



Systematic approach to data acquisition for the preservation of heritage buildings

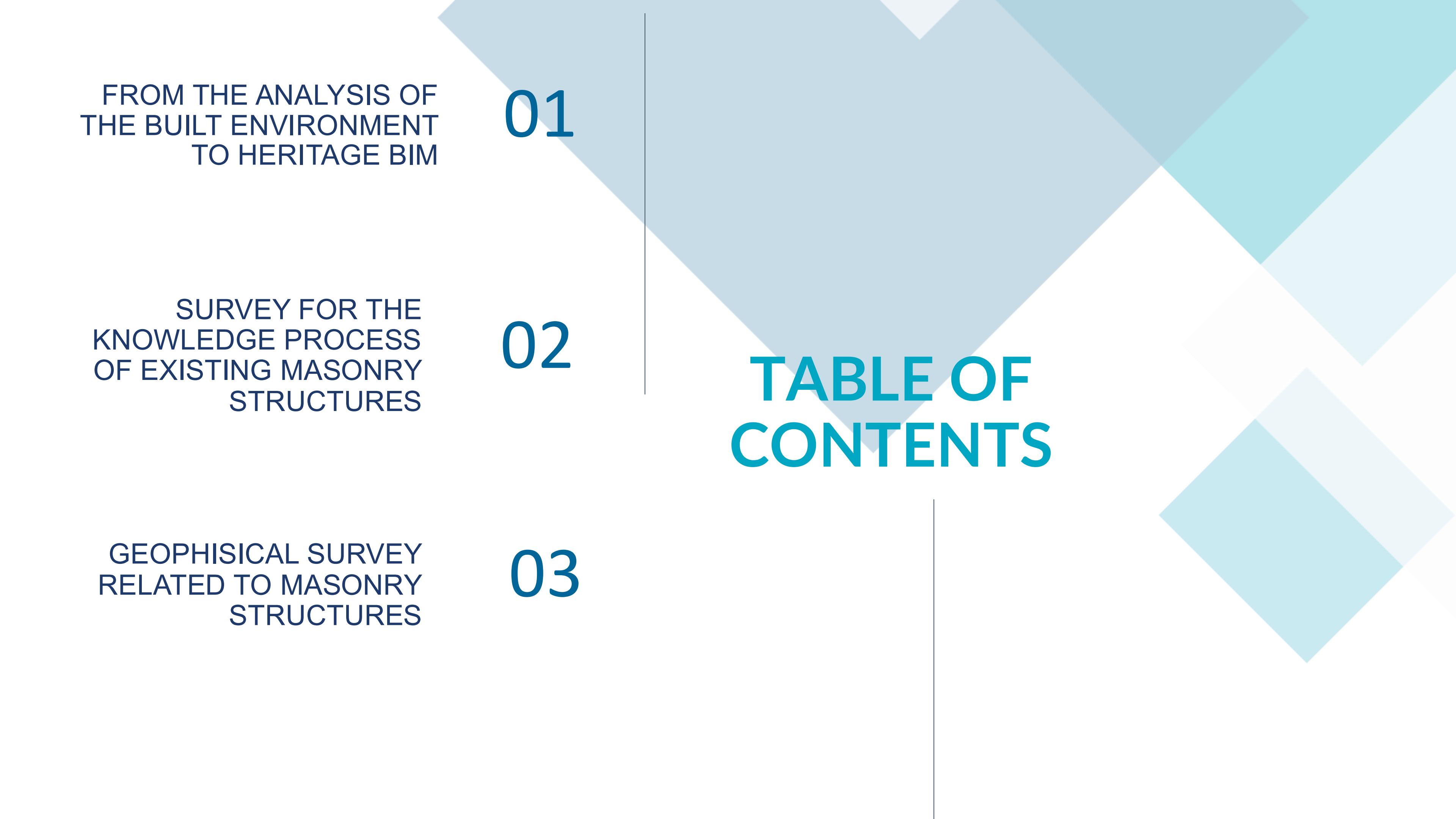
SURVEY FOR THE KNOWLEDGE PROCESS OF EXISTING MASONRY STRUCTURES

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INTERNATIONAL WORKSHOP
DIGITAL INTEGRATED STRATEGIES TO SAFEGUARD
HERITAGE CONSTRUCTION TECHNOLOGIES
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FROM THE ANALYSIS OF
THE BUILT ENVIRONMENT
TO HERITAGE BIM

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SURVEY FOR THE
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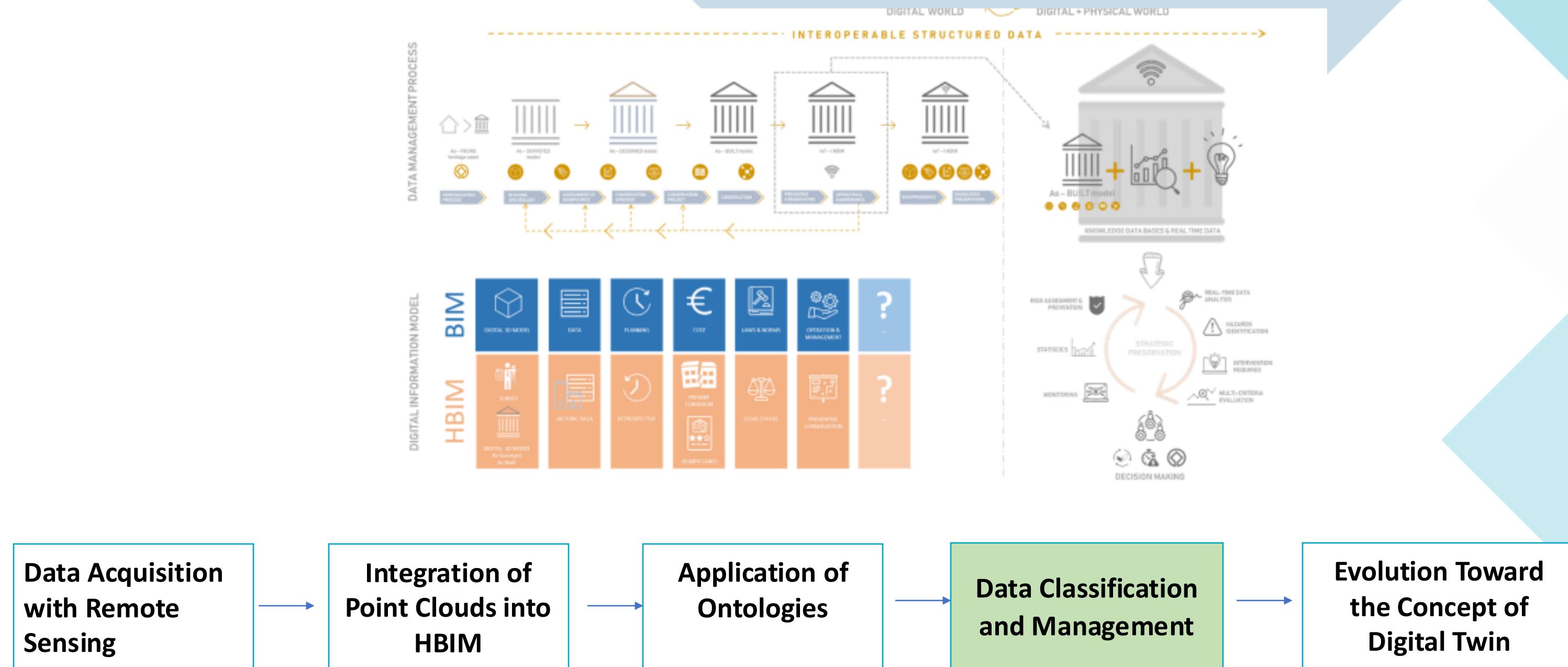
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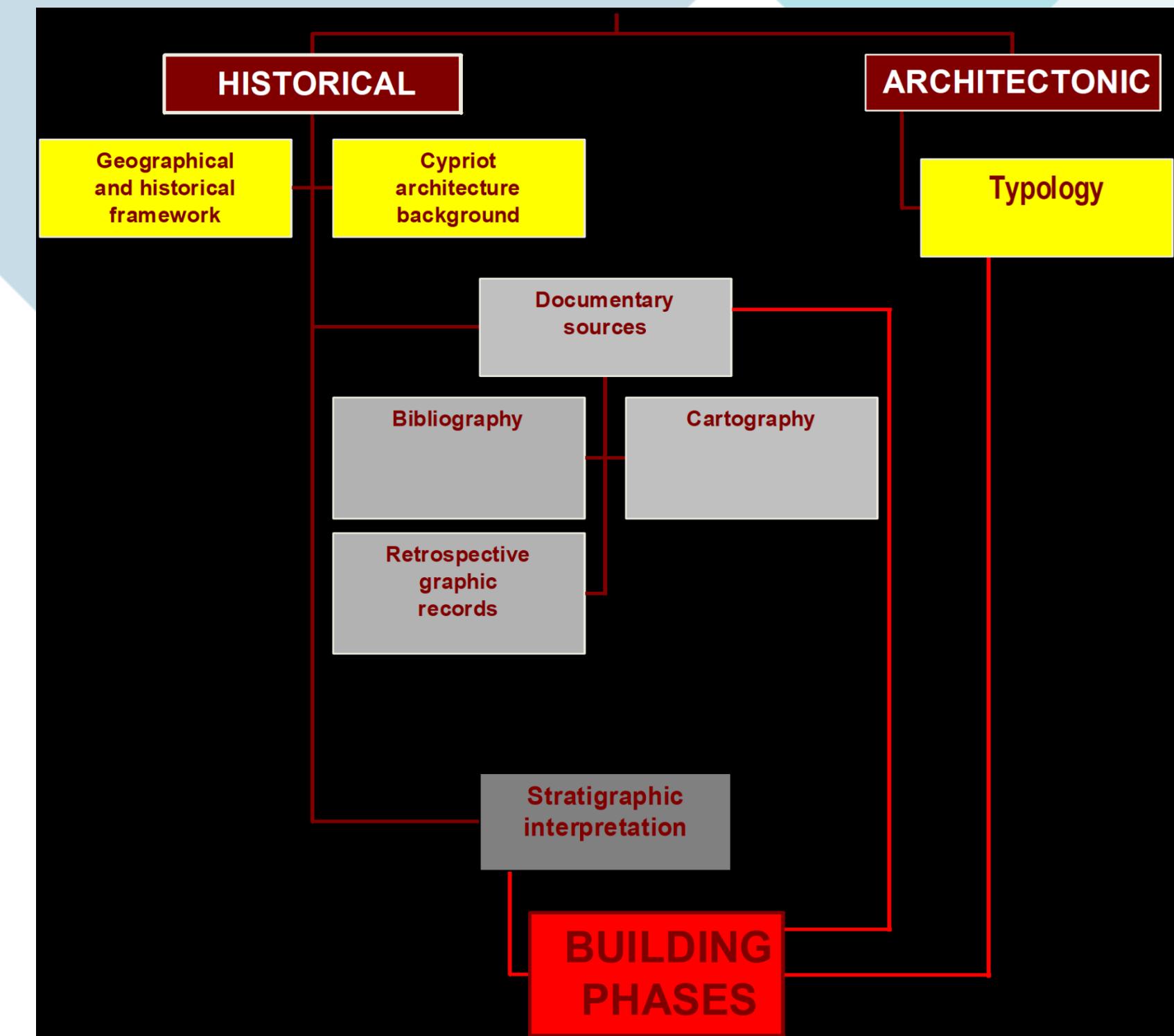
Systematic approach



Activities of the built analysis

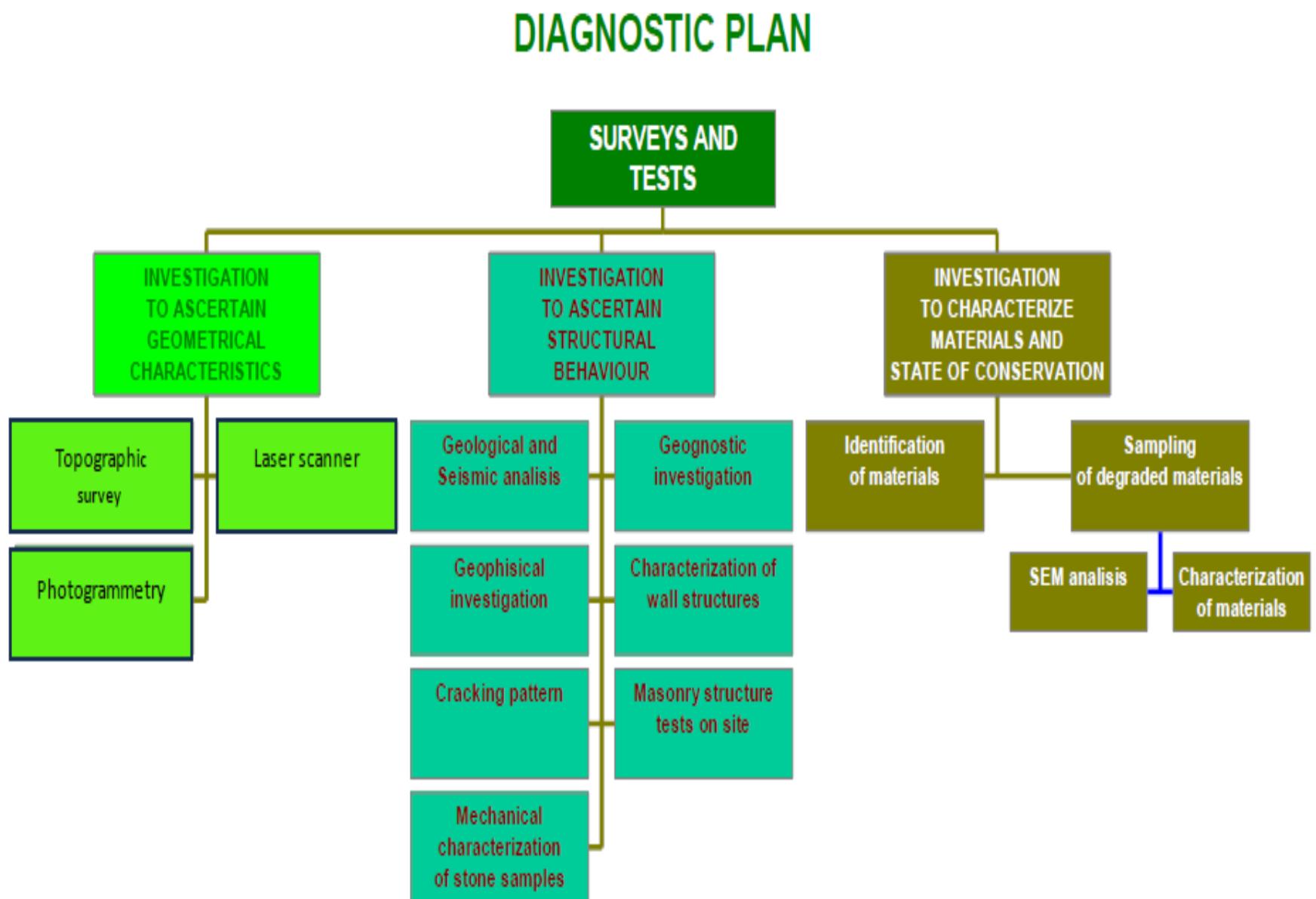
HISTORICAL - ARCHITECTURAL ANALYSIS

- Our team has started from years to develop the scientific methodology called "**built analysis**," in Italian "**analisi del costruito**" which is achieved through a detailed study that includes the examination of the building's historical, architectural, and structural characteristics
- **Historical and Documentary Study:** Before intervening on a historic building, all available information about its history, evolution, and transformations is gathered.
- **Architectural and Morphological Analysis:** The architectural features of the building are examined,.



Activities of the built analysis.

