European Centre for Vulnerability of Industrial and Lifeline Systems

ECILS, Skopje, North Macedonia

Report prepared by:

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Date: 30 November 2024

Activity 1:

Seismic behaviour of characteristic types of Byzantine Churches in Balkan Region

Narrative Report 2024

Project information	
Priority	1.Using scientific and technological knowledge to better assess evolving risks and adapt accordingly the resilience strategies 2.Strengthening disaster risk governance to manage disaster risk: Developing co-operation among all decision-makers to better define an adequate role for authorities in disaster risk reduction (DRR)
Name and place of the Centre	ECILS, Skopje, North Macedonia
Represented by	Prof. PhD Veronika Shendova, Prof. PhD Vlatko Sheshov
Title of the Project	Seismic behaviour of characteristic types of Byzantine Churches in Balkan Region
Implementation period	1st March to 15th November 2024
Grant by Council of Europe	4440 EURO
Contribution by ECILS	supervising of the activity by ECILS specialized engineers, working space, local transport, computer calculation costs, operational and administrative support
Planned and Realized Activities:	**A1:** Preparatory work, organizational activities, preparing presentations and organization of a Workshop in Ohrid to exchange ideas of the project subject
	A2: Assistance to the Greek representatives to collect preliminary data for Byzantine Churches in North Macedonia
	A3: Participation in the Workshop in Ioannina, exchange of ideas and further promote the cooperation between the two Centers during 2025
	A4: Preparation of final reports

Global overview of the project's implementation

The idea for this project on *Seismic behaviour of characteristic types of Byzantine churches in Balkan region*, which is to be implemented in two phases (2024 and 2025), arrows from the joint technical visit of representatives from the European Centers ECPFE and ECILS to Bitola and Ohrid within the framework of Activity 2023, as a follow up. It is coordinated by the ECPFE, while ECILS, ECRM, Croatian Center of Earthquake engineering and Albanian Cultural Heritage without Borders office are partners. Its main goal is to record the vulnerability, seismic behavior, pathology and the retrofitting measures undertaken in characteristic types of Byzantine Churches such as: architectural data (construction period, methodology), the bearing system type, local constructional and geomorphological characteristics, seismic hazard of the area, geometry etc. In the second project phase it is planned to categorize the examined churches and to compare the differences or similarities between the countries involved in this project, and to finally propose a pre-earthquake rapid visual inspection procedure and the restoration strategy.

The role of the partner Centre ECILS within the first phase of the project was as follows:

- Organization of a Workshop in Ohrid by ECILS to exchange ideas of the subject
- Assistance to the Greek representatives to collect preliminary data for Byzantine Churches in Ohrid, North Macedonia; exchange of ideas on the project subject
- Participation in the Workshop in Ioannina organized by ECPFE by the comprehensive presentation on the North Macedonia's experience in the field, exchange of ideas on the project subject and further promote the cooperation between the two Centers during 2025

Most significant project' achievements

From the realized activities in the reporting period 1st March – 30th September the main achievement was the organization of workshop by ECILS and realization of the technical visits to Byzantine churches in Ohrid, North Macedonia on 26-27 September 2024. Ohrid, a UNESCO-protected city, is famous for its many significant historical monuments, including Byzantine churches, well known for their topmost architectonic creation and invaluable fresco paintings. During the technical visit to six remarkable churches, (*St. Sophia, St. Mary Peribleptos, St. John Kaneo, St. Demitrius, St. Nicholas and St. Mary Bolnichki*), dated form the XI – XIV century, preliminary data on the specificities of churches in Ohrid region were collected, (fig. 1).

Figure 1. Visit to Byzantine churches in Ohrid, (26th September 2024)

The teams from both ECILS and ECPFE Centers had a possibility to exchange the knowledge, to visualize the specificities of the Byzantine churches in Ohrid, to realize the present state, level of authenticity and extent of both professional and non-professional interventions. The meeting finished by exchanging ideas for the following topics within the project, (fig. 2).

Figure 2. Exchanging of ideas and final discussion during Ohrid workshop, (27th September 2024)

From the realized activities in the reporting period 1st October – 15th November the main achievement was organization of the workshop in Ioannina, Greece on 19th October by ECPFE, as finalization of the first phase of the project. During the meeting all the participants (Greece, North Macedonia, Armenia, Albania and Croatia) presented the specific characteristics of Byzantine churches in their territory. The presentations were very valuable and useful, first because they highlighted the challenges that churches face and how they can be overcome, and especially because we could realize that although in different countries, we have many common challenges and possibility to discuss on common solutions.

