporary cities. Contributions address rapid urbanization, urban fragmentation, the transformation and loss of public space, informal and spontaneous development, and the challenges associated with balancing growth and modernization with human-scale urban environments. Particular attention is given to the evolving conditions of Albanian cities and to planning approaches capable of supporting more inclusive, sustainable, socially responsive, and livable urban environments.

SESSION II
Sustainable Materials, Resilient Construction & Smart Design

Chair: Dr. Endri Duro

This session explores innovative approaches to sustainable construction, resilient structural systems, and environmentally responsive design. Particular attention is given to sustainable materials, energy-efficient and climate-responsive strategies, prefabricated and lightweight construction technologies, and human-centered approaches to structural and architectural design. The session investigates how material innovation, technological development, and responsible design practices can contribute to safer, more efficient, adaptable, and environmentally sustainable built environments.

SESSION III
Technological Advancements and Seismic Design for Resilient Places

Chairs: Dr. Seyyed Behrad Emadi & Dr. Ornela Şen

This session examines the role of technological innovation and advanced engineering methodologies in developing safer, more resilient, and adaptable built environments. Contributions address seismic hazard and risk assessment, digital fabrication, parametric and computational approaches, transformations of building envelopes and prefabricated housing systems, and emerging concepts for future urban mobility. The session highlights how the integration of engineering knowledge, digital technologies, and resilience-oriented design can strengthen the capacity of buildings, infrastructure, and urban environments to respond to contemporary and future challenges.

SESSION IV

Cultural Heritage

Chairs: Dr. Nikolla Vesho & Dr. Marsela Demaj

This session addresses the preservation, interpretation, and transformation of cultural heritage within contemporary architectural and urban contexts. Contributions explore conservation strategies for historic buildings and sacred architecture, seismic assessment and strengthening of heritage structures, adaptive reuse, and the social implications of urban regeneration and heritage loss. Particular emphasis is placed on achieving a responsible balance between conservation ethics, cultural identity, structural safety, and the evolving functional requirements of historic buildings and urban environments.

SESSION V

Spaces of Connection: Art and Design for an Interspecies and Interdisciplinary Environment

Chair: Dr. Francesco Scasciamacchia

This session explores the intersections of art, architecture, design, technology, and the built environment through interdisciplinary and experimental perspectives. It investigates changing relationships between human and non-human systems, spatial perception, adaptive reuse, post-industrial landscapes, urban representation, digital heritage, and environmentally and socially engaged design practices. Through critical, speculative, participatory, and research-based approaches, the session examines how art and design can generate new forms of connection, reinterpret existing environments, and contribute to emerging cultural and spatial narratives within contemporary cities.

SESSION VI

Next-Generation Pioneers of the Built Environment

Chair: Dr. Flogerta Krosi

This session provides a dedicated platform for emerging researchers and students to present innovative, experimental, and forward-looking approaches to the built environment. Contributions span architecture, engineering, urban planning, environmental resilience, design, and related creative disciplines, reflecting the interdisciplinary character of a new generation of researchers and practitioners. Through projects addressing topics such as bioclimatic design, flood-risk management, structural technologies, architecture-inspired design, and critical interpretations of objects and social space, the session encourages critical inquiry, experimentation, and new perspectives on the future of the built environment.

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SESSION IV

Cultural Heritage

Architectural and urban heritage: Historic buildings / Sacred architecture / Historic urban environments / Cultural identity.

Conservation and preservation: Heritage conservation strategies / Conservation ethics / Preservation of historic structures / Protection of architectural values.

Adaptive reuse and transformation: Adaptive reuse / Contemporary interventions in heritage / Functional transformation / Urban regeneration.

Heritage resilience and structural safety: Seismic strengthening / Structural assessment of historic buildings / Risk mitigation / Integration of conservation and structural performance.

Heritage and urban change: Urban renewal / Heritage loss and demolition / Social implications of transformation / Balance between preservation and development.

Seismic Performance Assessment of Historic Stone Masonry Buildings:
The Case of the Angonate Residence, Gjirokastër

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Abstract

Historic stone masonry structures constitute a fundamental component of architectural heritage; however, in seismically active regions such as the Balkans, their stability is highly vulnerable to earthquakes, necessitating conservation approaches that balance structural enhancement with the preservation of architectural authenticity. This study provides a general conceptual framework for the assessment and reinforcement of historic stone buildings, using the Angonate House (built around 1880) as a case study. Located in Gjirokastra, a UNESCO World Heritage Site, this building exemplifies the characteristic features of Ottoman architecture.