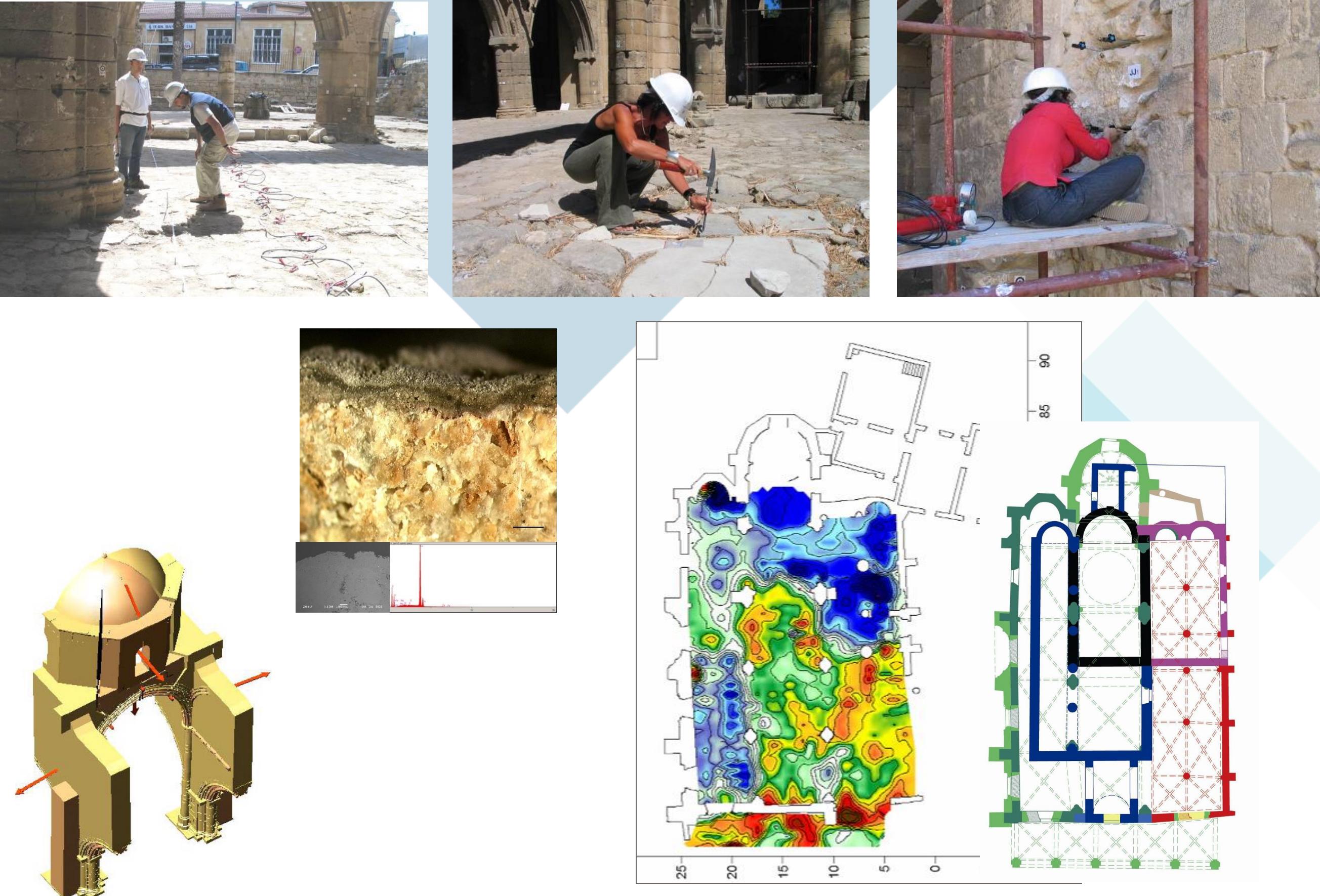
DIAGNOSTIC SURVEYS



- **Study of Materials and Construction Techniques:** A fundamental element of the analysis is the identification of the materials used and the original construction techniques.
- **Evaluation of the Conservation State:** The analysis must include a detailed assessment of the current state of the building, identifying any structural issues, damage caused by moisture, material degradation, and other pathologies.
- **A fundamental tool for addressing these two crucial issues in restoration is the planning of a program of diagnostic survey**

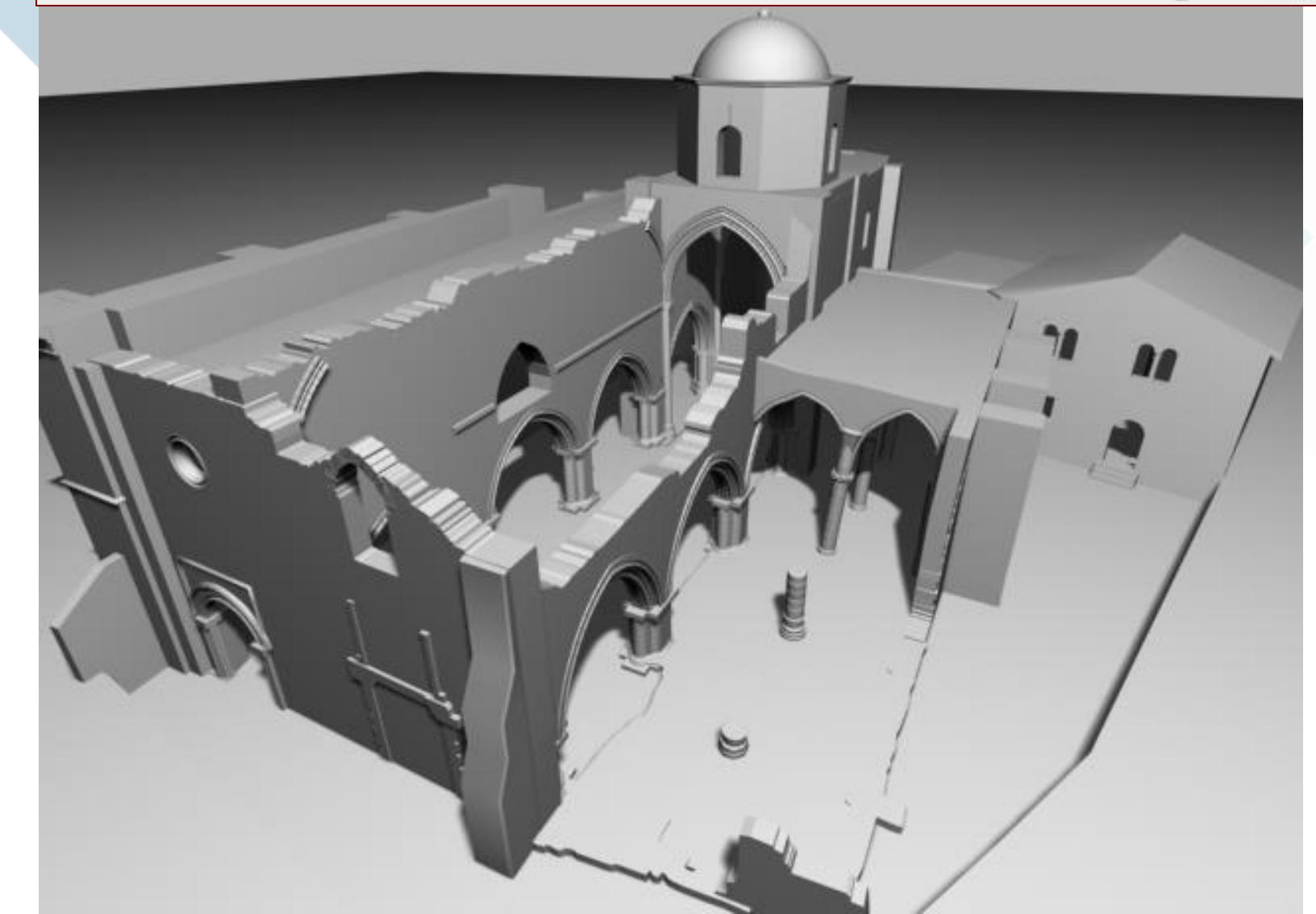
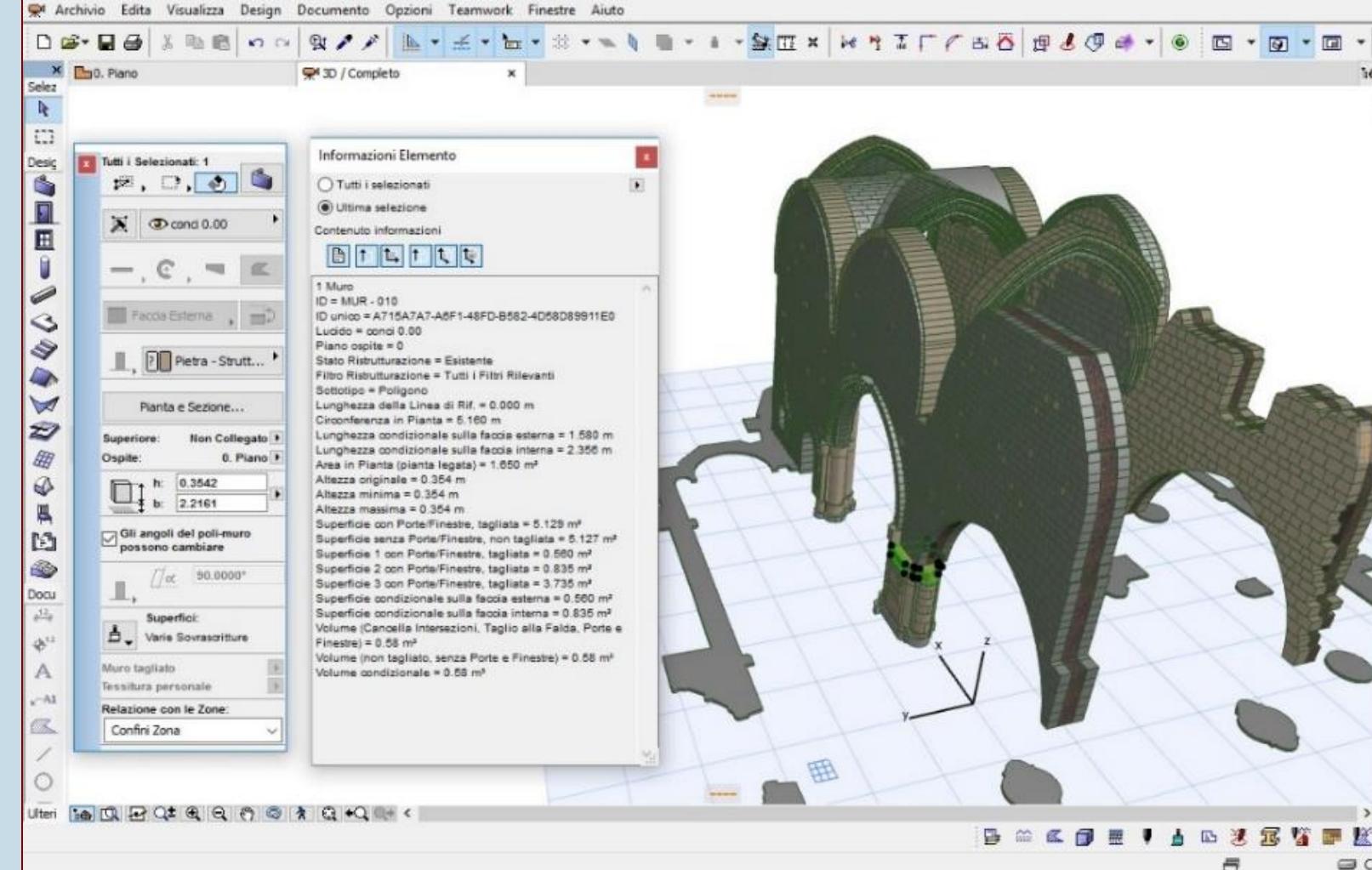
Coordinated approach of the built analysis

- Multidisciplinary collaboration,
- participation of experts and specialists,
- exchange and interpretation of complex information and data