Six colleagues representing ECILS team attended this workshop and contributed by presentation on the typology, structural systems, pathology and retrofitting of Byzantine churches on the territory of North Macedoni in general, but the presentation includes also valuable data on 50 Byzantine churches collected previously, (fig. 3).

Figure 3. ECILS presentation and group photo, (Ioannina workshop, 19th October 2024)

Story which best illustrates the project' successes

The success of this project is that it continues and deepens the cooperation of experts from the two neighboring countries on important cultural heritage structures, but it also expands the cooperation with Albania, Croatia and Armenia focused on Byzantine churches and their seismic performance. It should be noted that ECILS presentation was important contribution to the workshop, as the only presentation that gives the review on the specific characteristics of all Byzantine churches on the territory of North Macedonia, briefly presented below.

Based on the available data from six-century period in question, (9th to 14th century) and their review and systematization done by ECILS team, it can be concluded that the chronology of Byzantine churches in North Macedonia coincides with the several different typologies: the

basilicas were the predominant structures at the beginning of this period, (9th to 11th century), the three or four_*conchal church with a dome* was characteristic for the middle of this period, while the *single-dome with inscribed cross* in a rectangular plan and *single-nave church* prevailed between the 12th to 14th century, (fig. 4). Regarding the period of construction, over 60% were built in the 14th century.

Figure 4. Typical typology of Byzantine churches in North Macedonia

Figure 5. Typical structural elements and interiors of Byzantine churches in North Macedonia

The structural system consists essentially of columns and walls with massive cross-sections, capable of sustaining the compressive stresses due to gravity loads, and vaulted elements, usually constructed with great precision. In almost all churches there are timber ties placed at several levels

in the interior, as well as in the walls themselves. These ties sustain the tensile stresses occurring in the structure due to differential settlement, wind and seismic effects. The interior of the churches is completely decorated with mural paintings of Bible scenes, (fig. 5). Most of the churches are in good or satisfactory physical condition. However, the fact that mural paintings on the upper vaulted areas dates from the later period in comparison with the paintings of lower parts, without signs of earlier mural paintings, speaks that in the past they were damaged or destroyed during earthquakes, and that the current state is most likely the result of their post-earthquake rehabilitation or complete walling. Main causes of actual damage are capillary and atmospheric moisture, (fig. 6), climatic variations, biological factors, earthquakes and floods, human negligence, unskilled conservation due to insufficient training of staff, lack of finances. In the rest of the presentation ECILS team introduced several case studies for seismic upgrading of Byzantine churches in the country, including investigation, design and execution issues.

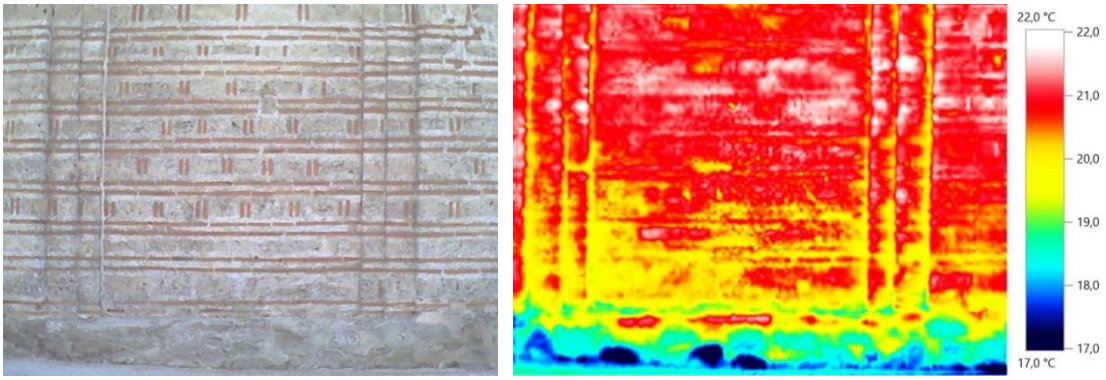

Figure 6. Presence of capillary moisture, (segment of facade wall and corresponding thermal image)

Strategies used to reach the key target groups

The project in its first phase envisages the collection of required data on Byzantine churches specific to the territories of the participating countries (Greece, North Macedonia, Albania, Croatia, Armenia). The successful implementation of this goal was made possible by appropriate meetings, constant communication, and especially the workshop in Ioannina, where after all the presentations an interesting and fruitful discussion developed on how to continue the project in the second phase. The activities organized and implemented in this way are well on the way to reaching a final project goal of categorization of Byzantine churches in Balkan regions and proposition of pre-earthquake rapid visual inspection procedure and the restoration strategy.

Modifications in the project work plan

The ECILS activities in the project were realized according to the plan and Grant Agreement GA/2024/09 concerning Activity 1, there were no modifications in the reporting period March-November 2024.

