

EDICULA

Educational Digital Innovative Cultural heritage related Learning Activities



THE EDICULA IMMERSIVE EVENT

19 December 2022 || 10:30-14:30

National Technical University of Athens, Patission Campus, Averof Building, Kaftatzoglou Ceremony Hall

Interdisciplinary methodology

**Interdisciplinary
study**

**Rehabilitation
project**



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Interdisciplinary study for Varnakova Monastery Catholicon rehabilitation

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Interdisciplinary study and rehabilitation project proposal

Includes multispectral & interdisciplinary analysis:

- I. **historical** documentation and important aspects of the monument,
- II. **architectural** analysis and proposals,
- III. on site **non destructive testing**,
- IV. **structural analysis**, regarding the stability of the monument, as well as proposals
- V. **characterization** of historical materials and diagnosis of their decay, as well as the **design and selection** of compatible and performing restoration materials,
- VI. **project management plan** for the rehabilitation project.

AIM OF REHABILITATION

The purpose of the rehabilitation project is to **revoke the pathology of the monument, highlight its historical and aesthetic values**, and, finally, make it once again safely **accessible**.

I. VARNAKOVA CATHOLICON – HISTORICAL VALUES

Elements of historical significance are documented and placed in the center of the rehabilitation project in order to be protected and highlighted

It preserves the **elaborate decorated 11th century floor**



The **Templon** from the Kapodistrias reconstruction is also of high historical and architectural value



II. VARNAKOVA CATHOLICON – ARCHITECTURAL ANALYSIS

TYPE

The Catholicon is a **three-nave basilica** with a dome, with a main temple, a narthex to the west and a prominent semicircular niche to the east.

SIZE

The perimetrical masonry is **0.80m** thick, while the inner masonry that separates the main church with the narthex is **0.65m** thick.

HISTORICAL PHASES

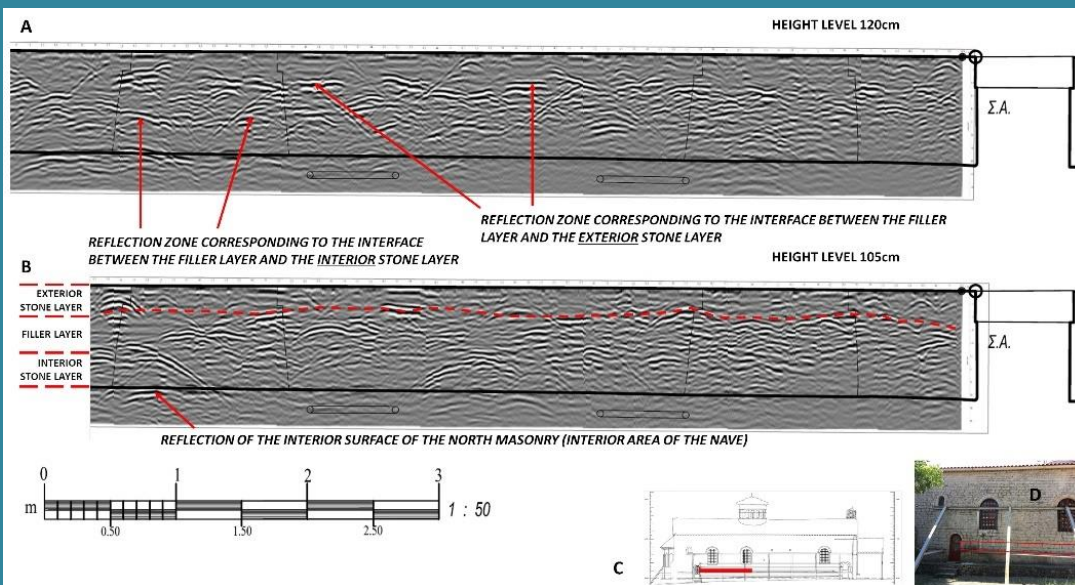
- The wheelbase of the columns is not constant. The four central columns are equally spaced (approximately 3.78 m), forming an ideal square and supporting the dome. From this element we conclude that the **original basilica also had a dome.**

Architectural features and elements are documented and act as:

- Important input information for the interdisciplinary study
- Core values, which must be protected and highlighted