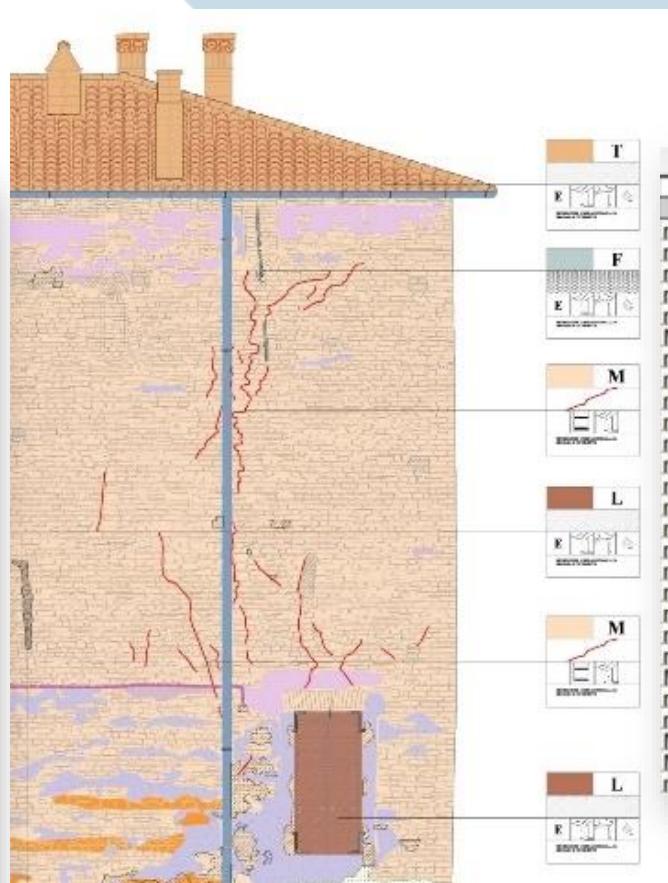


The Applications of BIM in cultural heritage

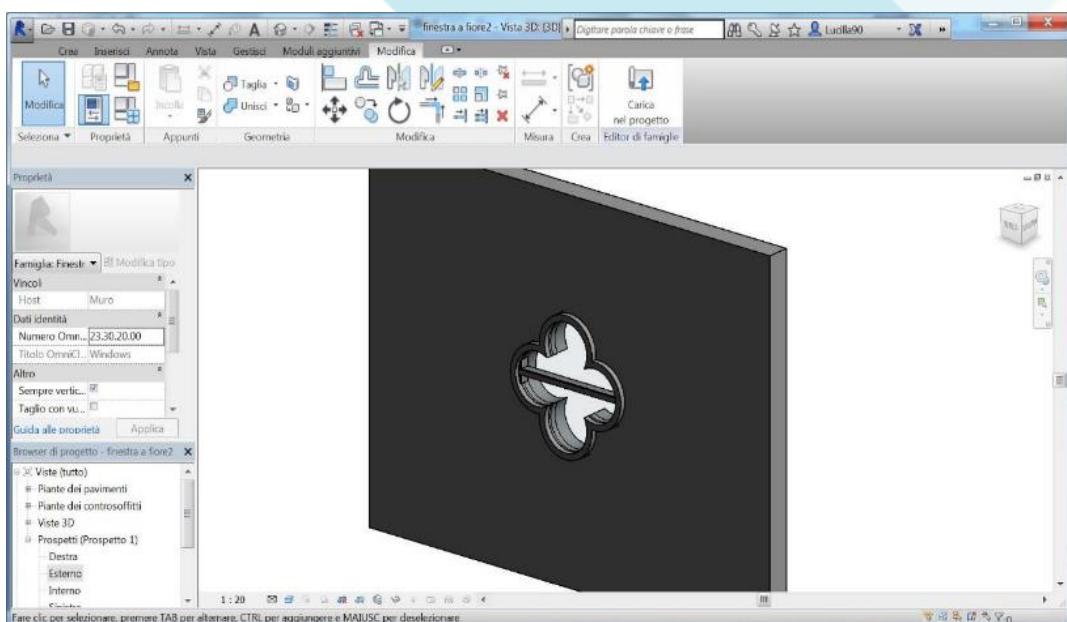
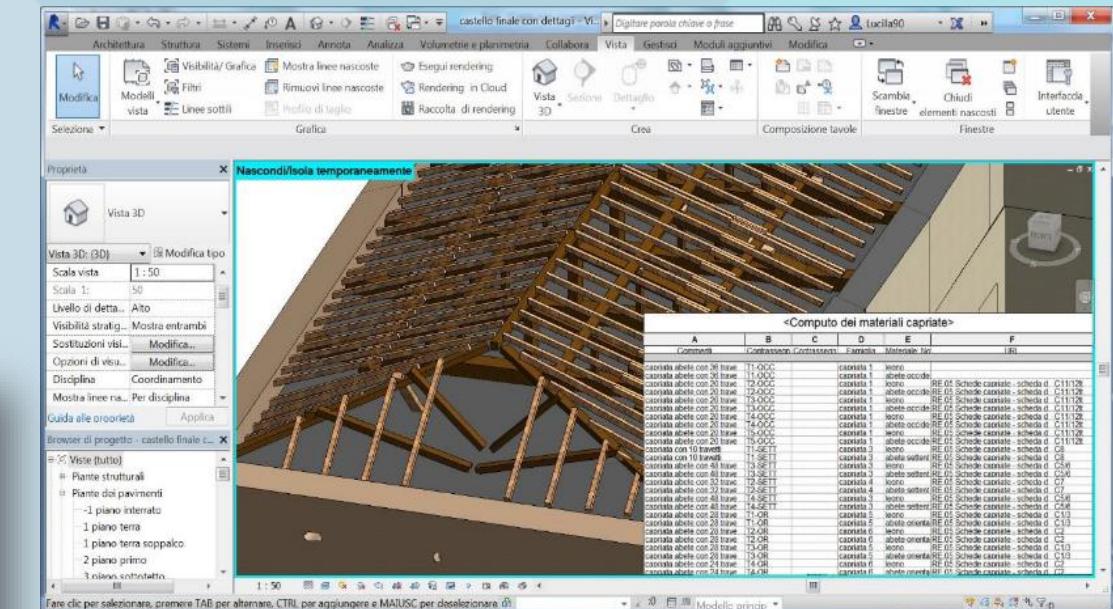
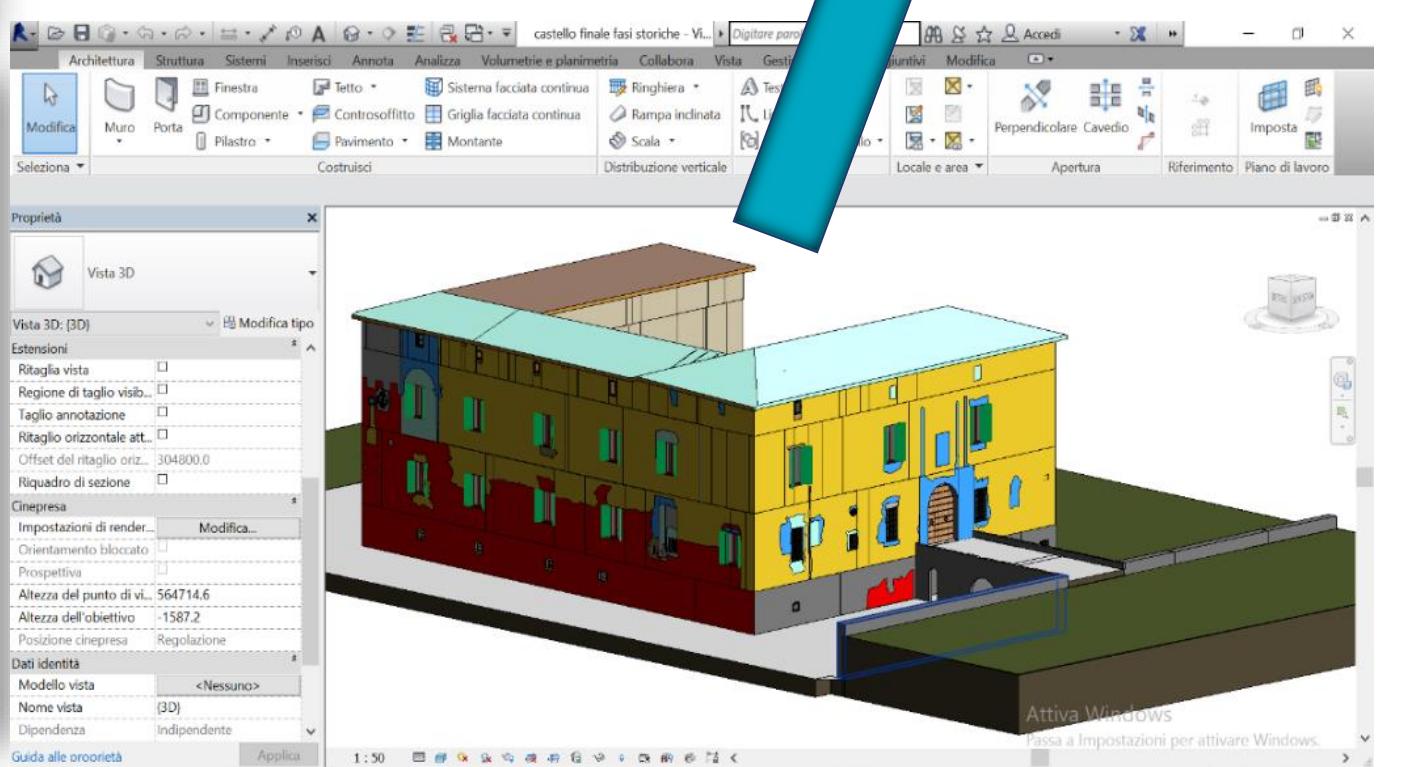
The problem of the heterogeneity and accessibility of the vast amount of knowledge produced by the conservation process and how to organize this data into an information system led us toward HBIM systems



TRANSITION TO BIM

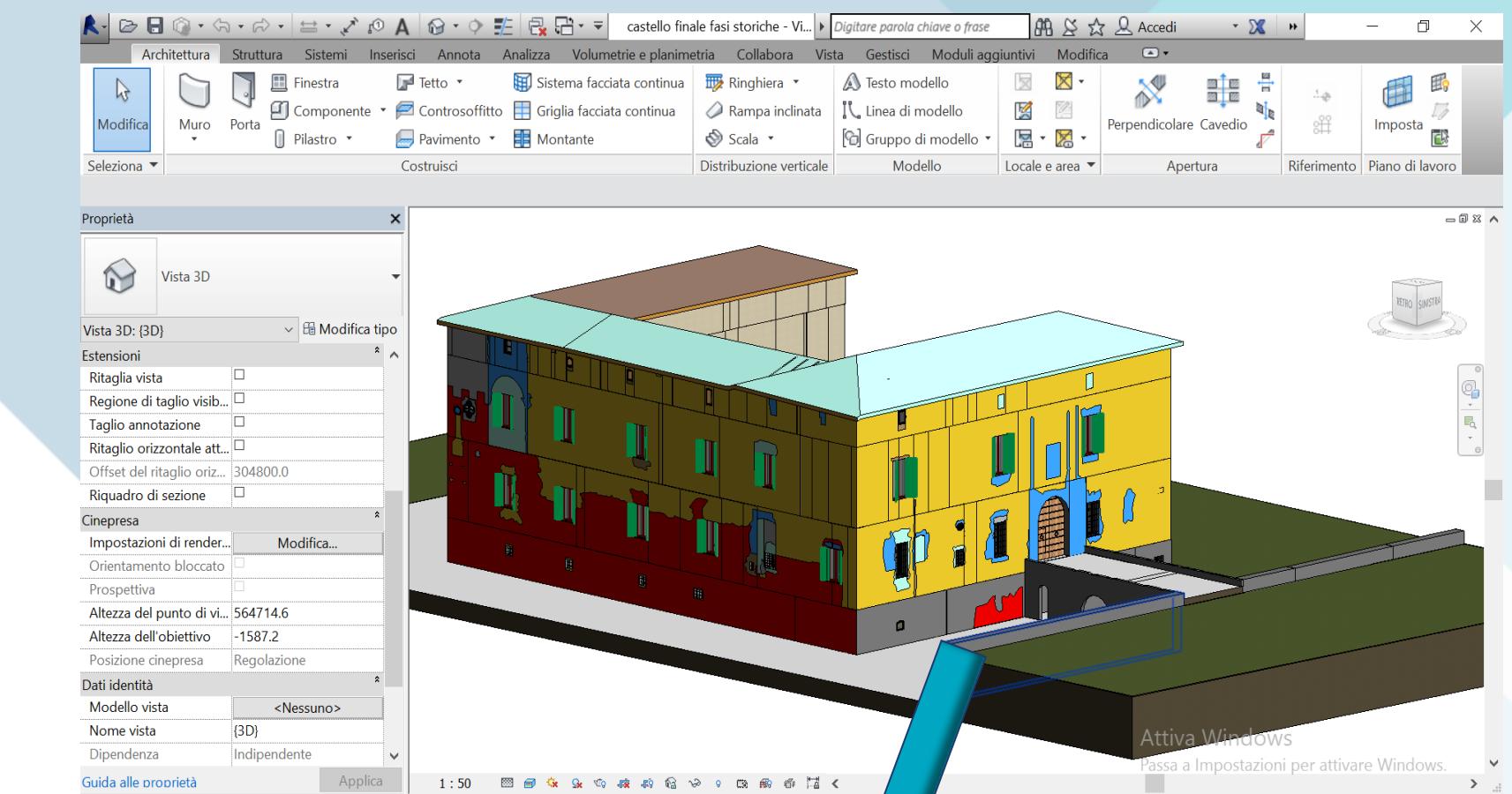


A	B	C
Materiale: Nome	Area	Materiale: Descrizione
mattone comune2	9 m ²	Mattone comune
muro-fase1nord	9 m ²	Fase storica 1 - XIV secol
mattone comune2	25 m ²	Mattone comune
mattone comune2	36 m ²	Mattone comune
muro-fase1ovest	36 m ²	Fase storica 1 - XIV secol
Muro di default	4 m ²	
mattone comune2	82 m ²	Mattone comune
mattone comune2	20 m ²	Mattone comune
mattone comune2	87 m ²	Mattone comune
muro-fase3nord	87 m ²	Fase storica 3 - XVII secol
muro-fase1nord	87 m ²	Fase storica 1 - XIV secol
mattone comune2	20 m ²	Mattone comune
mattone comune2	7 m ²	Mattone comune
mattone comune2	11 m ²	Mattone comune
mattone comune2	8 m ²	Mattone comune
mattone comune2	28 m ²	Mattone comune
mattone comune2	22 m ²	Mattone comune
mattone comune2	7 m ²	Mattone comune
mattone comune2	17 m ²	Mattone comune
mattone comune2	1 m ²	Mattone comune
mattone comune2	8 m ²	Mattone comune
Muro di default	55 m ²	
mattone comune2	17 m ²	Mattone comune
mattone comune2	5 m ²	Mattone comune
Muro di default	1 m ²	
Muro di default	2 m ²	
mattone comune2	3 m ²	Mattone comune

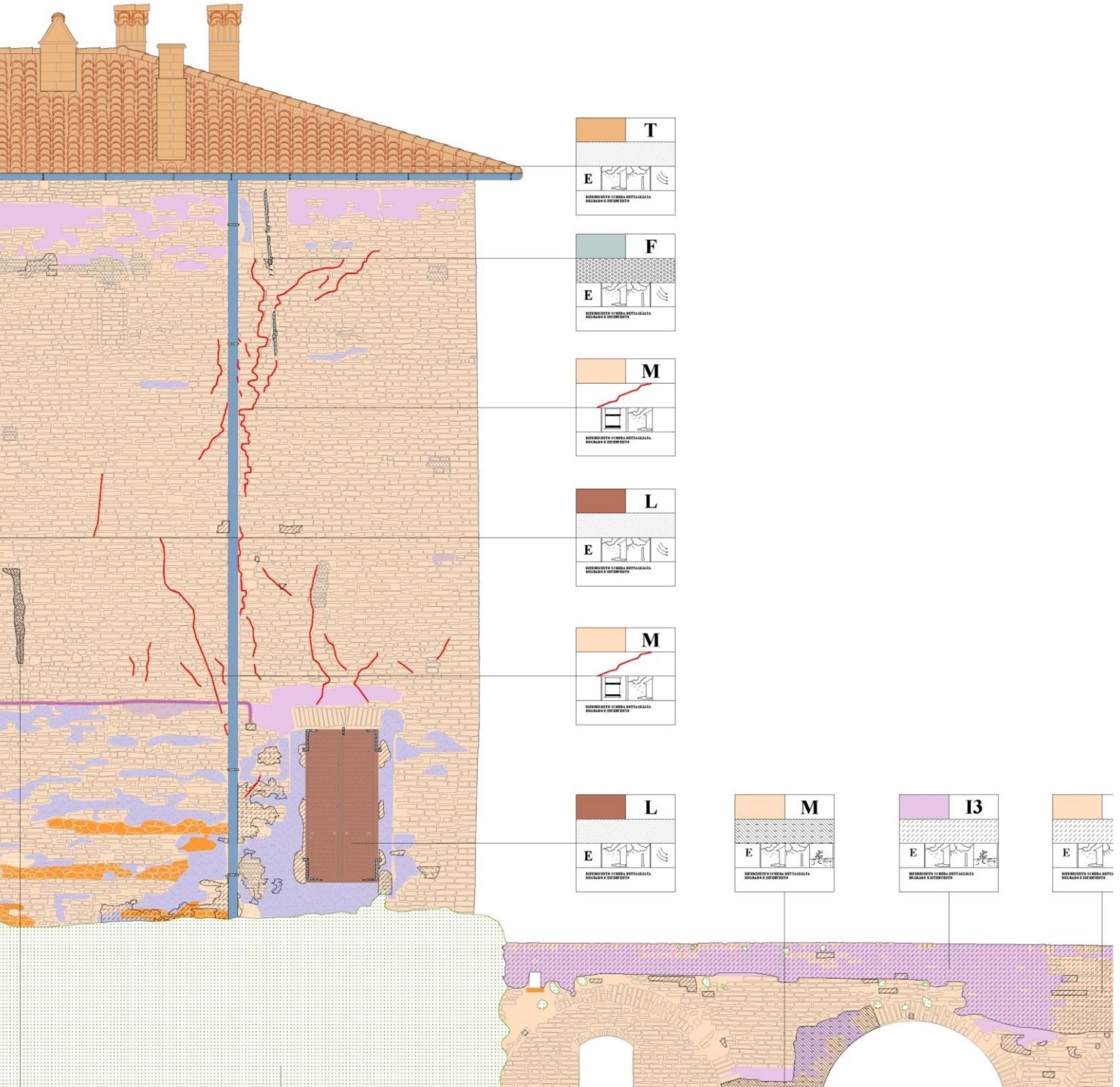


Information Modeling of Historical Analysis

FASE
1 - Fine XIV
2 - XVI
3 - XVII
4 - XVIII
5 - XIX
6 - XX - XXI



A	B	C		D	E	
Materiale	Nome	Area	Materiale	Descrizione	Commenti	URI
mattone comune2		9 m ²	Mattone comune			
muro-fase1nord		9 m ²	Fase storica 1 - XIV secol	Durante questa fase si costruisce l'avancorpo ana		
mattone comune2		25 m ²	Mattone comune			
mattone comune2		36 m ²	Mattone comune			
muro-fase1ovest		36 m ²	Fase storica 1 - XIV secol	Durante questa fase si costruisce l'avancorpo ana		
muro di default		4 m ²				
mattone comune2		82 m ²	Mattone comune			
mattone comune2		20 m ²	Mattone comune			
mattone comune2		87 m ²	Mattone comune			
muro-fase3nord		87 m ²	Fase storica 3 - XVII secol	Durante questa fase si costruiscono i muri del cast		
muro-fase1nord		87 m ²	Fase storica 1 - XIV secol	Durante questa fase si costruisce l'avancorpo ana		
mattone comune2		20 m ²	Mattone comune			
mattone comune2		7 m ²	Mattone comune			
mattone comune2		11 m ²	Mattone comune			
mattone comune2		8 m ²	Mattone comune			
mattone comune2		28 m ²	Mattone comune			
mattone comune2		22 m ²	Mattone comune			
mattone comune2		7 m ²	Mattone comune			
mattone comune2		17 m ²	Mattone comune			
mattone comune2		1 m ²	Mattone comune			
mattone comune2		8 m ²	Mattone comune			
Muro di default		55 m ²				
mattone comune2		17 m ²	Mattone comune			
mattone comune2		5 m ²	Mattone comune			
Muro di default		1 m ²	Mattone comune			
Muro di default		2 m ²	Mattone comune			
mattone comune2		3 m ²	Mattone comune			