Sustainability of the project' results

Encouraging dialogue on the seismic vulnerability of common Byzantine cultural heritage fosters mutual understanding and establishes a foundation for future collaboration among Centers on similar projects. This approach supports sustainable preservation by enhancing cooperation between Balkan countries. The project's outcomes will contribute to raising public awareness about the importance of seismic safety for cultural monuments, promoting sustainable tourism development, and improving existing methodologies through shared expertise and innovation.

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Date: 30 November 2024

Activity 2:

Seismic assessment and retrofitting of masonry and preserved structures (PHASE 2)

Narrative Report 2024

Project information	
Priority	Using scientific and technological knowledge to better assess evolving risks and adapt accordingly the resilience strategies
Name and place of the Centre	ECILS, Skopje, North Macedonia
Represented by	Prof. PhD Veronika Shendova, Prof. PhD Vlatko Sheshov
Title of the Project	Seismic assessment and retrofitting of masonry and preserved structures (PHASE 2)
Implementation period	1st March to 15th November 2024
Grant by Council of Europe	4090 EURO
Contribution by ECILS	Technical, electronic, operational and administrative support of the activity (Skopje workshop)
Planned and Realized Activities:	**A1:** Preparatory work: organizational activities, preparing printed materials, preparing presentations
	A2: Organization of workshop in Skopje (23rd May 2024)
	A3: Organization of joint meeting with representatives (presenters) from ECPFE and Serbia (24th May 2024)
	A4: Preparation of final reports

Global overview of the project's implementation

The main goal of this project, which was coordinated by the ECPFE Centre, was reinforcing the network and providing knowledge among academics, experts and decision makers in the field of seismic assessment and retrofitting of masonry preserved structures. Starting from the fact that the range of old masonry buildings all around is enormous and that many of them are of public use, from one hand, and that they are highly vulnerable to earthquakes from the other hand, their relevant assessment and retrofitting is a common European engineering and risk mitigation challenge. In line with this issue, in 2022 the new Greek Code for the Assessment and Structural Interventions of Masonry Structures (KADET) was developed with the main scope to enactment the criteria for the assessment of the structural capacity of old masonry buildings, then for potential interventions, repair and strengthening, as well as their structural redesign after potential interventions. To introduce and present the Code to the professional public, the ECPFE Centre organized one-day workshop in Athens on 13 September 2023, where the doyennes in the particular field and at the same time members of the professional working team, explained the Code, first its scope and methodology in general, and then every single chapter.

Main goal of the project second phase was to introduce KADET to the professionals and authorities in North Macedonia. The role of the partner Centre ECILS' participation was as follows:

1. Organization of a workshop in Skopje on Seismic assessment and retrofitting of masonry and preserved structures where the new Greek Code (KADET) will be presented by the Greek representatives
2. Organization of joint meeting in Skopje, with representatives of each respecting country to exchange scientific opinions and share experience in the field.

Most significant project' achievements

From the realized activities in the reporting period the main achievement was organization and realization of intensive one-day workshop in Skopje on 23rd May 2024. Having in mind the importance of the KADET, as a document that will enable retrofitting of preserved masonry structures based on the established uniform methodology, ECILS organized the follow up seminar in Skopje to share the impressions from last year's seminar in Athens with colleagues in North Macedonia working in the field of cultural heritage buildings. Great interest was shown since among the participants there were representatives from the Ministry of culture, Directorate for cultural heritage protection, Civil and Architectural faculty from Skopje University "St. Cyril and Methodius", and many other colleagues from the Conservation Centers across the country.

Figure 1. Presenters on the Skopje workshop (23rd May 2024)

According to the agenda, in the first part of the workshop the professors from the expert team who prepared the Code presented KADET first in general, and then about the basic principles, step-by-step methodology on performance levels, masonry building structural members and their behaviour, investigation and documentation, modeling and analysis, repair and retrofitting techniques, safety verification and quality assurance, (figs. 1 and 2). Since there are historically significant and preserved masonry buildings across all Balkan, and there are also applied seismic retrofitting methodologies, in the second part of the workshop this issue was briefly covered by the final two presentations, given by representatives from Serbia and North Macedonia.