III. VARNAKOVA CATHOLICON – ON SITE NON-DESTRUCTIVE TESTING

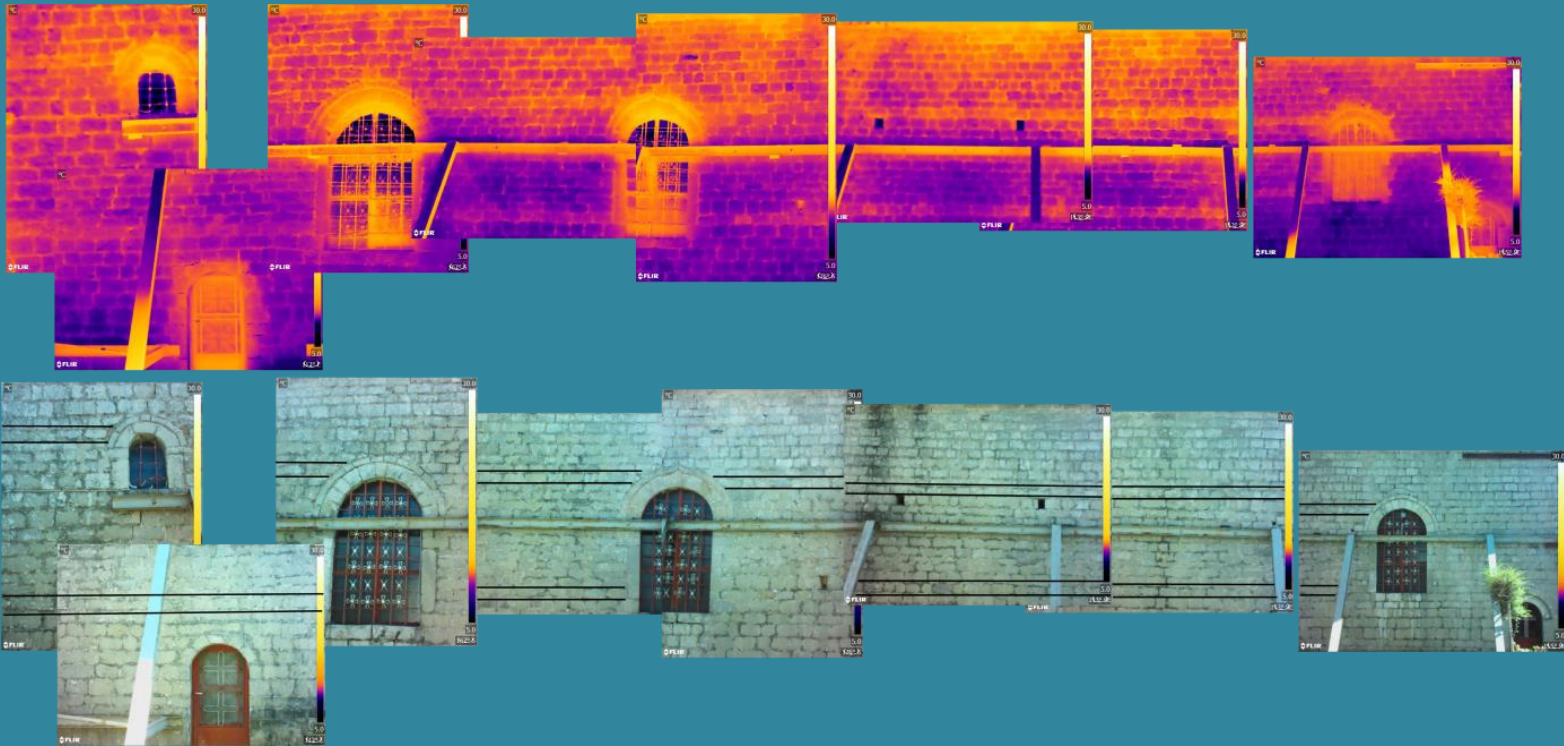
On site non-destructive testing provides complementary information regarding “unseen” features and pathology



- ❖ Information regarding the extension and interconnection of cracks **within the internal layers of the structure.**
- ❖ Information regarding possible **detachment of the masonry layers.**

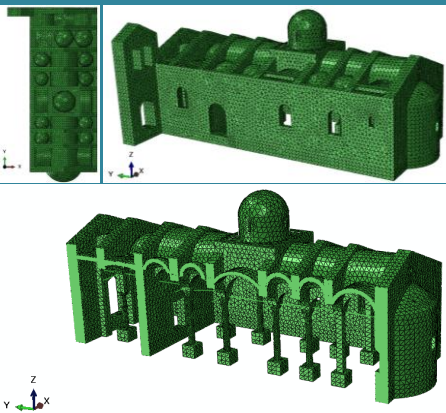
Three-leaf masonry: (i) Exterior stone layer (25 cm), (ii) Intermediate filling layer, (iii) Interior stone layer (25 cm)

III. VARNAKOVA CATHOLICON – ON SITE NON-DESTRUCTIVE TESTING



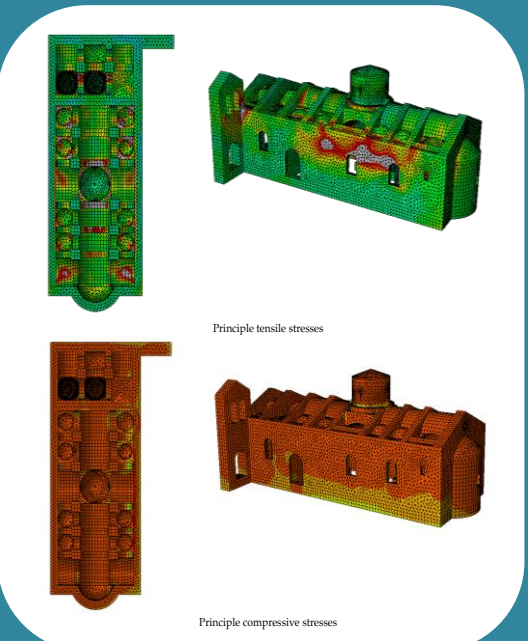
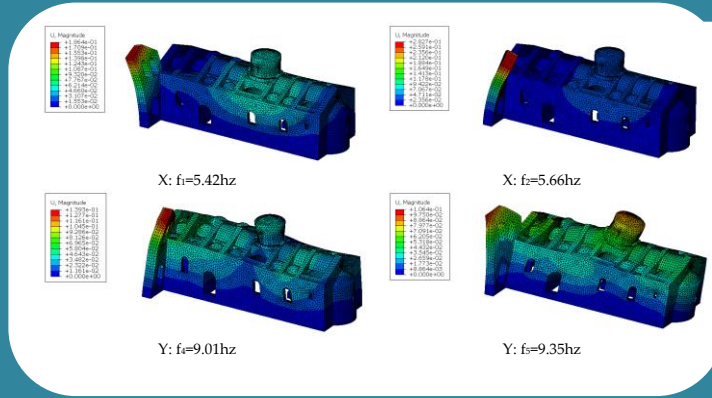
Infrared thermography measurements indicated areas of **mortar detachment** (lower temperatures) and areas where **incompatible mortars** have been used locally (higher temperatures), while it also revealed the presence of a (possibly wooden) **element surrounding** the structure in the internal layer.