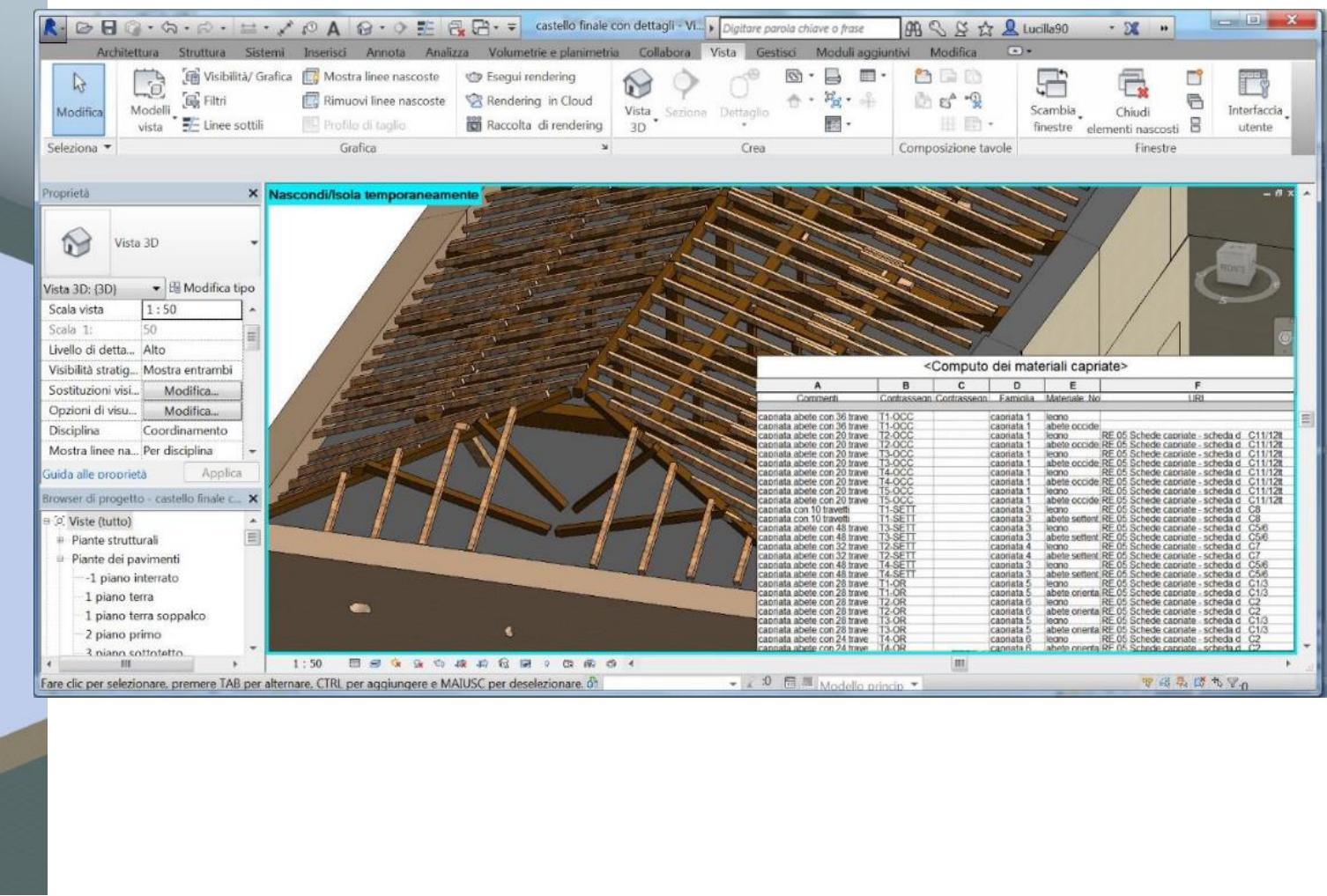
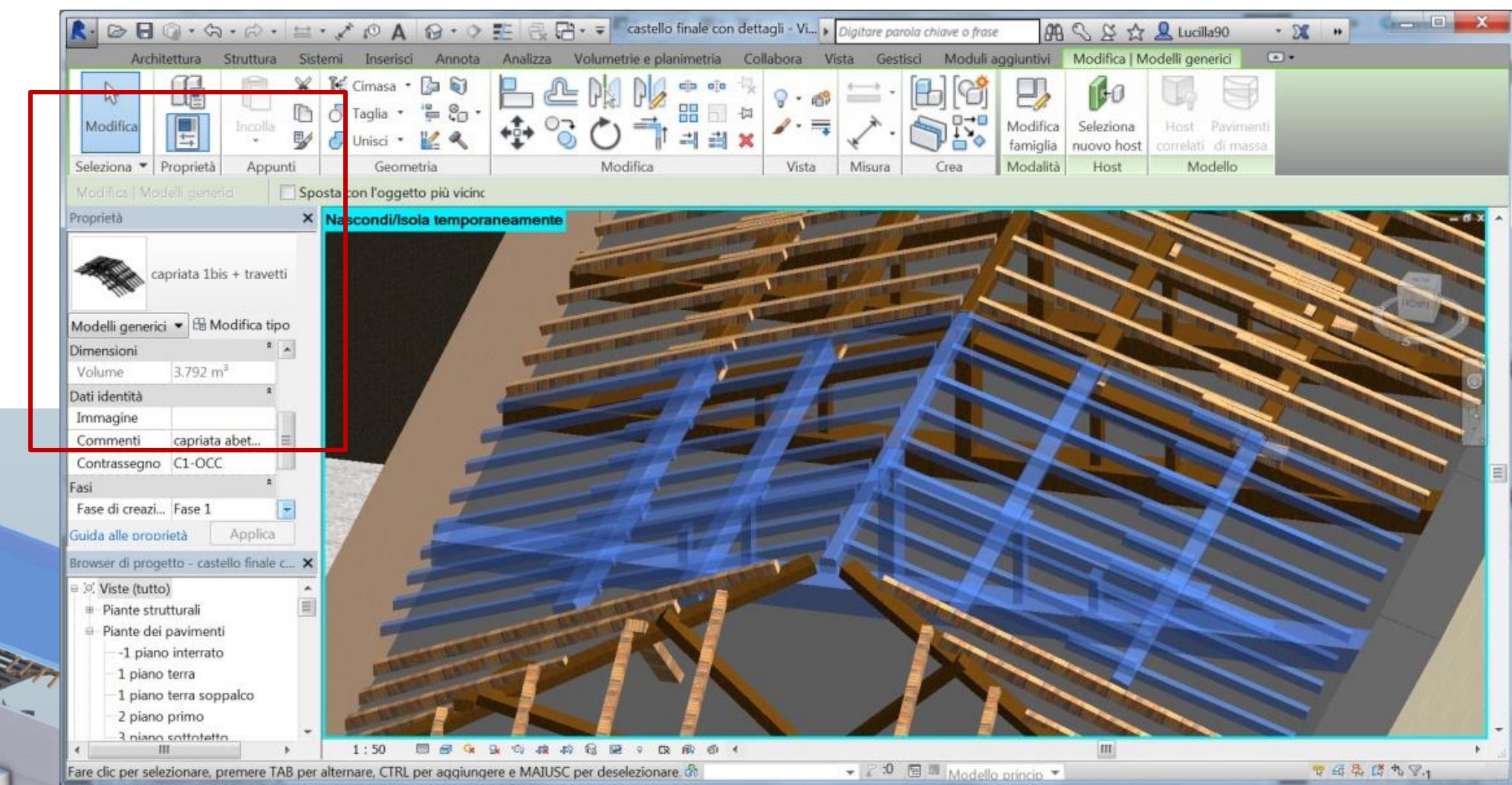
MATERIALI e ELEMENTI

	I1	Intonaco calce aerea		F	Ferro		N1	Elementi in cotto
	I2	Risarcitura intonaco in calce aerea		L	Legno		N2	Elementi ceramici
	I3	Residuo intonaco in calce aerea		D	Canali e discendenti		V1	Riempimento volta
	S	Stucco in malta di calce		P1	Pietra: Arenaria		E	Impianto tecnologico/canalizzazioni
	C	Risarcitura in malta cementizia		P2	Pietra: Granito		T1	Terra battuta
	T	Manto di copertura in coppi		P3	Pietra: Acciottolato		Q	Moquette
	V	Vetri		M	Muratura in mattoni		Dm	Dipinto murario

DEGRADO MACROSCOPICO

	Aggiunta impropria, degrado antropico e/o tecnologico		Disgregazione, Scagliatura, Polverizzazione		Macchie
	Alterazione cromatica		Erosione		Mancanza
	Colonizzazione biologica		Esfoliazione (PER ARENARIA)		Obsolescenza
	Deformazione/degrado meccanico		Efflorescenza		Ossidazione -corrosione del ferro
	Distacco		Fessurazione		Perdita cromatica
	Dilavamento		Frattura con perdita di materiale		Perdita di malta nei giunti
					Presenza di vegetazione superiore

CAUSE INTRINSECHE dovute alle caratteristiche chimico-fisiche dei materiali in opera				CAUSE ESTRINSECHE NATURALI			
	composizione chimica		struttura dei vuoti (pori e fratture)		proprietà meccaniche del cotto		proprietà meccaniche della ceramica
	proprietà meccaniche della muratura		proprietà meccaniche della pietra		proprietà meccaniche dell'intonaco		proprietà meccaniche del legno
	agenti biologici		proprietà meccaniche delle piante		accesso d'acqua		azione del vento
CAUSE ESTRINSECHE ANTROPICHE							oscillazione termica
	mancata manutenzione		deposito di materiali di varia natura				



SURVEY FOR THE KNOWLEDGE PROCESS OF EXISTING MASONRY STRUCTURES

02

Types and construction characteristics of masonry

The problem of identifying and representing the material and constructive characteristics of masonry within an HBIM system represents a complex challenge, due to several critical factors that influence the understanding of original construction techniques. These difficulties mainly arise from different causes.



Types and construction characteristics of masonry

1. VARIABILITY OF MATERIALS AND CONSTRUCTION TECHNIQUES

Ancient masonry, even within the same building, presents a great **variety of materials** (stone, bricks, lime, mortar, etc.) and **construction techniques**

2. COMPLEX GEOMETRIES

Historic masonry presents complex **geometric irregularities** due to structural modifications, deterioration, or construction errors.

MATERIALI	LAVORAZIONE	POSA IN OPERA	DIMENT.	DATAZ.
ARENARIA	CONCIO SQUADRATO	FILARI SFALZATI CON LETTO DI MALTA A GIUNTI ROTTIVI A 20x50	DA 10x50	XII SEC.
ARENARIA	CONCIO SGROSSATO	FILARI IRREGOLARI CON MALTA	15-30	XII-XIII SEC.
a. CIOTOLI b. RARI INSERTI DI MATTONE		MURATURA IRREGOLARE CON MALTA	15-25	XII-XIV SEC.
a. CIOTOLI b. INSERTI E FILARI DI MATTONE		MURATURA IRREGOLARE CON MALTA	20-25 31x5,5	XV SEC.
MATTONE	COTTURA	MURATURA REGOLARE A GIUNTI SFALZATI DI MALTA	31x5,5	XVI SEC.



Types and construction characteristics of masonry

3. LACK OF STANDARDIZATION.

One of the most significant issues in the HBIM field is **the lack of shared international standards** for the representation of historical masonry.

A potential solution lies in the development of **material libraries specific to heritage within HBIM software**, which take into account the characteristics of historical materials, including their variations over time. This is one of the objectives of the **ARCHETIPO Working Group**, launched by ISPC and BHILAB as part of the DARIAH infrastructure.

Historic period	Monument/ Date	Monument	Macroscopic figure	Microscopic figure
Prehistoric	Toumpa, Thessaloniki / 1200BC			
Hellenistic	Ancient theatre of Argos / 3rd cent. BC			
Roman	Galerius Palace / 3rd cent. AD			
Byzantine	Early Cristian Basilica C', Filippoi / 6th cent. AD			
Ottoman	Pazar Hamam, Thessaloniki 1500			
19 th -20 th century	Koligospita Zografou / 1845			
	Administrati n building o Allatini / 1879			

The Royal Site of Carditello

Methodology for studying the topic of masonry was addressed in a project developed with a thesis of the BIM Master's program at Sapienza University of Rome. The case study was **the Royal Site of Carditello**, also known as the Carditello Palace. This is a Bourbon residence built by Ferdinand IV in 1787, dedicated to hunting, the breeding of royal thoroughbred horses, and experimental agricultural production.