The methodology used includes digital documentation and structural analysis. The current condition of the building was assessed through field measurements and mapping of identified pathologies, combined with high-resolution photogrammetry to create an accurate three-dimensional geometric model. This model served as the basis for numerical simulations with the Finite Element Method (FEM) in ETABS. Modal and seismic analyses, conducted in accordance with Eurocode 8 and the National Technical Design Codes (KTP), revealed the building's dynamic behaviour and identified the main structural weaknesses.

Based on these results, a conservative intervention strategy is proposed, aiming at improving

the seismic performance in harmony with preserving the historical integrity of the building. The proposed measures include the selective use of Fiber Reinforced Polymers (FRP), the consolidation of the masonry through deep reinforcement and injection with chemically compatible mortar, as well as the installation of discrete fixing elements to improve the diaphragm action. This study shows that the synthesis of digital diagnostics, engineering assessment and conservation ethics constitutes a powerful and applicable methodology for the protection of historic masonry structures in environments with high seismic risk.

Keywords: *Architectural Heritage, Heritage Conservation, Structural Reinforcement, Structural Behavior, Finite Element Method (FEM).*

1. INTRODUCTION

Historical buildings constitute a special cultural and architectural asset for any society, documenting its social, historical and technical development. In the case of Gjirokastra, these buildings become the defining element of urban identity and national heritage. The city of Gjirokastra remains one of the most important historical and cultural centers of Albania, representing a rare example of an Ottoman settlement preserved in an exceptional state. Located in the south of the country, in the Drino valley, it lies on the slopes of the Gjerë Mountain (Figure 1), a key position that has dictated the formation of its urban structure and characteristic architecture.

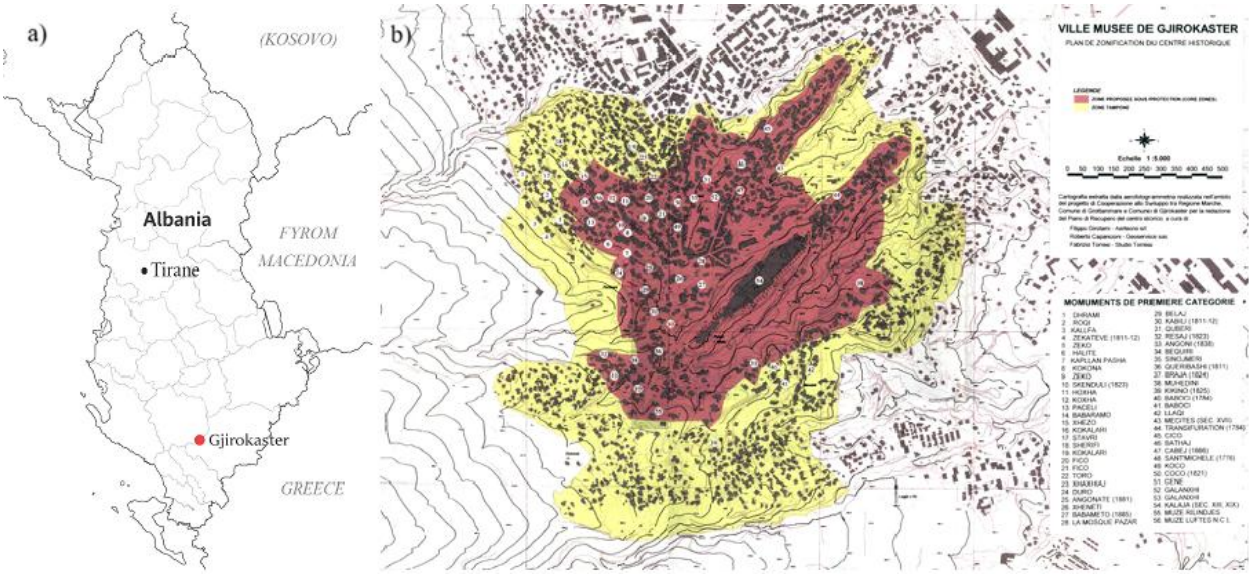


Figure 1. a-Map of the geographical location of Gjirokastra (Source:Author); b-Zoning plan of the historical center of Gjirokastra and the location of historical monuments (Source: UNESCO)

The beginnings of the birth of the city are associated with the construction of the castle during the 13th century, around which the settlement slowly developed. During the Ottoman Empire,

Gjirokastra became an important administrative and commercial hub, without losing its special urban and architectural identity. The development of the city has been organic, conditioned by the broken relief: the streets and neighborhoods have been laid out following the shape of the terrain, giving the city the unique appearance that is known today (Figure 2).