IV. VARNAKOVA CATHOLICON – STRUCTURAL ANALYSIS



The Catholicon structure was modeled in the Abaqus 6.19 using **3D continuous solid elements**

Fundamental frequencies and mode shapes



SD limit state – mean values of principle stresses envelope

The examination of the current state provides information regarding the **vulnerability of the monument**, while analysis of different repair scenarios reveals the optimum solutions to reinstall structural integrity

V. VARNAKOVA CATHOLICON – MATERIALS CHARACTERIZATION

CHARACTERIZATION OF HISTORIC MORTARS

- ❖ The historic mortars were categorized as **lime-based mortars of hydraulic nature** and appear separated into two basic groups
- ❖ the mortars are **lightweight** and present **high porosity values**
- ❖ The presence of **chloride** indicates that the monument is **affected by rising damp phenomenon and precipitation**

Historical mortar characteristics act as the basis for the design of restoration mortars, while their decay indicates the factors which negatively affect resilience of the materials

V. VARNAKOVA CATHOLICON – MATERIALS CHARACTERIZATION

CHARACTERIZATION OF HISTORIC STONES

Regarding the building elements of the structure, the Catholicon presented **the same lithotype** as building element regarding the masonries, at least in relation to the external facades which were accessible (the internal facades are to a great extent covered with plaster). This lithotype corresponds to a **low porosity grey-beige fossiliferous biomicritic limestone**

Characterization of the historical stone acts as the basis for the selection of the new restoration stone

V. VARNAKOVA CATHOLICON – RESTORATION MORTARS CRITERIA

Aim: Compatibility and Performance

DIAGNOSIS RESULTS

Hydraulic nature of historical mortars

Presence of chloride in all historic materials

Indication of rising damp and precipitation issues

High porosity of historical mortars - sporadic presence of porous stones

Mechanical performance demands deriving from building's FEM analysis

RESTORATION MORTAR CRITERIA AND DEMANDS

Hydraulic nature of restoration mortar

Appropriate microstructure in order to avoid salt accumulation in historic materials