Fronte SE della Tenuta di Carditello



Fronte NO della Tenuta di Carditello



Vista Sud della Tenuta di Carditello



Dettaglio della soluzione angolare della facciata



Dettaglio della soluzione angolare della facciata



Vista Sud della facciata della Tenuta di Carditello



Dettaglio della facciata



Dettaglio della facciata



Dettaglio della facciata

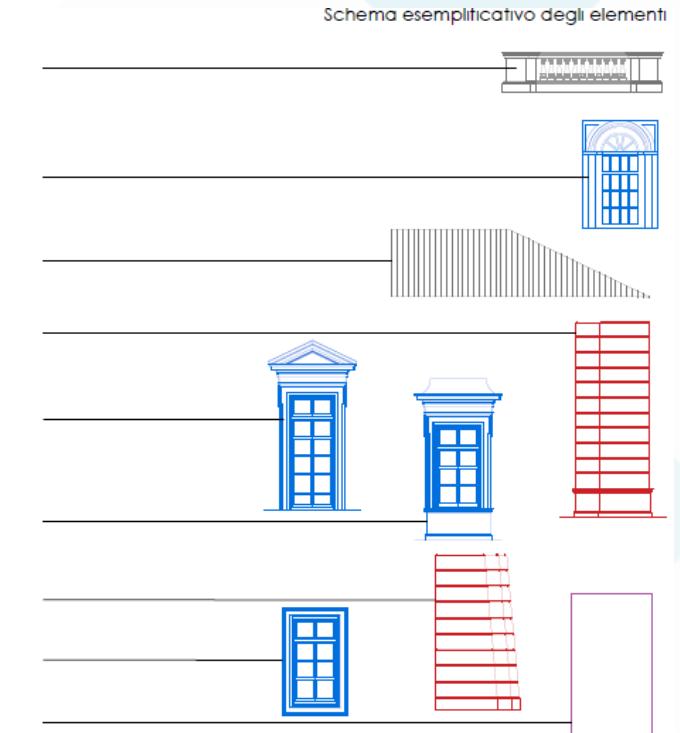
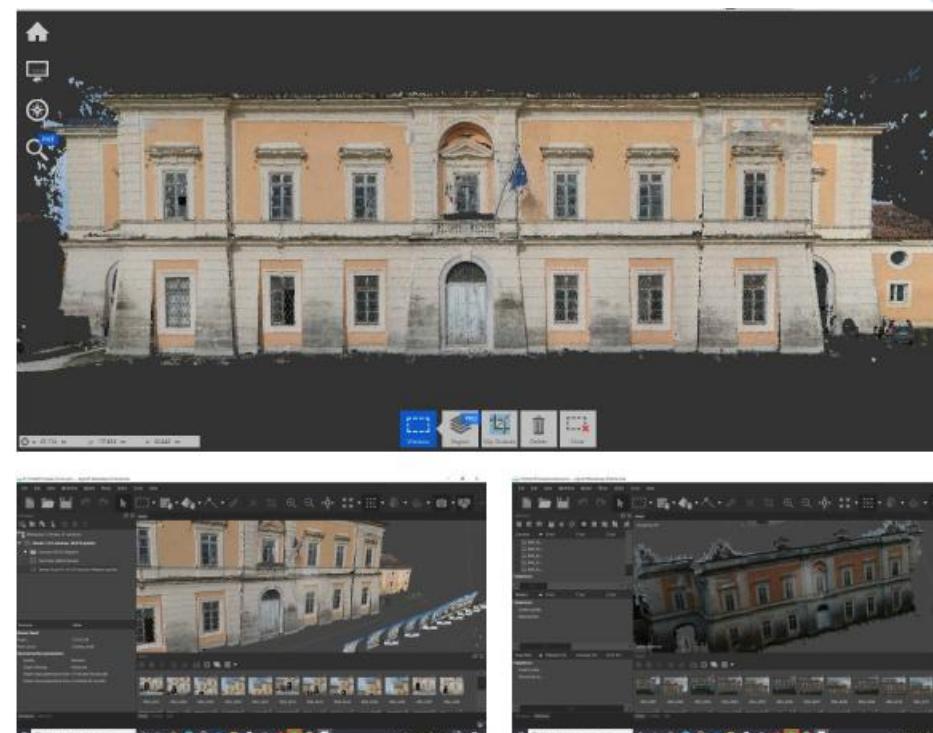


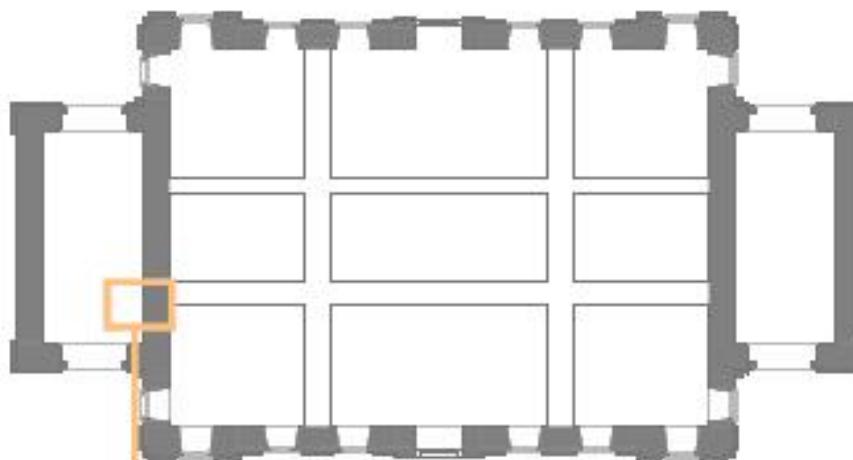
Dettaglio della finestra



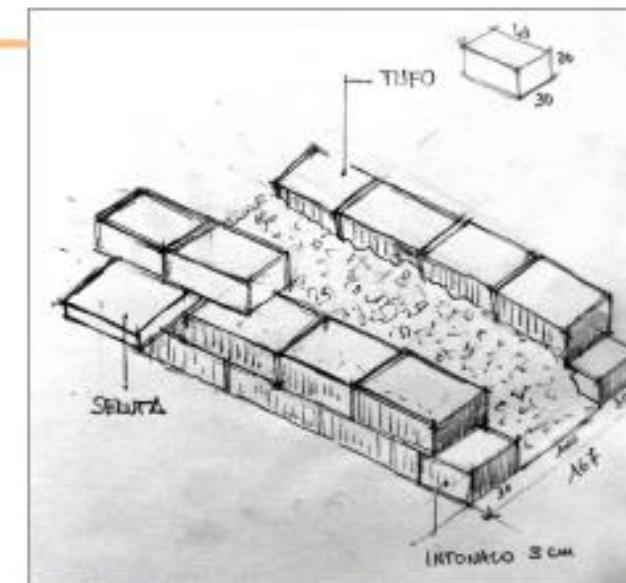
Dettaglio del portale di ingresso

The Royal Site of Carditello





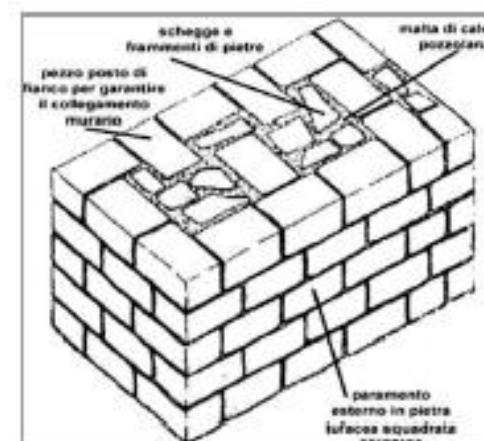
Appunti di sopralluogo
(fonte: ISPC)



Attraverso l'osservazione di alcune porzioni di muratura, prive dello strato di finitura esterno, è stato possibile verificare la presenza di paramento murario in tufo e nucleo interno. La muratura a sacco, presente nel corpo centrale della reggia, è utilizzata anche in altri fabbricati del complesso attualmente in stato di rudere.

METODOLOGIA DI MODELLAZIONE: FAMIGLIE MURI E LESESE

- 1 - Individuazione degli elementi costitutivi la muratura attraverso l'analisi della documentazione fotografica (ove disponibile) e la consultazione della letteratura sulle tecniche costruttive nel napoletano.
- 2 - Realizzazione di famiglie di sistema: i vari strati del muro vengono definiti dal punto di vista metrico e materico

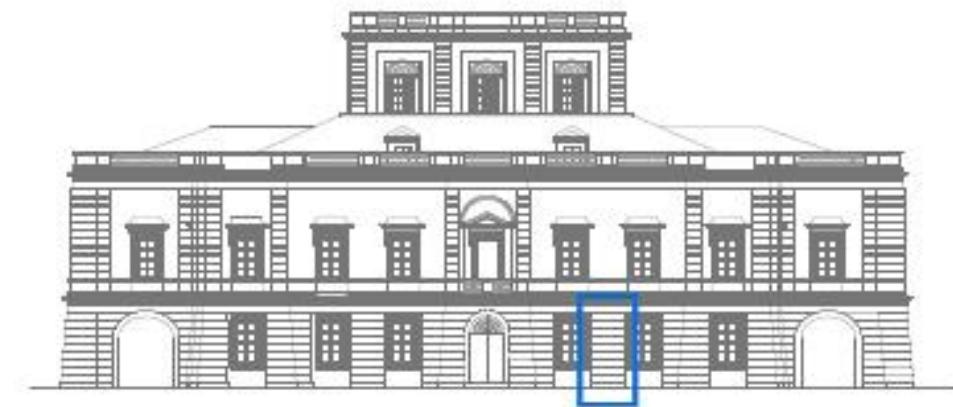


Muratura di tufo con organizzazione a sacco (tratto da A. Aveta, Materiali e Tecniche Tradizionali nel napoletano, 1987)

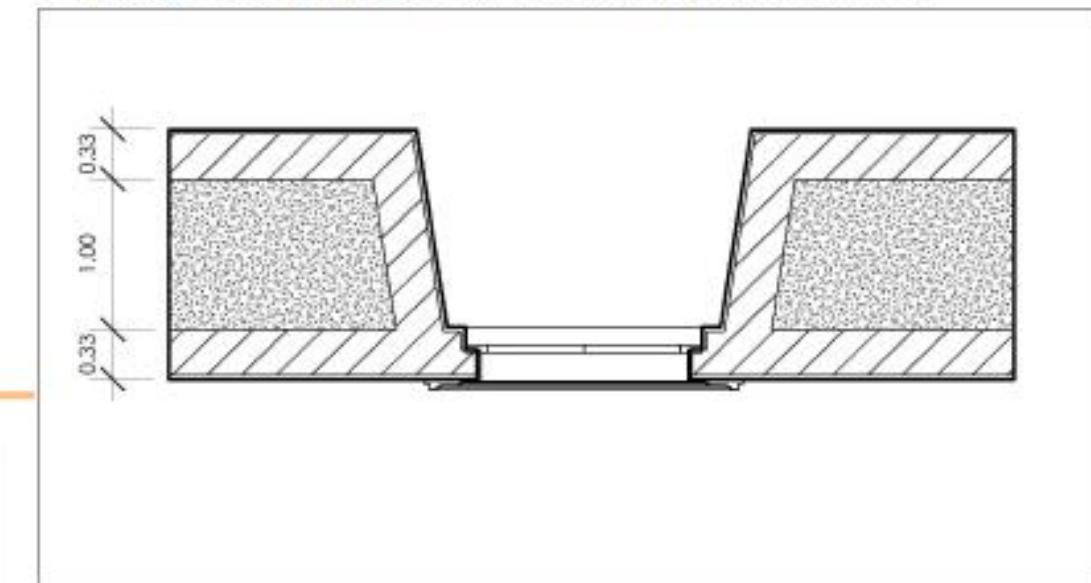
Function	Material	Thickness	Wrap	Structural Material
1. Finish 1 [4]	CA_RIL_Rivestimento intonac	0.0300	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2. Core Boundary	Layers Above Wrap	0.0000	<input type="checkbox"/>	<input type="checkbox"/>
3. Substrate [2]	CA_TUF_Mattoni di tufo	0.1000	<input type="checkbox"/>	<input type="checkbox"/>
4. Structure [1]	CA_CON_Riempiimento cong	1.0000	<input type="checkbox"/>	<input type="checkbox"/>
5. Core Boundary	Layers Below Wrap	0.0000	<input type="checkbox"/>	<input type="checkbox"/>
6. Structure [1]	CA_TUF_Mattoni di tufo	0.3000	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
7. Finish 1 [4]	CA_RIL_Rivestimento intonac	0.0300	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Dati editabili_Stratigrafia

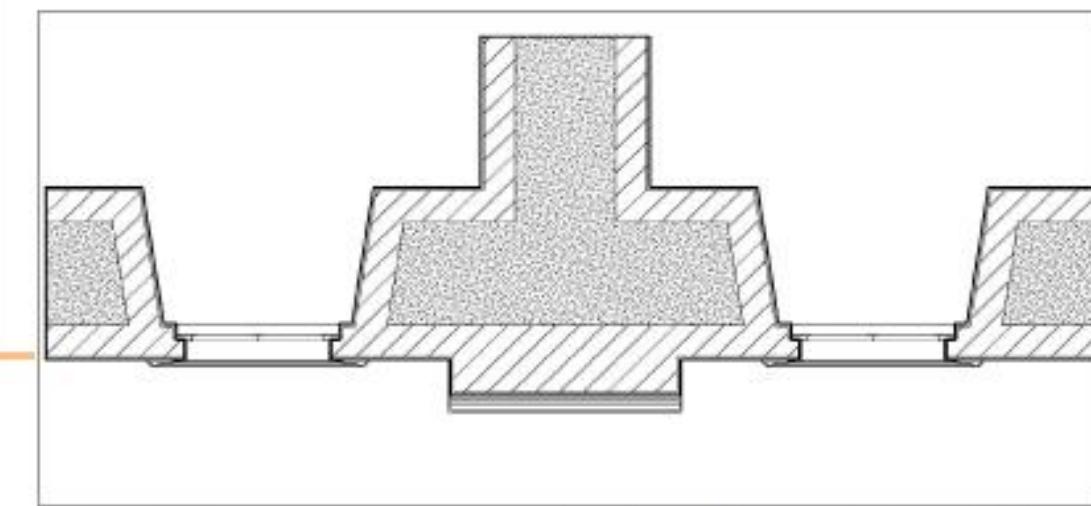
1. strato di finitura esterno
2. strato di elementi in tufo
3. conglomerato
4. strato di elementi in tufo
5. strato di finitura interno



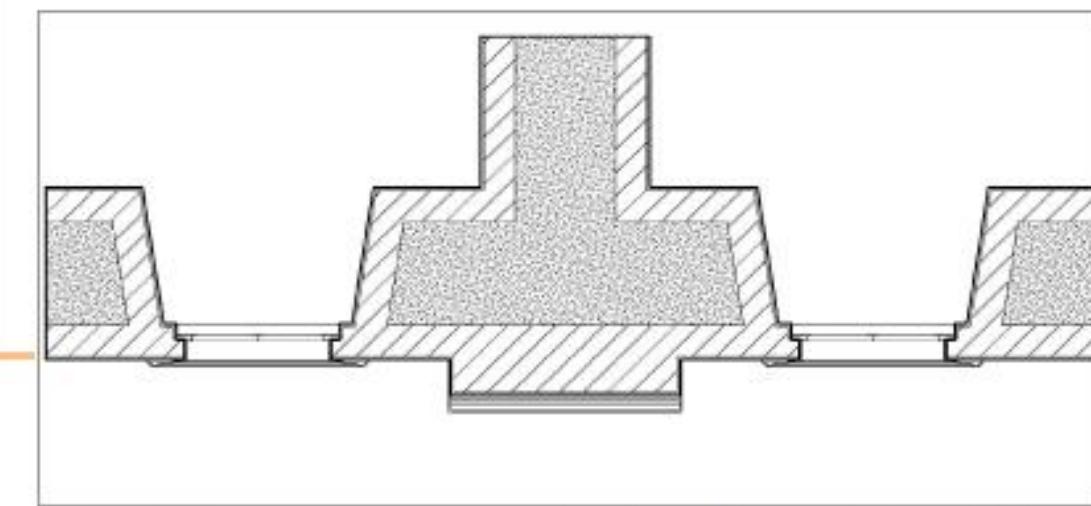
La famiglia è stata personalizzata nel seguente modo:



Famiglia Muri



Famiglia Lesene



La scelta di utilizzare la famiglia "Lesene" per la modellazione del contrafforte ha permesso di **associare automaticamente** a quest'ultimo il materiale del muro esterno a cui, nella realtà, l'elemento architettonico è molto probabilmente ammorsato.

RECURRING ISSUES IN REPRESENTING ANCIENT MASONRY

For the representation of ancient masonry in the study of the Carditello site, as in many cases, we encountered the following problems:

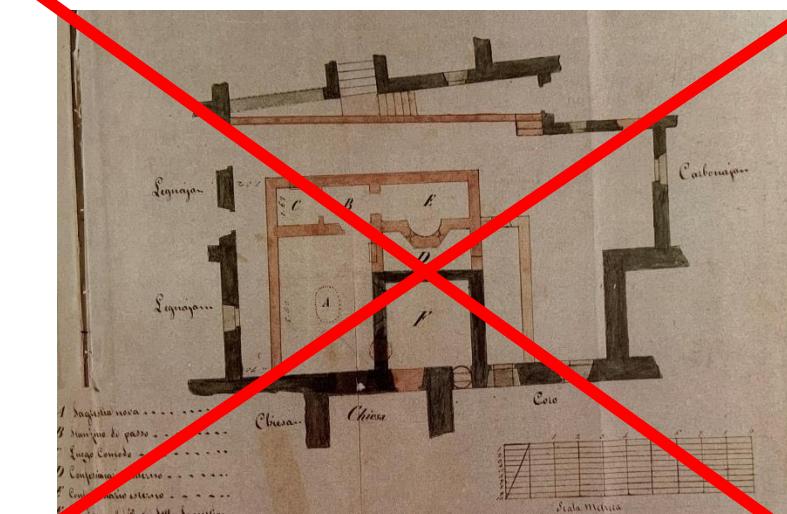
- **PROBLEMS OF ACCESSIBILITY AND PLASTER**

The presence of plaster on masonry surfaces represents an additional obstacle, as it covers and hides the historical layers of the masonry and the complexity of the construction techniques.