Among the features that distinguish Gjirokastra are, undoubtedly, the stone dwellings, known as “tower” or “kulla”, which represent a unique typology in the Balkans. These buildings, usually two to three stories high, were conceived to adapt to the changing seasons and daily needs, showing a harmony between the architectural form, the climate and the social structure of the time. Unlike Berat, where the dwellings appear more crowded, in Gjirokastra they take on a more monumental and isolated character, creating a unique urban landscape.

Since 2005, the city has been part of the UNESCO World Heritage List, an assessment that highlights its importance as evidence of Ottoman architecture and a traditional way of life that has managed to be preserved. However, today these values are facing real problems: the materials are degrading, there is a lack of continuous maintenance and the pressure of modern developments is increasing.

In this context, one of the most sensitive issues remains the improvement of the structural performance of these buildings, especially in an area with high seismic risk like Albania. Masonry constructions are by nature sensitive to horizontal forces, therefore any intervention requires special care so as not to damage their historical and architectural value.

This study is dedicated to this problem, which, through the case analysis of the Angonateve residence, aims to identify structural weaknesses and propose appropriate interventions, while respecting the basic principles of conservation and restoration. The main objective is to evaluate the seismic behavior of the Angonate Residence through FEM-based analysis and to propose compatible seismic retrofit strategies that preserve its architectural authenticity.



Figure 2. Panoramic view of the urban structure and vernacular architecture of Gjirokastra (Source: Author)

2. LITERATURE REVIEW

2.1 Main typologies of traditional houses in Gjirokastër

The architecture of traditional houses in Gjirokastër presents a clear typological development, influenced by topographical conditions, functional needs and the socio-economic strata of the inhabitants. The terrain plays a key role in the volumetric composition of the building. Most of the buildings are located on sloping terrain, generally broken and rocky, causing most of the houses to be developed with half a floor. Usually, the houses also include a courtyard, and large buildings can even have two courtyards. The structural system used in Gjirokastër buildings is with load-bearing masonry supported on continuous foundations. The masonry is built with stone, laid dry or with binding material.

The functions of Gjirokastra houses are organized in a vertical hierarchy. The lower floors, built of stone, were typically uninhabited and were used for housing livestock (katoi) and storing food reserves (qilari), rainwater (stera) and often a mill. The upper floors were designed with living areas, with large balconies, verandas or “çardak” with carved wooden railings, murals and other decorations. For security, the larger windows on the upper floors were equipped with wooden shutters (taraba) that were closed at night, and cross wooden bars.

The main entrances were located on the front facades. Side entrances were rare and were never located at the rear, as these positions were less visible and more vulnerable. The side facades had fewer openings than the main facades, while the rear facades, which leaned against the mountain slope, had minimal openings.

The upper residential floors of these houses were designed to reflect the hospitable nature and social status of the inhabitants. The main spaces included the living room, or as it was also called the fire room, and the guest room or guest room. In smaller houses, the guest room also served as a men's room (selamlik), while in larger houses this was a separate building. Three-story houses had large central halls or mezzanines to facilitate movement, equipped with the Turkish divan, a large sofa for entertaining guests. This design displayed the cultural values and hospitality of the inhabitants, despite the protective needs dictated by the external architecture.

According to the typology of development, buildings are classified into three variants:

- Perpendicular variant
- Single-wing variant
- Double-wing variant

Perpendicular variant

The perpendicular variant represents one of the earliest and simplest forms of housing organization. In this typology, the dwelling is developed with 2 or 3 floors, and in many cases, it is developed with a half-floor. The main function can be a dwelling or the role of an "outside

room" of large dwellings. The internal organization is relatively simple and functional, with spaces that serve daily uses and with a less pronounced division of functions. The main characteristic of this variant is the placement of stairs that make the transition from one floor to another on the exterior of the building.

Single-wing variant

The single-wing variant represents a more developed phase of the traditional dwelling, adopted by folk craftsmen. This variant can be found developed with half a floor, 3 floors or built with two blocks. Unlike the variant, the stairs are placed inside the building; the organizational method and the environments are more developed, creating a more articulated plan and a clearer functional division of spaces. In this typology, one of the most important elements is the creation of the reception area (room), which takes on a central role in the social life of the family. The additional wing can serve for auxiliary functions or for the expansion of the living spaces.

This variant shows an increase in architectural complexity and an improvement in spatial organization, reflecting a higher economic and social level of the residents.

The two-wing variant

The two-wing variant represents the most developed and monumental typology of housing in Gjirokastër. In this case, the building is organized around a central volume, with two side wings that create a more balanced and symmetrical composition. This organization allows for an advanced functional division, where the representational, living and auxiliary spaces are clearly differentiated. The upper spaces are more developed and often contain rich decorative elements, reflecting the social status of the family. From an architectural point of view, this variant is characterized by more articulated volumetry; the pronounced presence of protruding elements (such as gazebos); better integration with the urban landscape.