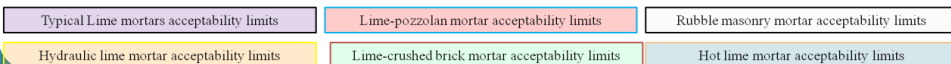
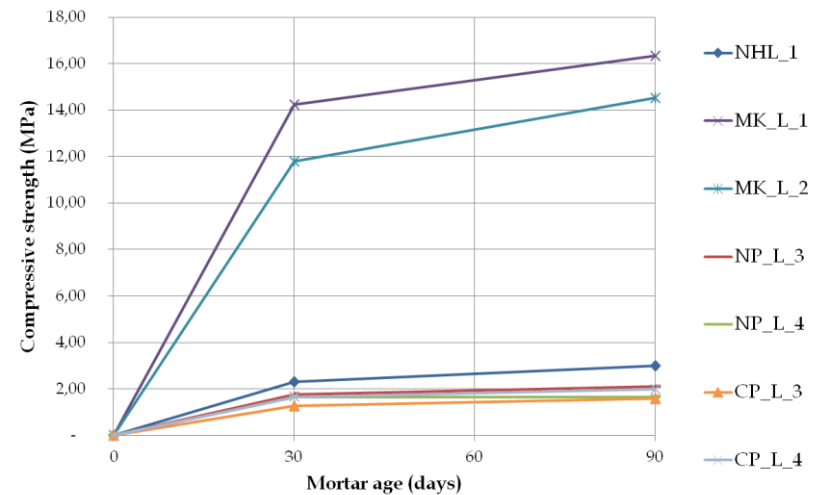
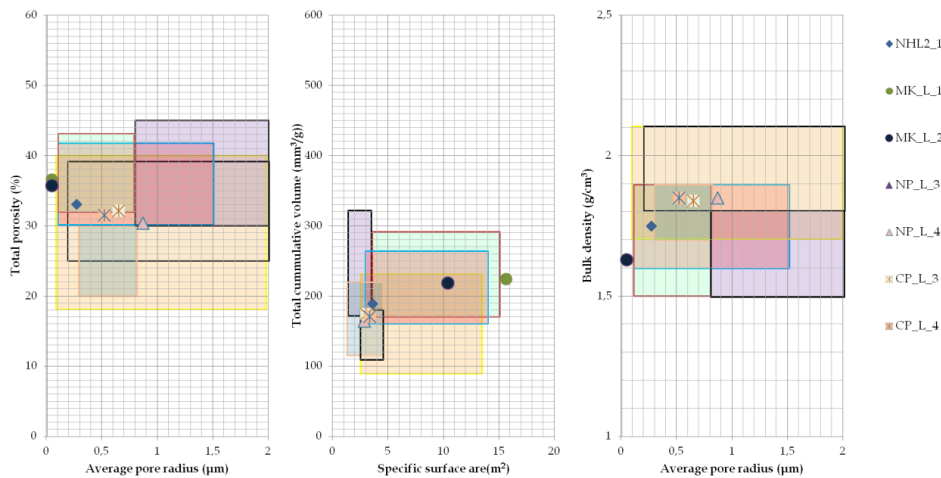
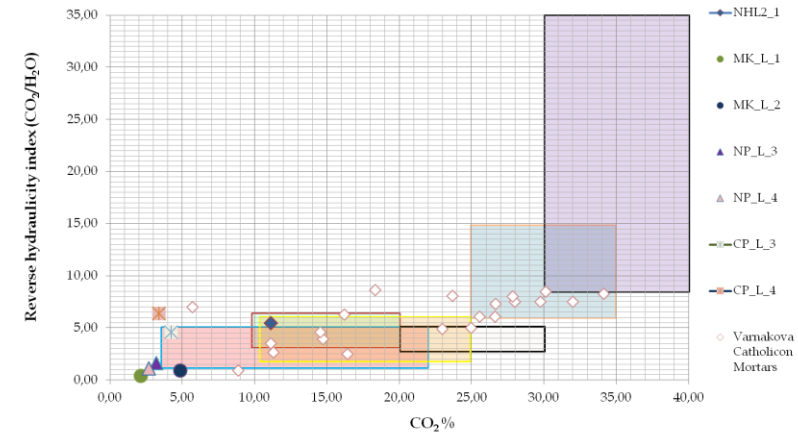
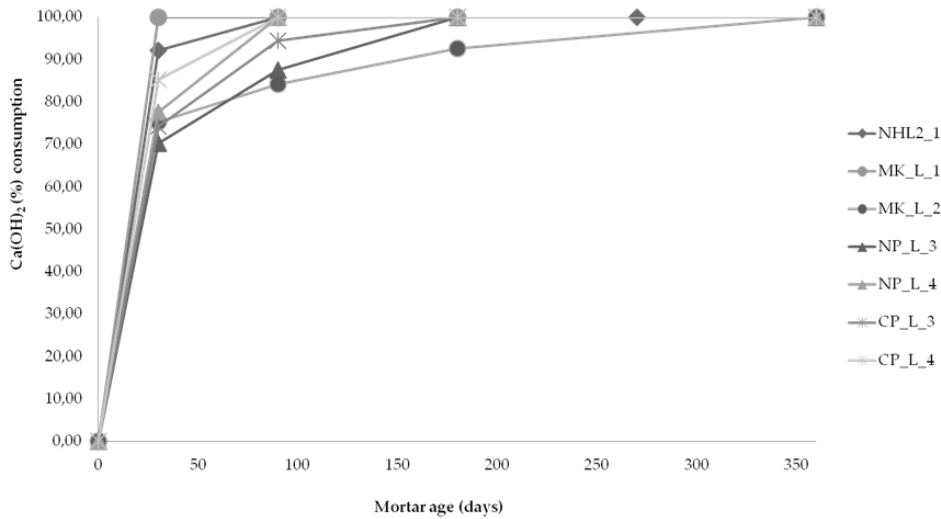
Appropriate microstructure in order to ensure resilience in an aggressive environment

Hydraulic restoration mortar in order to ensure setting and hardening in high humidity conditions

Hydraulic restoration mortar in order to achieve early and adequate mechanical performance



V. VARNAKOVA CATHOLICON – RESTORATION MORTAR DESIGN AND ASSESSMENT



V. VARNAKOVA CATHOLICON – RESTORATION MORTAR DESIGN AND ASSESSMENT

❖ **Lime-metakaolin mortars** present the **highest compatibility and performance**