- **GAPS IN HISTORICAL DOCUMENTATION**

In many cases, information on the original designs and subsequent interventions is missing or incomplete. The lack of historical documents also makes it difficult to understand the evolution of the building and its functions over time.

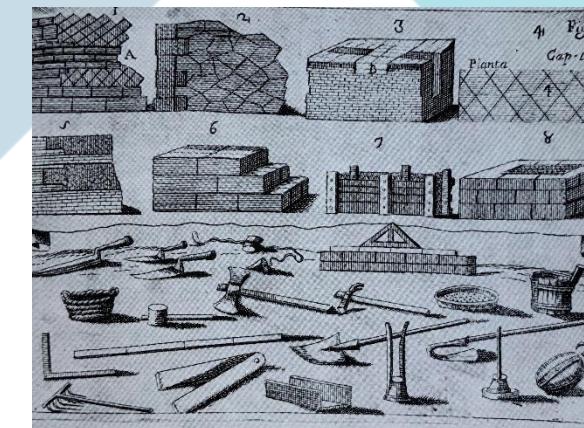


POTENTIAL SOLUTIONS

To address the challenges posed by incomplete and non-visible data, several investigative actions has been suggested, to be integrated into a systematic approach:

- **CONSULTATION OF HISTORICAL LITERATURE AND MANUALS**

These documents provide explanations of masonry techniques



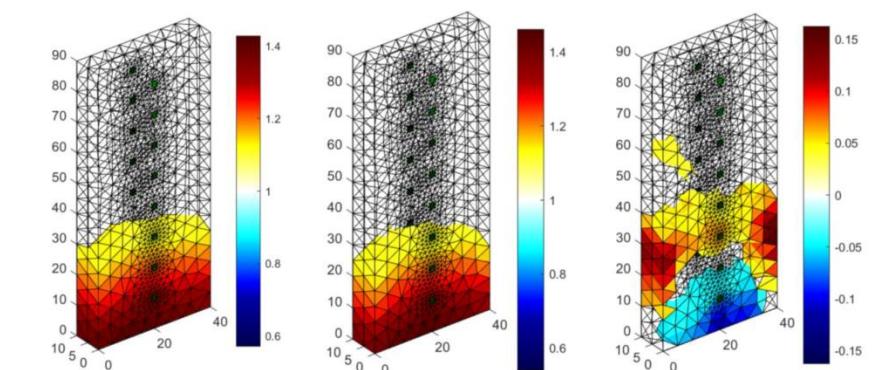
- **SURVEY OF EXPOSED MASONRY PARTS**

Uncovered or open portions of masonry, often resulting from earthquakes or prolonged degradation, as opportunity to identify ancient construction techniques

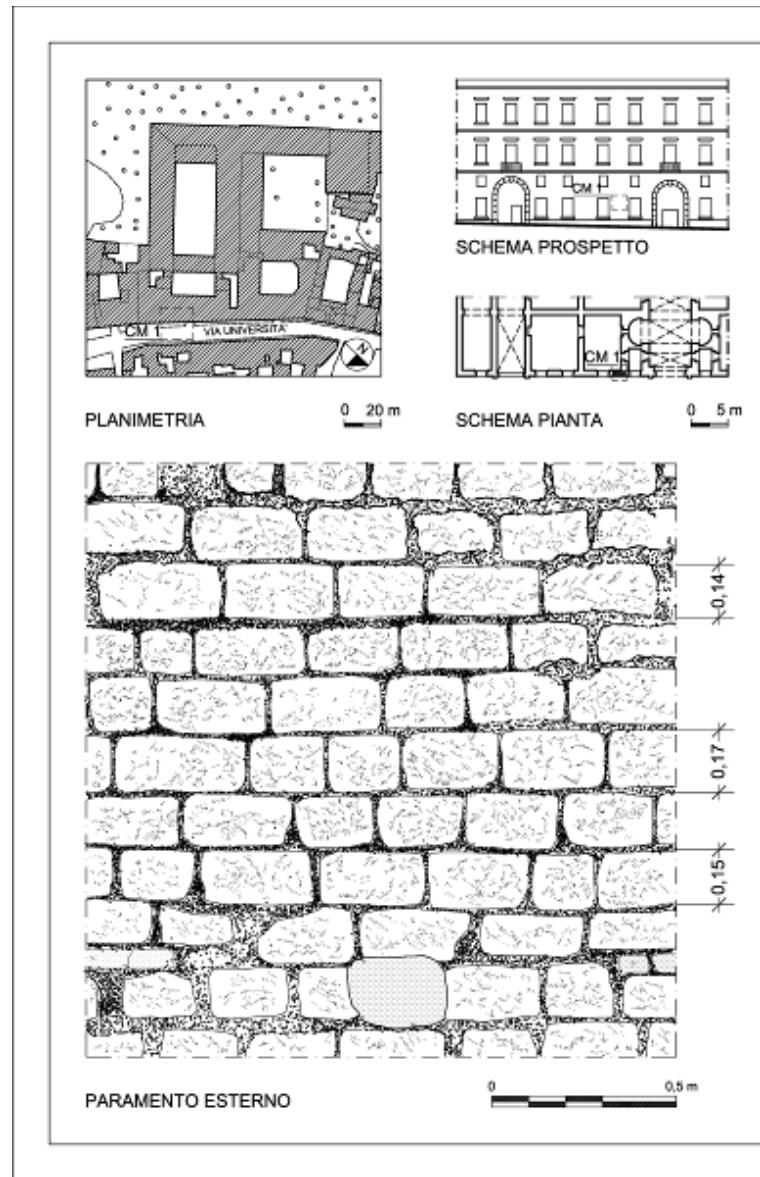


- **INTEGRATED SURVEY TECHNIQUES**

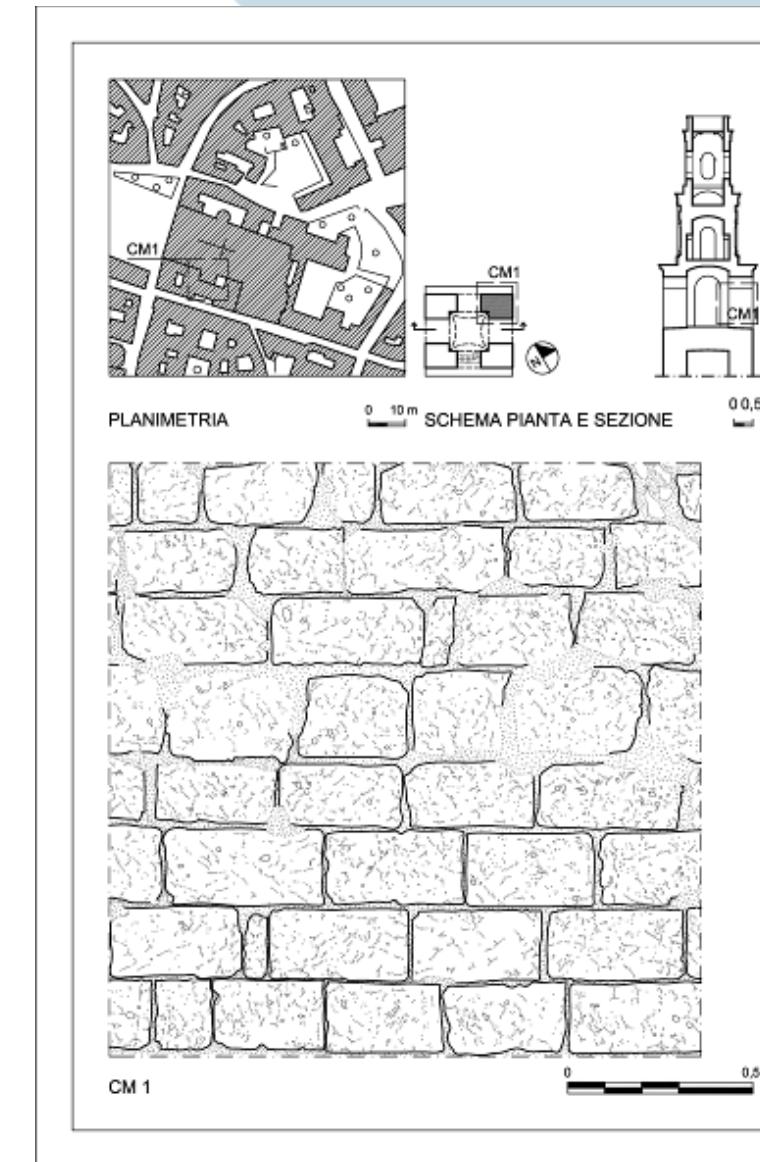
Combined use of photogrammetry, laser scanning, and geophysical surveys can provide accurate data that, once interpreted, can be incorporated into the HBIM model



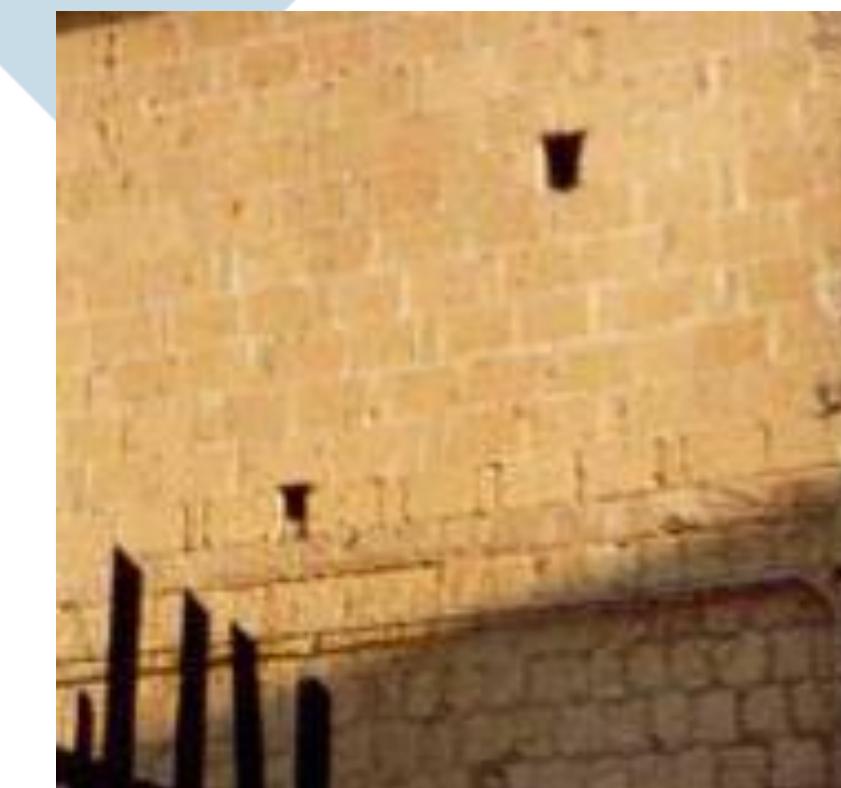
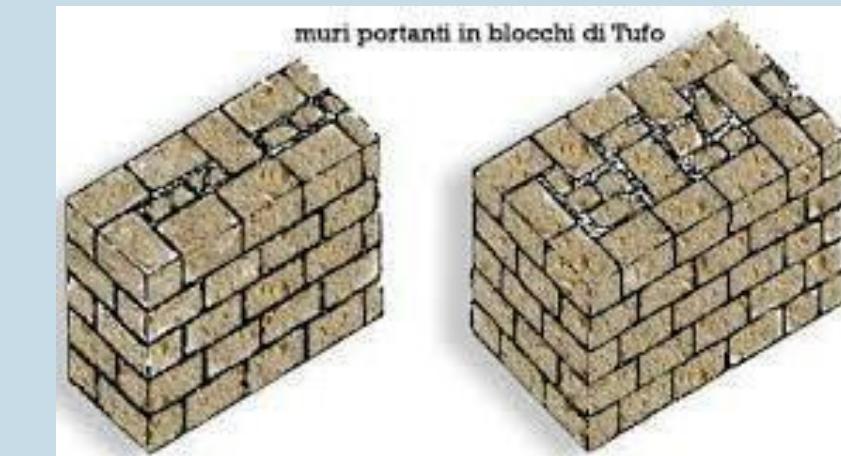
1. CONSULTATION OF HISTORICAL LITERATURE AND MANUALS



Portici (NA), Mascambruno Palace, 'bozzette' masonry (13-17 cm x 20-26 and 30-36 cm) (mid-18th century). There are 'spaccatelle' arranged alternately in the flat and edge orientations.



Nola (NA), cathedral, bell tower, ashlar masonry 16-20 x 32-40 cm (1806)



Tuff masonry "a sacco"

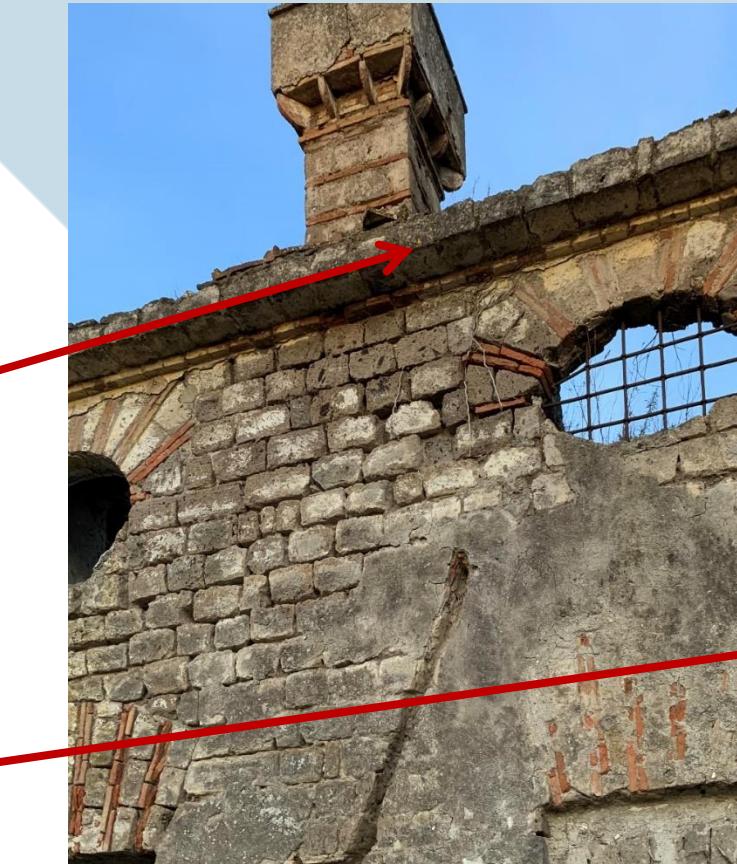
2. SURVEY OF EXPOSED MASONRY PARTS

- Some unrestored buildings provide a detailed view of the construction methodologies used