2.2 Materials and Construction Characteristics

The selection of local materials gave Gjirokastra the unique form for which it is still known today. The buildings constructed during this period optimally utilized the available local resources. The selection of building materials was also influenced by factors such as accessibility, durability, and sustainability.

The main structural material is stone, the widespread use of which has given the city the name "City of Stone". Limestone was widely used due to its wide availability in the area. For the construction of masonry it could be used and combined with lime-based mortar, which binds the masonry and ensures durability. Stone (stone slabs) was also used for roof covering. Wood was also very common, and its role varied depending on the type used. It was mainly used in floors and roofs (roof trusses), where it added flexibility and helped distribute horizontal loads throughout the structure.

From a mechanical point of view, the compressive strength of stone provides vertical load-bearing capacity, while the low tensile and shear strengths make masonry susceptible to

horizontal seismic loads; the integration of wood offers some ductility and energy dissipation, but this depends on the integrity of the connections. The combination of stone, mortar and wood creates a system resistant to vertical loads, but sensitive to seismic actions, where cracks usually develop at the corners of the wall, near openings and where the wood elements interact with the masonry, while the degradation of the materials, especially mortar and wood, further reduces the stability of the structure.

Knowledge of the mechanical-physical characteristics of the materials used is essential for the study of seismic assessment and for the design of appropriate and compatible interventions, as the behavior of the building to horizontal loads is directly influenced by the typology, materials and construction techniques.

2.3 Seismic behavior of masonry buildings

Masonry buildings constitute one of the most widespread typologies in historic areas, but at the same time also among the most sensitive to seismic actions. Their structural behavior is characterized by a high compressive resistance, but by a very limited tensile and shear capacity, which makes them particularly vulnerable to horizontal loads caused by earthquakes.

Under seismic conditions, masonry structures do not behave as monolithic systems, due to the often weak connections between the constituent elements. As a result, they develop different failure mechanisms, which depend on the geometric configuration, the quality of the materials and the integrity of the structural connections.

The most common failure mechanisms in masonry buildings include the following typical forms: out-of-plane failure, which occurs mainly from problematic connections between walls and other structural elements, causing the walls to lose stability in the direction normal to their plane; diagonal cracks (shear cracks), which are created as a result of shear forces developed during seismic activities. Another significant damage mechanism is the separation at the building corners, which arises from insufficiently strong connections between orthogonal walls, resulting in the structural elements behaving independently rather than as an integrated system. One commonly observed damage mechanism in historic masonry buildings is the separation at the corners, usually caused by weak or inadequate connections between intersecting walls. In these situations, structural elements may behave independently rather than as a cohesive system. Similarly, areas around openings, such as windows and doors, tend to be particularly vulnerable, as the reduction in load-bearing capacity in these sections can create stress concentrations, increasing the likelihood of local failure.

Wooden elements, including floors and roofs, also play a significant role in the seismic response of these buildings. When properly connected to the masonry, they can act as horizontal diaphragms, distributing seismic forces more effectively and enhancing overall stability. Nevertheless, in many historic structures, these connections are either insufficient or have deteriorated over time, which reduces their positive contribution to structural performance.

In addition to the materials and quality of the connections, the typology of the building also directly affects its seismic performance. Buildings with a more regular organization and a more balanced distribution of mass and stiffness usually exhibit a more stable behavior during earthquakes, compared to those with irregular shapes or more complex configurations.

Due to the complexity of this behavior and the heterogeneity of the materials, the evaluation of masonry buildings requires the use of advanced analytical methods. In this context, the finite element method (FEM) constitutes an important tool for analyzing the distribution of stresses, deformations and identifying critical areas in the structure.

3. METHODOLOGY

This study focuses on the analysis of the seismic behavior and structural characteristics of traditional stone masonry buildings in Gjirokastra, taking as a case study the historic Angonate residence. The building, built in 1881, is a work of great architectural value. It is developed into two apartments, in front of the main one a two-story building has been developed, quite spacious, which performs the function of an "outdoor room" and partially opens onto the central courtyard, which has two small courtyards on its sides. The building has numerous and large windows, a balcony that is considered a unique element. It has a symmetrical composition and in some specific parts there are non-parallel developments due to the terrain.

The field survey included architectural measurements and the assessment of existing damages and pathologies, including cracks, mortar degradation and damage to the wooden elements of the floors and roof. The field studies were carried out within the framework of the "Restoration of Cultural Heritage" course held at the University of Polis and the support of DRTK Gjirokastër. To document the condition of the building, the main facade is presented below in photogrammetry and drone views.