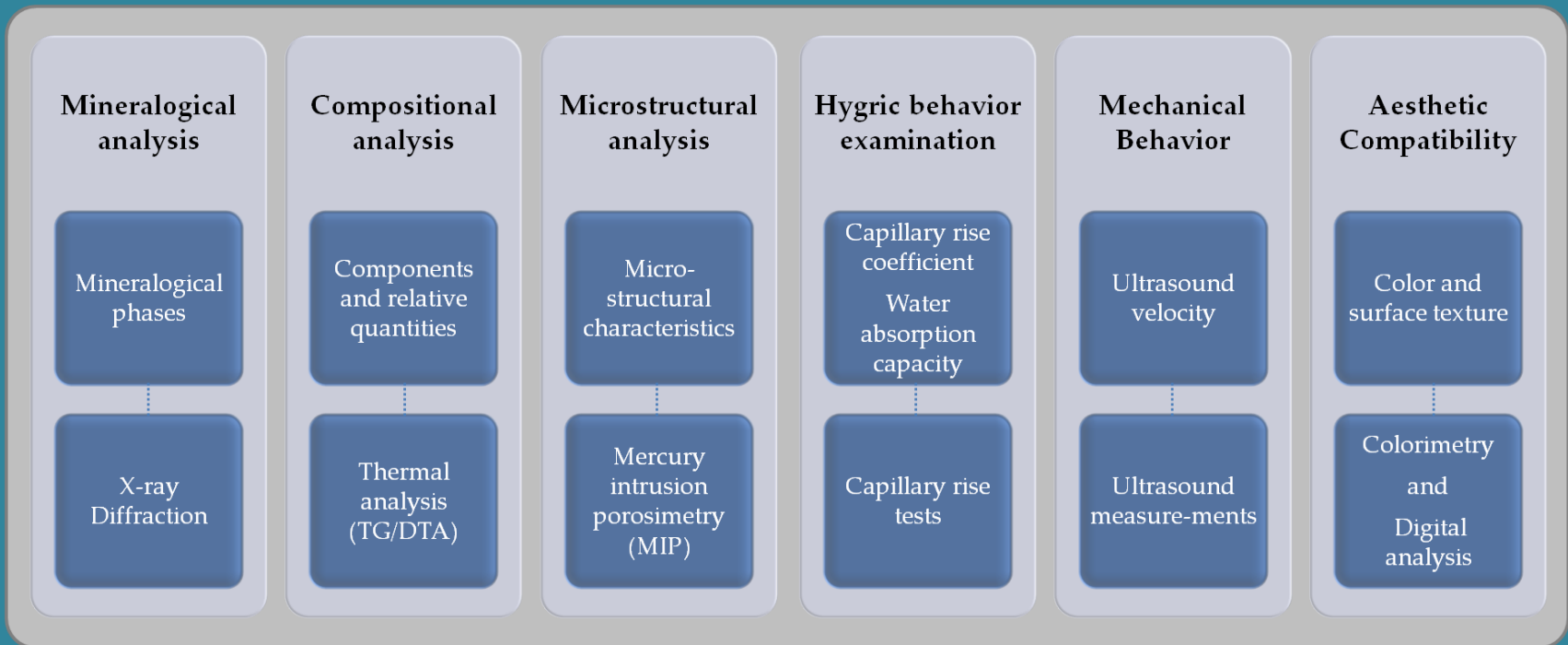
❖ A commercial lime-metakaolin mortar (**M15**) was selected

❖ A lime-metakaolin based grout was selected for the grouting process

Thus fulfilling compatibility criteria, as well as structural stability demands

V. VARNAKOVA CATHOLICON – RESTORATION STONE SELECTION

Aim: Similar characteristics with original stone



Lithotypes from near-by quarries were examined in order to find (if possible) the same lithotype as the historic stone - **The same lithotype was found**

VARNAKOVA CATHOLICON – PATHOLOGY

- ❖ The bearing structure of the Catholicon is a **seismically vulnerable body**, exhibiting a variety of pathology.
- ❖ The church presents **significant deformation**, which led to the buttress of the perimetrical masonry and the support of its roof.
- ❖ The temple is made externally of isodomic stonework, which shows **cracks of significant width** in the areas of openings and corners, as well as **loss of bonding mortar**.
- ❖ The floor of the temple shows **significant deformations, cracks and loss of material**.

VARNAKOVA CATHOLICON – REHABILITATION FOCAL POINTS

Protect important historical and architectural features:

- No damage must be caused to the Byzantine era floor of the Catholicon.
- The possible existence of murals must be investigated, before applying the coatings on the interior surfaces of the temple.

Reveal and highlight historicity:

- The outbuilding must be removed from the west side of the Catholicon.
- The outer surface of the walls must remain uncoated. The stone elements (doorsteps, headers, etc.) should be visible.
- The metal frames and metal doors and windows should be replaced with new wooden elements, of traditional form.

VARNAKOVA CATHOLICON – PROPOSED INTERVENTIONS

Structural Reinforcement measures

- ❑ Global **grouting** of all Catholicon masonry and domes.
- ❑ Installation of **steel struts-ties** in the arches.
- ❑ **Lining** of the interior and exterior of the domes and the interior of the sanctuary apse **with stainless steel meshes**
- ❑ **Reconstruction of the roof.**
- ❑ Use of a **compatible M15 restoration mortar.**
- ❑ Installation of **in-plane steel tie** in the sanctuary apse.
- ❑ **Stainless steel hoops** of 50mm thickness/500mm along the height of the columns, in accordance to the columns crack patterns.
- ❑ Concrete tie beam at **column foundations**

VARNAKOVA CATHOLICON – PROPOSED INTERVENTIONS

According to the structural analysis results, the suggested interventions are considered adequate for the **enhancement of the seismic response** of the Varnakova Monastery Catholicon for seismic events of **PGA=0.24g with repairable damages**

VI. VARNAKOVA CATHOLICON – PROJECT MANAGEMENT PLAN

The management of the project is based on the following objectives and practices:

Communication. The continuous and open communication between all the involved parties is essential for the success of the project and is supported and practiced daily.

Transparency. Project information is widely available to all concerned.

Timeline. The project completion milestone is the end of July 2022. The project schedule and its management aim to meet this deadline without missing any intermediate milestones.

Effectiveness. All project tasks are defined in such a way that the supervising engineers can check their successful completion. In this way the team that executes the tasks is enabled to perform their job effectively.

VI. VARNAKOVA CATHOLICON – PROJECT MANAGEMENT PLAN

Collaboration. The project is the result of joint efforts of a team of scientists and a construction team. These roles are not disjoint, they are supplementing one another.

Ownership and Accountability. Each task has an owner, be it a scientist who designs, an engineer who supervises, a contractor who builds. Each owner is also accountable for the tasks they own. And they need to get them right the first time. There is no time for errors and recoveries from errors.

Agility. Planning and scheduling for this type of projects requires agility. Work is planned and scheduled for short periods of time, using all the available information. In each iteration new information is integrated into the process and the next period is planned and scheduled.