Carditello: rear service buildings, not restored

2. CARDITELLO : SURVEY OF EXPOSED MASONRY PARTS



Tuff bracket for cornice support



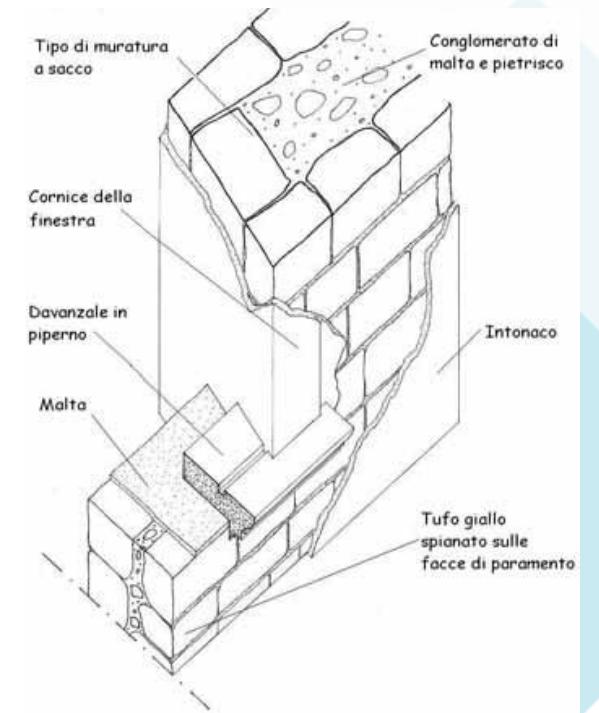
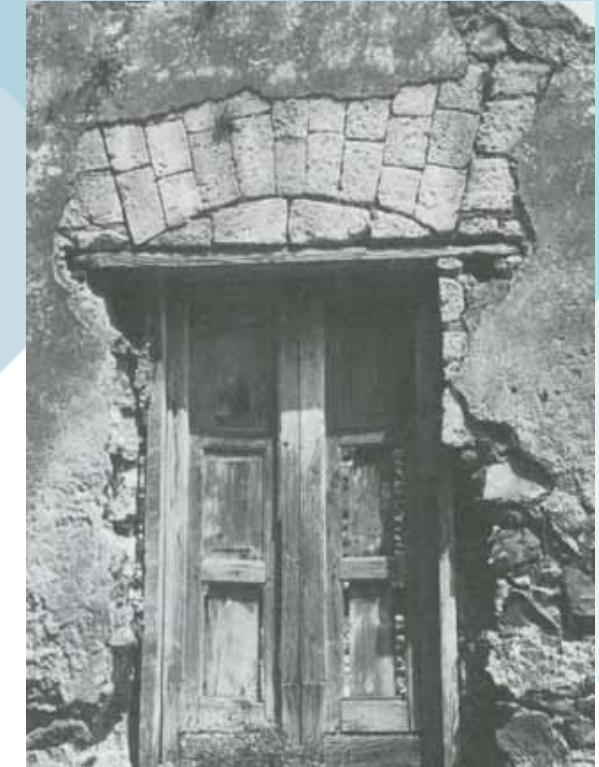
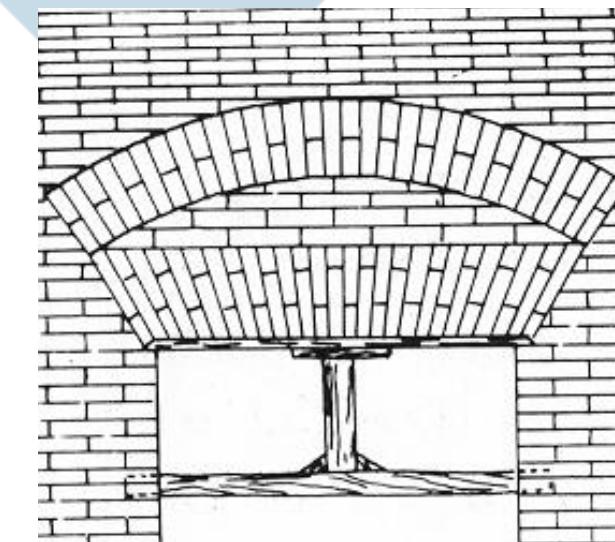
Cornerstone with buttress

Jack arch in tuff oblique ashlars and bricks

Construction techniques

Carlo Sartori
Conservazione e restauro
di edifici storici

Flat arch of the
openings at Carditello



Traditional construction techniques

Construction techniques

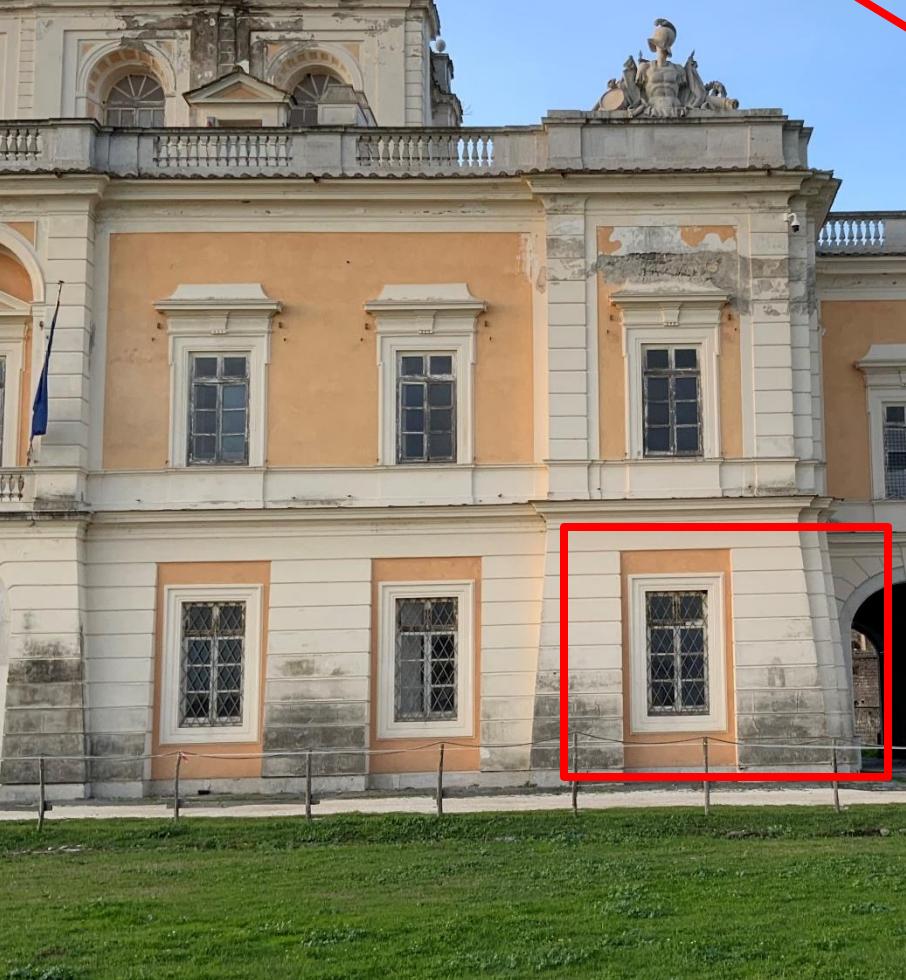
The corner and details of the materials and techniques of the masonry



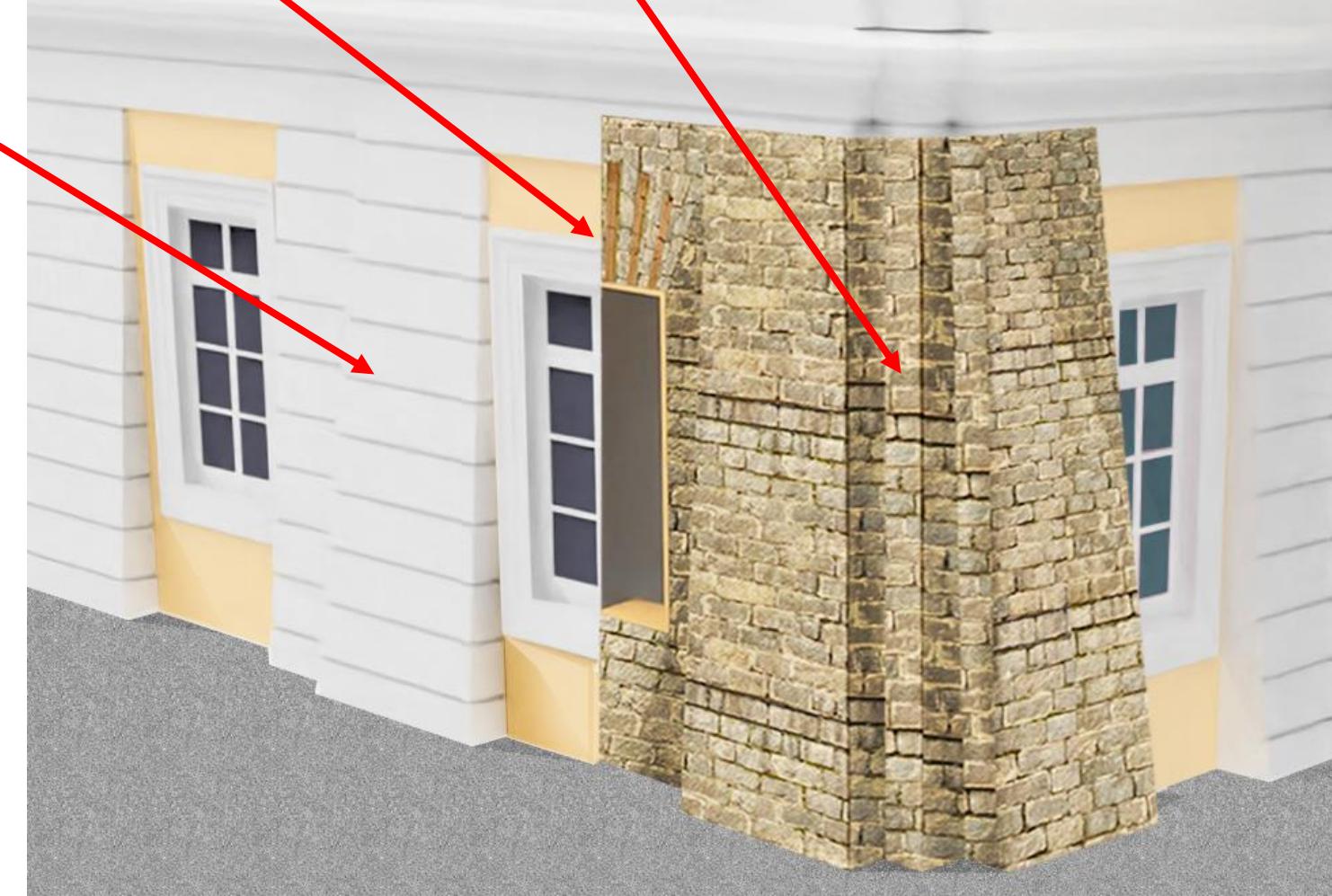
Construction techniques

Insert your long title here

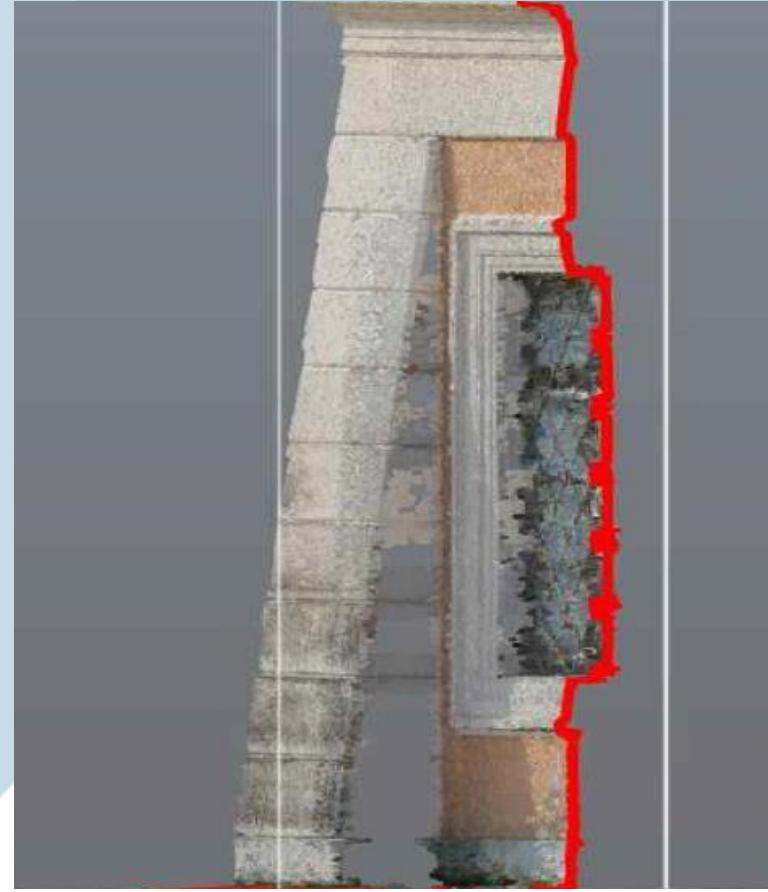
Finish with plaster, worked in strips, in lime and sand mortar