ECILS/ECPFE Workshop Program

"Seismic Assessment and Retrofitting of Masonry and Preserved Structures"

Skopje 23rd May 2024, IZIIS Premises

9:00 – 9:30	**Registration of participants**	
	WELCOME ADDRESS	
9:30- 9:45	**Krzysztof Zyman** (online)	Executive Secretary EUR-OPA
	Vlatko Sesov	EUR-OPA Permanent Correspondent for North Macedonia/ IZIIS director
	Zoran Pavlov	Director, Directorate for Protection of Cultural Heritage, North Macedonia
	Linda Pelli (online)	ECPFE/EPPO
	Veronika Shendova	ECILS/IZIIS
Presentation of the new Greek Code for the Assessment and Structural Interventions of Masonry Structures (KADET)		
	speaker	**presentation title**
9:45 -10:15	**S. Dritsos** Professor Emeritus University of Patras Deputy President of ECPFE	**THE GREEK CODE FOR ASSESSMENT AND *STRUCTURAL* INTERVENTIONS OF MASONRY STRUCTURES *(KADET)* AND THE SEISMIC CLASSES OF BUILDINGS**
10:15 -10:45	**A. Miltiadou** Associate Professor National Technical University of Athens	**INVESTIGATION AND DOCUMENTATION IN KADET**
10:45 – 11:00	**COFFEE BREAK**	
11:00 -11:30	**E. Vintzileou** Professor Emeritus National Technical University of Athens	**BASIC BEHAVIOUR MODELS, REPAIR and STRENGTHENING TECHNIQUES OF MASONRY STRUCTURES**
11:30-12:00	**S. Pantazopoulou** (online) Professor, Lassonde School of Engineering, York University, Canada	**PERFORMANCE LIMITS AND VERIFICATION CHECKS IN KADET**
12:00-12:30	**QUESTIONS/ROUND TABLE**	
12:30 – 13:30	**LUNCH BREAK**	
Presentation of the experience in the field of preserved masonry structures in Serbia and North Macedonia		
	speaker	**presentation title**
13:30 – 14:00	**Svetlana Brzev** Adjunct Professor University of British Columbia, Canada	**PROTECTION OF HERITAGE STRUCTURES FROM EARTHQUAKE EFFECTS: STATUS OF REGULATIONS AND PRACTICE IN SERBIA**
14:00 – 14:30	**Veronika Shendova** Professor, UKIM-IZIIS, Skopje North Macedonia ECILS Director	**HISTORIC BUILDINGS AND MONUMENTS IN NORTH MACEDONIA: TREATMENT AND RETROFITTING ASPECTS**
14:30 – 15:00	**FINAL DISCUSSION and CLOSING**	

Figure 2. Skopje workshop agenda

Story which best illustrates the project' successes

The real success of this workshop is what follows the presentations. It was a really great opportunity to hear about the new Greek Code in considerable detail directly from the team who prepared the Code. Their presentations initiate great interest, as evidenced by the discussion and dialogue that followed, (fig. 3). The seminar was very successful, since it sparked engaging discussions among attendees during the discussion panel, lunch time and joint meeting organized next day among the representatives from Greece, North Macedonia and Seria. Participants from various Macedonian institution actively contributed, sharing diverse perspectives and insights.

Figure 3. Fruitful discussion during the workshop and joint meeting

The event provided an excellent platform for networking, leaving everyone inspired and looking forward to future opportunities for continued dialogue and widening of collaboration between experts from Greece, North Macedonia and Serbia in the field of education and sharing practical experience. In addition, this workshop confirms once again that in the Balkan region we have many common challenges and that we can work together on the common solutions and reciprocal upgrading of the existing relevant methodologies for seismic assessment and retrofitting of masonry and preserved structures.

Figure 4. Group photo of the workshop presenters and joint meeting participants

Strategies used to reach the key target groups

Workshops organized in this way are the best way to achieve the goal, to present the possibilities of the Code concept and its target achievement to Macedonian decision makers, to provide knowledge to the engineers and reinforce the collaboration between experts. In addition, KADET serves as non-contradictory complementary information to the Greek National Annex to Eurocode 8 part 3, providing more detailed approach in each of the phases from structural assessment to structural retrofitting of preserved masonry structures. Having in mind that due to recent introducing of the Eurocodes and still exceptionally modest experience in this field in North Macedonia, expressed willingness of experts from Greece for further cooperation in practicing Eurocodes, (especially Eurocode 8 part 3), is of extraordinary importance.

Modifications in the project work plan

The ECILS activities in the project were realized according to the plan and Grant Agreement GA/2024/09 concerning Activity 2, there were no modifications in the reporting period March-November 2024.

Sustainability of the project' results

The knowledge gained through this action, as well as other EUR-OPA Major Hazard Agreement actions will be shared across various professional and academic platforms to promote sustainable practices in earthquake engineering and heritage protection. Insights will be shared at national and regional structural engineering meetings and symposia in Serbia and Croatia, fostering professional collaboration and capacity building. International exposure was achieved at the 18th World Conference on Earthquake Engineering in Milano (June 2024), while scientific findings will be published in the *International Journal of Architectural Heritage*, promoting sustainable preservation practices.