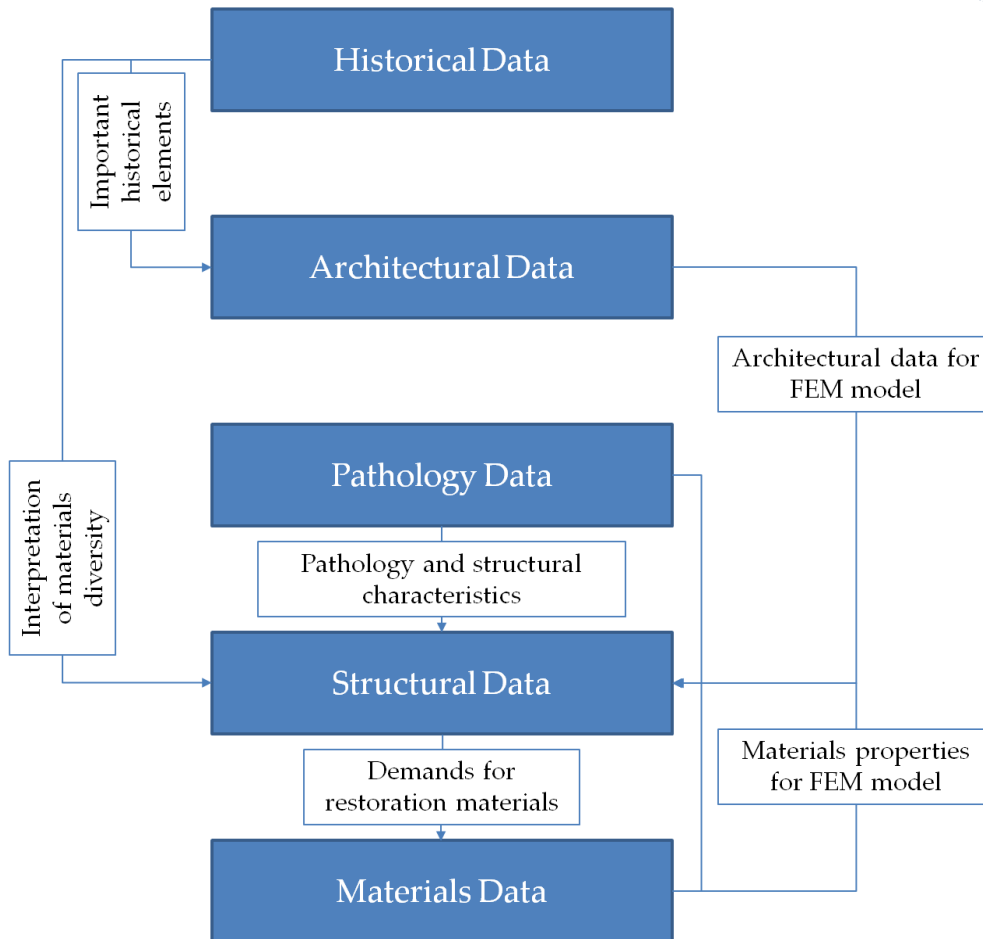
VI. VARNAKOVA CATHOLICON – PROJECT MANAGEMENT PLAN

Reporting and Control. Bringing new data to light and reporting them is essential. Controlling the project activities by comparing the planned to the actual is a key responsibility of PM, and it includes the financial part of the project.

Interdisciplinary study and project planning

PROJECT MANAGEMENT

Continuous update and interrelation process during the diagnostic study and throughout the rehabilitation project



The interdisciplinary methodology, along with the project management plan allow for the dynamic readjustment of the restoration plan



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Varnakova Monastery Catholicon rehabilitation project

**Vasileios Zafeiris, Nikos Moropoulos, Stergios Roumeliotis, Vasileios Keramidas,
Maria Apostolopoulou, Georgios Andriotakis, Charalabos Mouzakis and
Antonia Moropoulou**

THE PROJECT

The rehabilitation project is **ongoing**, it **began in July 2021** and is programmed to end in August 2023 in order to allow for the Assumption of Mary religious ritual to take place in the Catholicon

The project is **funded by the own resources** of the Varnakova Monastery monastic community and therefore also donations made by people to the community

GOVERNANCE

The **integrated governance of the project** under the responsibility of the Ephorate of Antiquities of Phocis, is scientifically supported in real scale and real time by the NTUA interdisciplinary team, which has the scientific supervision with all engineers responsible for the implementation studies, in cooperation with the contractor responsible for the construction site.

All works conducted are based on studies, submitted and approved by the Directorate for the Restoration of Byzantine and Post-byzantine Monuments

The Reverend Metropolitan of Fokis Theoctistos is also informed regarding the progress of the works

STAGES OF THE PROJECT

The project follows specific stages, which in many cases are interlinked, allowing for dynamic readjustments:

- Installation of supports and scaffoldings
- Restoration of the roof
- Masonry restoration, cleaning repointing and grouting
- Reinforcement of arches
- Restoration of domes and vaults
- Removal and restoration of plasters
- Resetting of arches
- Excavation works around the perimeter of the Temple for project purposes