In order to achieve the most realistic behavior of the structure, it is very important to determine the properties of the materials. The mechanical parameters of the stone masonry were based on the values reported in the literature for similar historical buildings, while the wooden elements were determined taking into account their anisotropic behavior and contribution to the overall stiffness. Equivalent data were obtained due to the lack of field data. The interaction between the structural components, especially at the wall-floor connections, was carefully considered, as these areas significantly affect the seismic response of these buildings. This approach allows a reliable interpretation of the analysis results and supports the identification of the most sensitive parts of the structure. The material properties were adopted from previous studies on comparable Ottoman-era masonry buildings in Gjirokastër and aligned with Eurocode recommendations.



Figure 3. Photogrammetry of the main facade. (Source: N.Vesho)



Figure 4. Drone photograph of the main facade of the Angonate building. (Source: (Vesho & Nika, 2025))

For the modeling of the structure, the ETABS v.21 software was used, which uses the finite element method (f.e.m), dividing the masonry panels into small square fractions of 1x1m. A 1×1 m mesh size was adopted to achieve a balance between computational efficiency and numerical accuracy.

The walls were modeled according to the simple "shell thick model", with thicknesses corresponding to the dimensions measured during the field survey process, specifically 100 and 80 cm. The foundations were modeled as a continuous beam, connected with needle joints every 1 m and the presence of springs to create the cooperation of the foundation structure. While the roof is modeled as a sloping base with wooden beam elements. Stone masonry structures have large seismic loads due to the weight of the materials used. Initially, we created the model in ETABS, as follows. A shell-thick modeling approach was selected to realistically represent the in-plane and out-of-plane behavior of thick masonry walls. The foundations were assumed fixed at the base level. Dead loads included the self-weight of masonry and roof components, while live and seismic loads were assigned according to Eurocode 8 and Albanian Technical Codes.

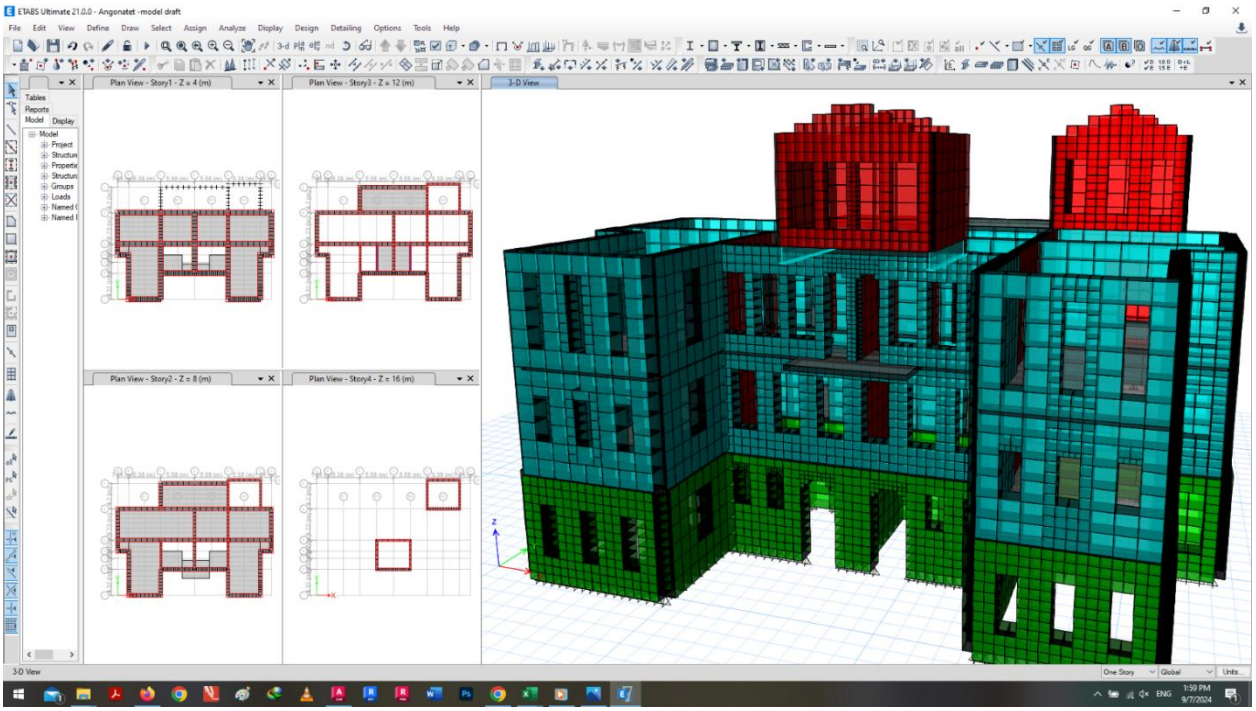
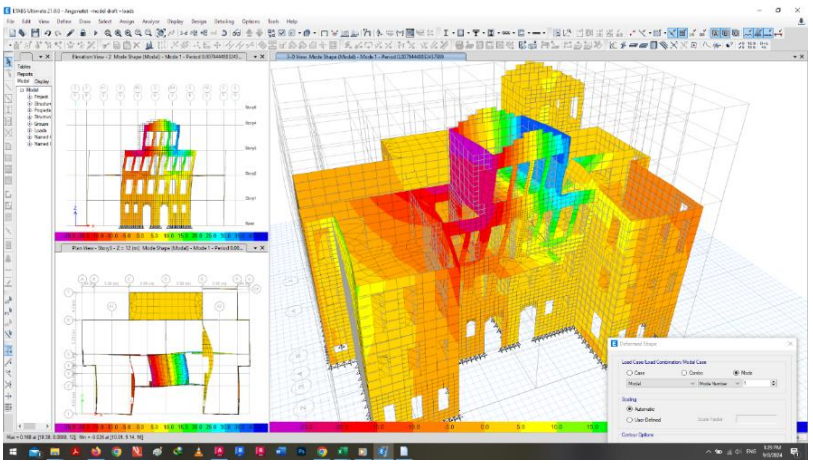