Installation of supports and scaffoldings

Exterior scaffolding system of high safety and resilience



South side



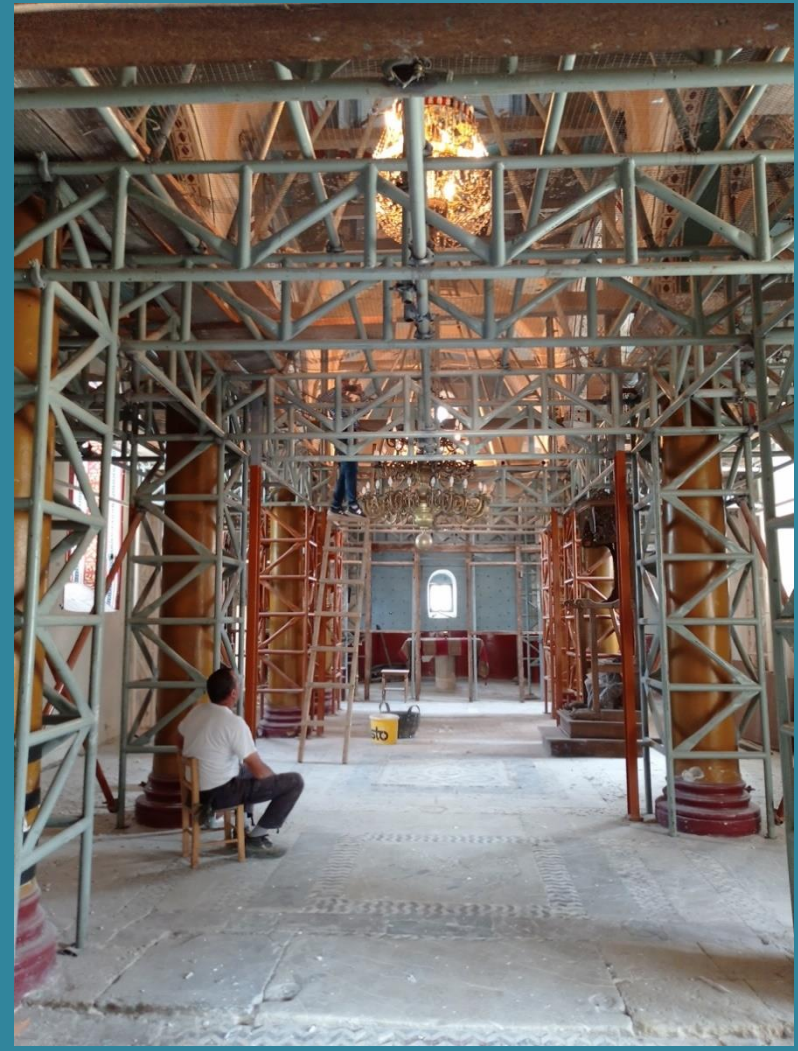
North side



East side

Installation of supports and scaffoldings

Readjustment and reinforcement of interior scaffoldings



Restoration of the roof system

The roof was opened, revealing a complex system



Stones and deteriorated materials were carefully removed (300 tons!)



Restoration of the roof system



Over the Pronaos, traces of the original ceramic roof tiles were revealed

The underlying roof system was completely revealed and documented

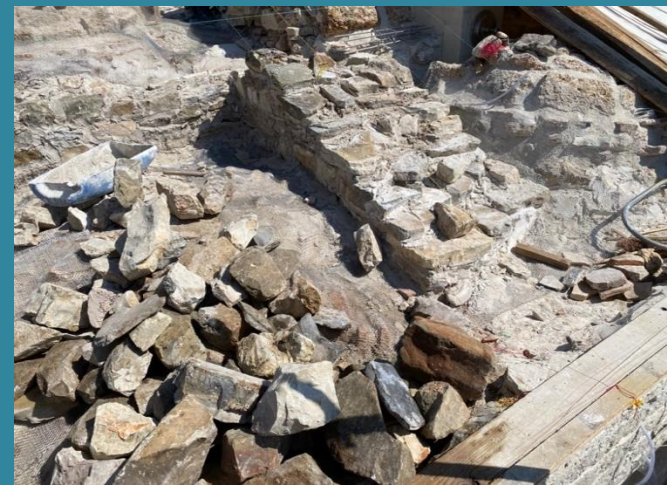


Restoration of the roof system

The works were carried out in stages, while reinforcing and grouting the supporting structures, where necessary.



Compatible Pozzolan concrete, stainless steel meshes and reinforcement elements and selected historic stones (only in good condition and after cleaning) were used in the reconstruction



Restoration of the roof system

The works were carried out in stages, while reinforcing and grouting the supporting structures, where necessary.



Restoration of the roof system



The main dome was restored, revealing and highlighting the authentic ceramic design and removing later additions



Restoration of the roof system



Finally, after the ceramic tiles were readjusted the original cross was repositioned