Figure 5. 3D modeling in ETABS according to f.e.m. Building plans and axonometric views. (Source: Author, ETABS v.21)

For the case study, the material parameters of the masonry, slabs and cover during the work on creating the model in ETABS were taken into account the current conditions of the object and the assessment made during the field visits. We have also based ourselves on the results obtained from the literature for similar concrete cases for these typologies of objects. Modal analysis determines the natural frequencies, mode shapes and periods of a structure. These are critical for understanding how the building will react to dynamic loads such as earthquakes or wind. Three modes have been generated for our object. Modal analysis identifies the first important forms of modal vibration, periods and natural frequencies, the latter presented in Table 1. Through this analysis, a basic determination of the seismic performance of the structure is provided. In order to better analyze and have more achieved results, inter-story displacements and drifts are studied.



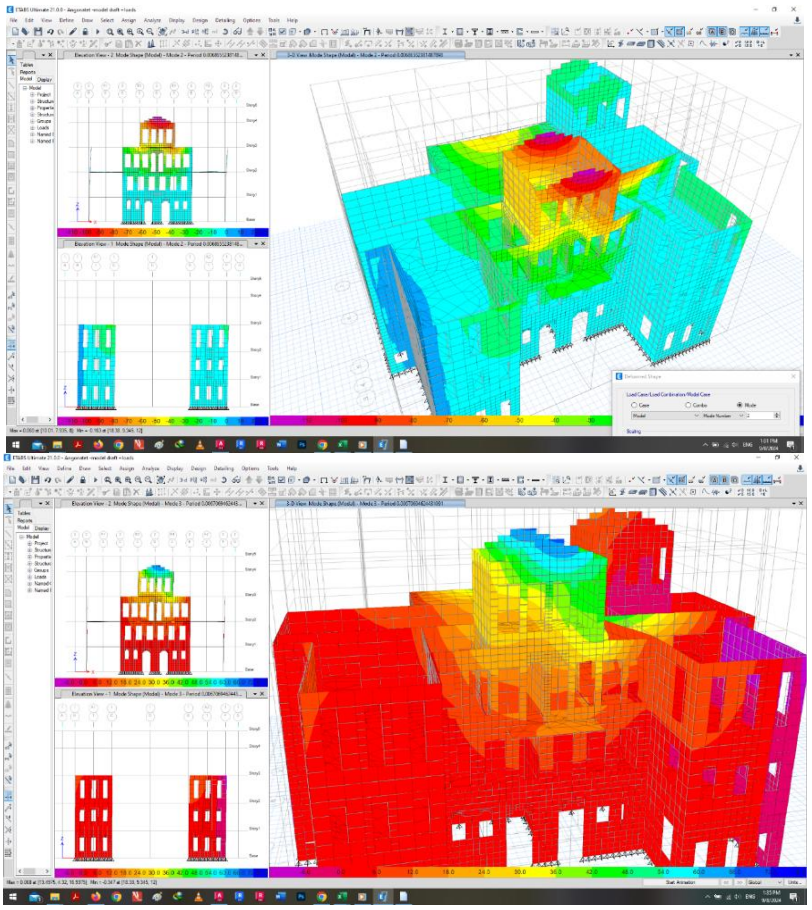


Figure 6. Seismic vibration modes; first, second and third mode in plan and facade (Source: Author)