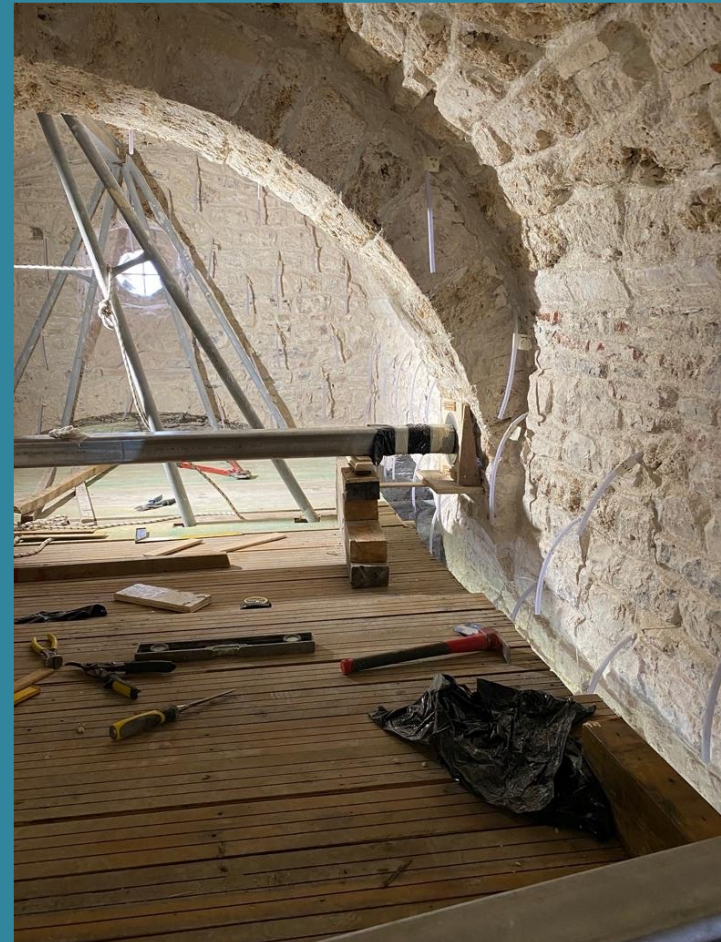
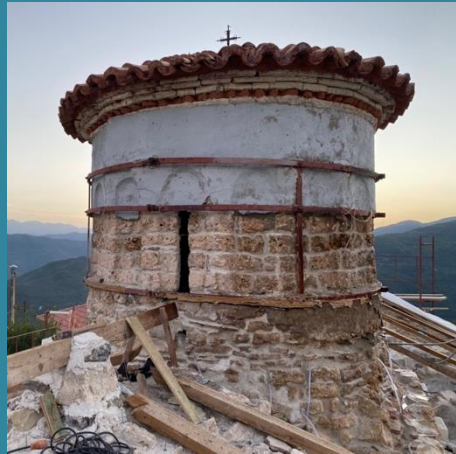
Masonry restoration, cleaning, repointing and grouting

The masonry was cleaned of newer and loose plasters and mortars, highlighting the stone masonry system



Masonry restoration, cleaning repointing and grouting

The masonry was repointed both regarding the exterior and the interior, as well as the dome and roof systems



Masonry restoration, cleaning repointing and grouting

Grouting was conducted, from lower areas to higher areas to reinforce the structure (6.500 injection grouts were installed)



Reinforcement of arches

The arches were reinforced with stainless steel elements



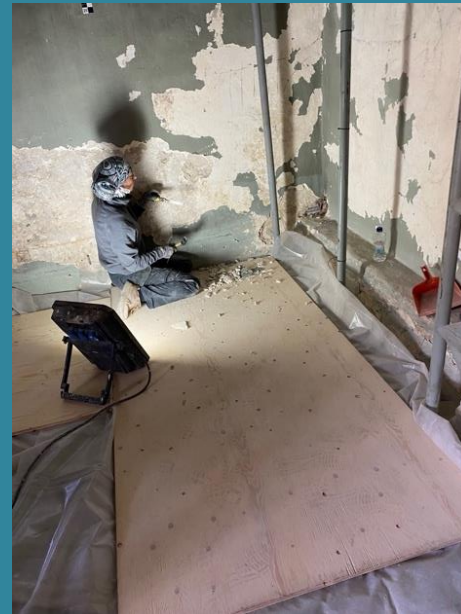
Restoration of domes and vaults

Dome and vault systems are restored, repositioned, repointed and reinforced, both internally and externally



Removal of plasters

The presence of plasters was fully documented and they were carefully removed in order to investigate the possible presence of wall paintings beneath the different phase layers



Resetting of arches

16 arches were reset



Reinforcement materials used for restoration

The materials used for the restoration works were continually **assessed** throughout the project and, if needed, **readjusted**. The aim is always to achieve **compatibility, performance and durability** in a case to case manner



NTUA Scientific Support

The NTUA Interdisciplinary team continuously supports the project, throughout the works:

- Application of NDT to assess the interventions
 - Documentation of new findings
- Readjustments of restoration interventions and materials





Byzantine masonry construction



Removal of cement tiles



Documentation of roof system

Ceramic jugs in the dome to enhance acoustics



Wooden reinforcement



Stone pillar behind plaster



CONCLUSIONS

- ❖ The **interdisciplinarity**, as well as the diversity of the research and rehabilitation teams, allows for a **multileveled analysis**, throughout the implementation of the rehabilitation project.
- ❖ The innovative project management plan and continuous NTUA scientific support allows for optimization of the rehabilitation, through a **dynamic process throughout the project**, according to the new findings, revealing the values of the monument, while ensuring structural integrity and sustainability

Historical documentation continues throughout the rehabilitation project, as **new findings emerge**, thus providing data and guiding the optimum rehabilitation process, which can **reveal and highlight the values of the monument**

NEW FINDINGS -
VALUES OF THE
MONUMENT

DYNAMIC
READJUSTMENT OF
RESTORATION
PLAN

CONCLUSIONS

❖ This is an exemplary work transferring the model of the Rehabilitation of the Holy Aedicule project to Greece, searching out a **transdisciplinary approach and multi-actors cooperation.**

THANK YOU FOR YOUR ATTENTION!