Table 1. Modal periods and frequencies. (Source:Author)

Case	Mode	Period	Frequency	CircFreq	Eigenvalue
		sec	cyc/sec	rad/sec	rad²/sec²
Modal	1	0.008	125.873	790.8861	625500.8072
Modal	2	0.007	145.655	915.1793	837553.1587
Modal	3	0.007	149.099	936.8176	877627.2222
Modal	4	0.006	155.856	979.2716	958972.859
Modal	5	0.006	157.708	990.9072	981897.1234
Modal	6	0.006	162.002	1017.8883	1036096.62
Modal	7	0.006	166.828	1048.2127	1098749.765
Modal	8	0.006	177.933	1117.9847	1249889.817

4. RESULTS AND DISCUSSIONS

The period for mode 1 (as shown in Fig. 6) is very short. This indicates that the structure is quite stiff, thus indicating that it resists significant deformations during low-frequency dynamic loadings such as seismic events. The deformed shape shows the displacement contours, with the areas near the roof (especially the “tower”) experiencing the highest deformation (red areas), indicating that this part of the building is most responsive to lateral forces in mode 1. The walls, especially at the lower levels, experience much less displacement (yellow to green colors). The extremely short modal periods indicate a highly stiff numerical

response of the structure, likely influenced by the large wall thicknesses and the simplified assumptions adopted in the FEM model.

The deformations are concentrated in the upper parts of the building, meaning that the upper floors of the structure are more flexible compared to the lower parts. Although the structure exhibits global stiffness, the concentration of deformations in the upper levels indicates local vulnerability mechanisms, especially in the roof and tower areas.

The period for mode 2 is also short. This indicates stiffness, usually for buildings with many symmetrical elements like this one. The deformation is also more complex in the dome area and the upper structures, which still show significant displacements (red areas), but the displacement at the lower levels remains minimal (blue and green colors).

Mode 2 involves rotation around a vertical axis, which means that different parts of the building move in opposite directions, especially the dome part, which may be twisted. Regarding the distribution of the seismic load (Fig.7), a large concentration is observed in the foundation of the building, while regarding the displacements of the mezzanine floor they reach their maximum in the upper area, especially in the roof (tower) part.

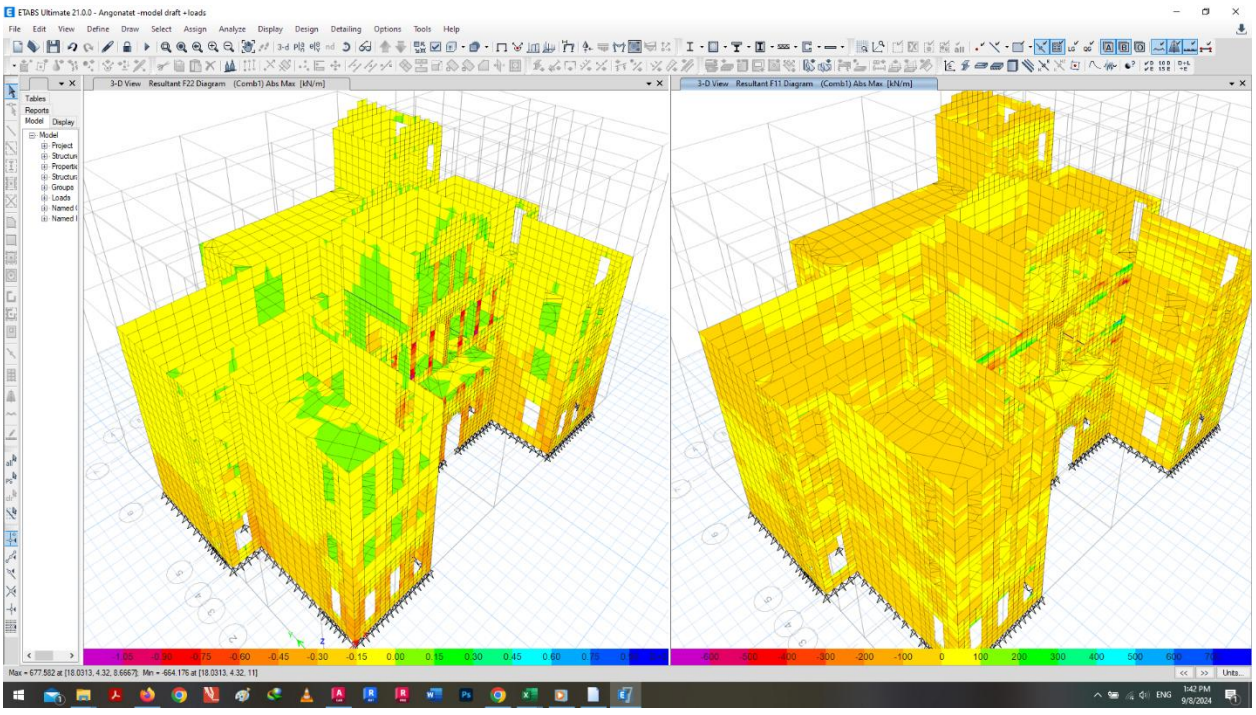


Figure 7. Seismic load distribution according to the first load combination COMB1. (Source:Author)

Proposals for "seismic retrofit" interventions.

To strengthen the structure and improve its performance during seismic activities, taking into account the weaknesses observed in the modal analysis, including the larger displacements in the upper parts, several measures can be taken. All proposed interventions follow the principles of minimum intervention, reversibility, and material compatibility recommended for heritage structures.

The upper levels, especially the dome, which has larger deformations, need to be improved in stiffness. An effective way to achieve this is to reinforce the dome with materials that increase its stiffness. Another method can be to add steel frames or additional concrete reinforcements that can provide the necessary stiffness. Also, modern materials such as fiber-reinforced polymers (FRP) can be used to strengthen these parts without adding much weight. Another method to strengthen the upper levels is to place steel braces or diagonal reinforcements. They can be placed in the walls under the dome to help distribute seismic forces during an earthquake, reducing large deformations.

Mode 2 analysis shows signs of torsional deformation, where different parts of the structure rotate in opposite directions. This is usually due to uneven distribution of mass or stiffness in the building. To reduce torsional effects, it is important to ensure that the mass of the building is distributed symmetrically. Any areas with excessive mass or stiffness concentrations should be adjusted to minimize torsional movement during earthquakes. Adding retaining walls in critical areas can help resist torsion. These are vertical walls of reinforced concrete that provide stiffness and help transfer horizontal forces to the foundation. By placing retaining walls in peripheral parts of the building or in areas of large deformation, torsional movement can be reduced. Fiber Reinforced Polymers (FRP) can improve both the strength and ductility of existing structural elements. FRP can be wrapped around beams and walls to increase their load-bearing capacity without adding much weight. This is particularly useful for preserving the building's historical elements, while also ensuring earthquake resistance. The model does not fully account for material degradation, discontinuities, and nonlinear cracking behavior typical of historic masonry.

5. CONCLUSIONS AND RECOMMENDATIONS

The restoration of a historic building should aim to preserve authentic and original elements. For historic buildings, structural interventions should be as minimally invasive as possible, maintaining a balance between restoration and protection of original features.

Given that Gjirokastra is in an active seismic zone, it is essential to take measures to reinforce the structure against earthquakes. For the Angonate House, this could include adding steel or concrete reinforcements, while preserving the appearance and integrity of the building. Based on the modal and seismic analyses performed using ETABS software, issues were noted with stiffness, deformations and displacements in the upper part of the structure, and torsion.

The Angonate House is composed of two main buildings and an additional part. The typology used is stone masonry, which has the function of bearing loads and maintaining stability. As can be seen from the images above, from the modal analysis, almost 60% of the masonry has lost its bearing capacity. There are areas with large cracks in the masonry due to high stress concentrations. Also, the additional building part affects the increase in stress in the main structures. To solve this problem, we suggest that an anti-seismic joint be placed between the additional and the main buildings.

Also, to avoid subsidence in this area, there is a need for foundation reinforcement. Another problematic part is the socles. All the socles have problems with stability, where one of the socles in the habitable building has fallen and two socles in the other building, which is uninhabitable, have also been destroyed.

Therefore, it is necessary to intervene to prevent the collapse of other slabs and to repair those that have collapsed. The slabs that are irreparable can be replaced with steel frames hidden/captured in the masonry. Another solution could be to intervene with stilts, a traditional method.

From the analyses carried out, another problem found is the displacements in the roof section, which is partially destroyed. For this problem, we propose dismantling the roof and replacing it with a new supporting structure, trusses with wood or steel material. While regarding the tiles, we suggest replacing them with authentic tiles, so that the original characteristics of the house are preserved. The study is limited by the absence of in-situ mechanical testing and the use of linear elastic FEM assumptions. Future studies should include nonlinear analysis, experimental material testing, and validation through ambient vibration monitoring.

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