Flat arch of tuff and bricks

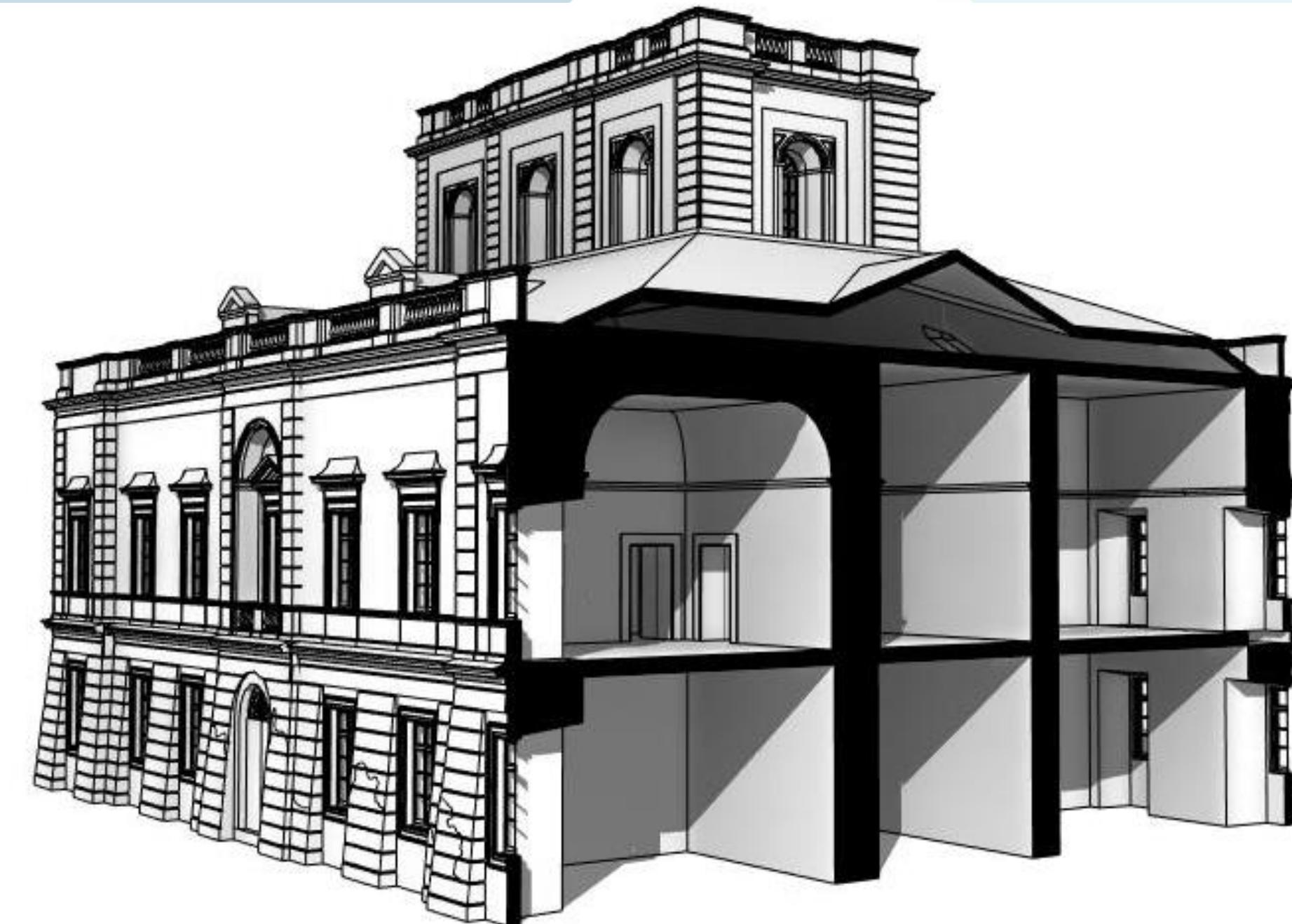
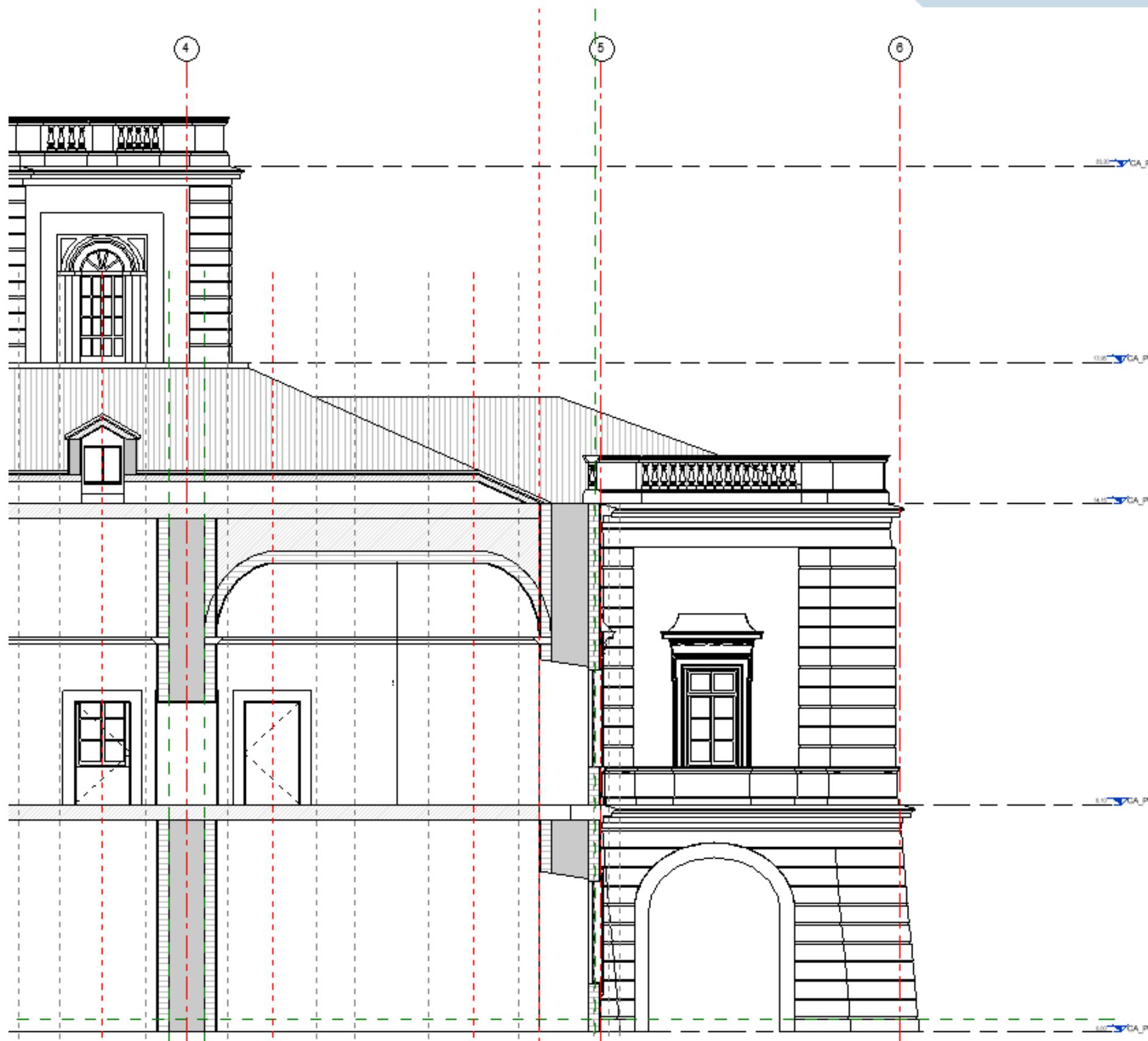


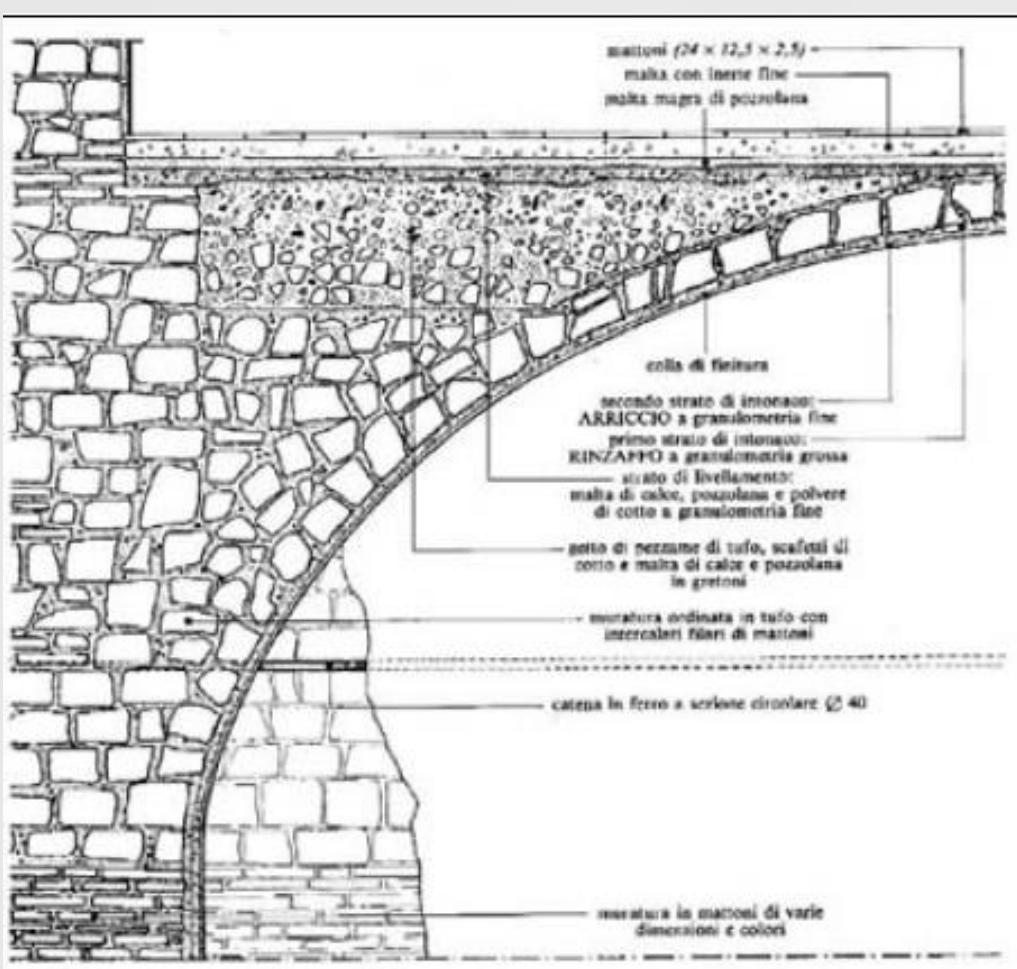
Cornerstone with buttress



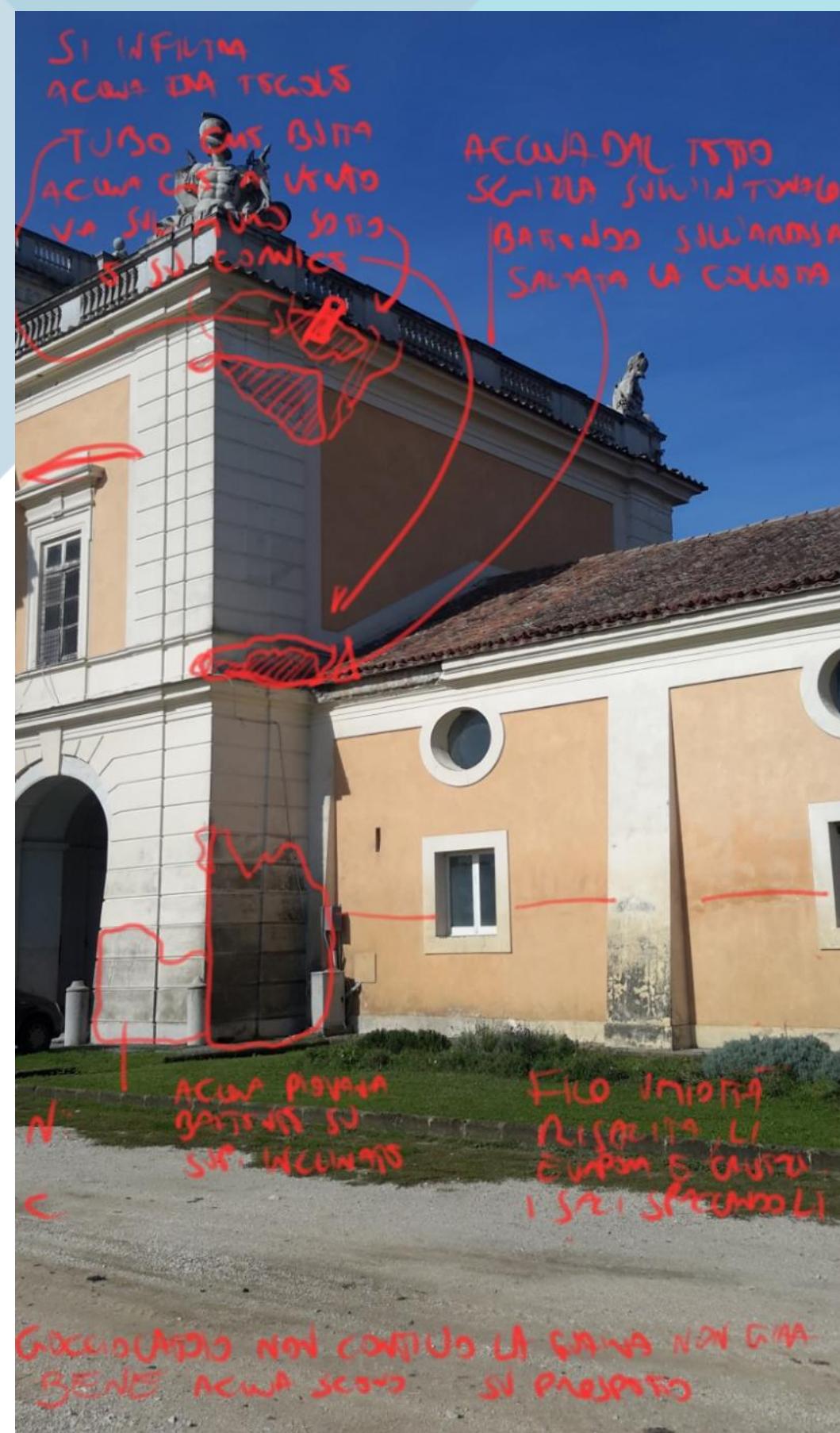
Construction techniques

Barrel and Pavilion vaults



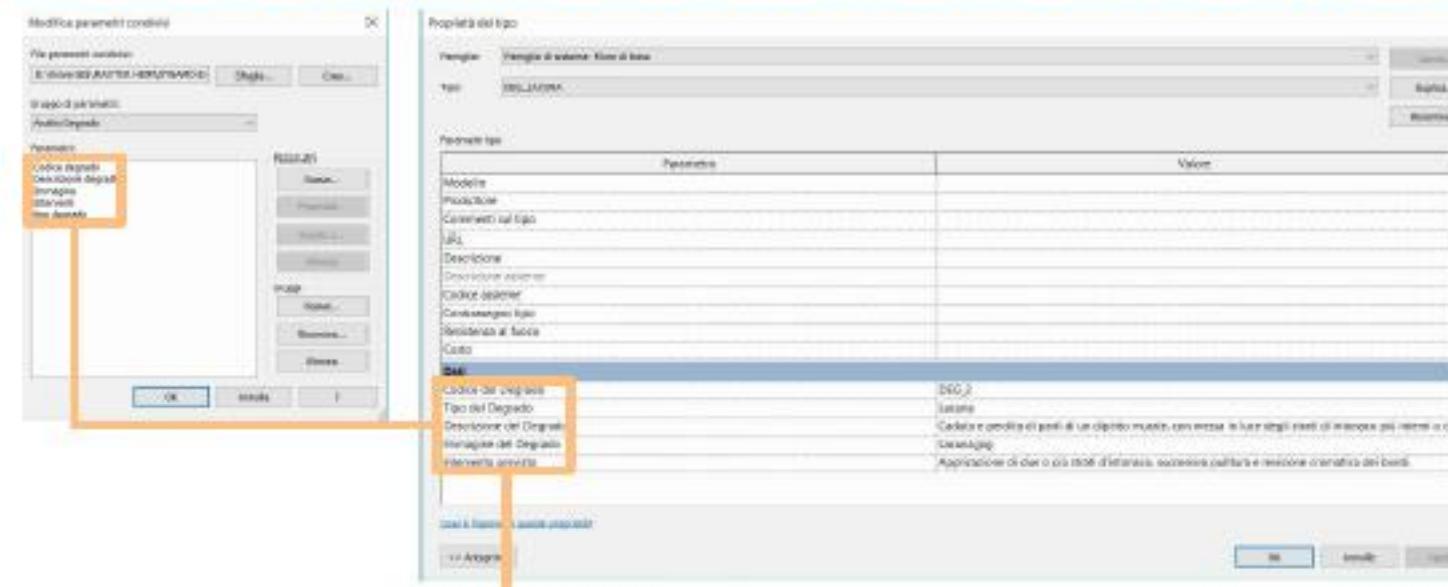


DETERIORATION ANALYSIS



RAPPRESENTAZIONE DEL DEGRADO NEL MODELLO BIM

L'analisi del degrado è stata effettuata individuando principalmente 4 patologie presenti sul fronte SE: presenza di muffe, lacuna, mancanza e vegetazione. E' bene sottolineare che l'elaborato mira ad esemplificare il processo utilizzato per la rappresentazione grafica del degrado in ambito BIM, dove non esiste tuttora uno strumento apposito, rendendo quindi necessario l'utilizzo di altri strumenti presenti nei software. In virtù di questo per realizzare tale mappatura sono stati utilizzati 4 tipi differenti di muri (relativi alle 4 tipologie di degrado) a cui sono state associate diverse campiture e appositi parametri di tipo che sono stati poi collegati ad un abaco. Questa tecnica permette di visualizzare direttamente sul modello le aree colpite dal degrado e interrogarle per estrapolare le informazioni relative alla superficie interessata e all'intervento più idoneo per ognuna di esse.



A	B	C	D	E	F
Tipo del Degrado	Descrizione del Degrado	Superficie	%	Immagine del Degrado	Intervento previsto
Presenza di muffe	Deposito stratiforme, compatto e generalmente aderente al substrato, composto da sostanze inorganiche o da strutture di natura biologica	74,97 m ²	75%	Deposit.jpg	Disinfezione da colonie di microrganismi autotrofi o/ e eterotrofi mediante applicazione di biocida e successiva rimozione meccanica
Lacuna	Caduta e perdita di continuità delle superfici (parte degli strati di intonaco più esterni).	7,66 m ²	8%	Lacuna.jpg	Reintegrazione degli strati di finitura, successiva pulitura e revisione cromatica dei bordi.
Mancanza	Caduta e perdita degli strati di intonaco con conseguente messa in luce degli strati di cemento o calcestruzzo.	16,17 m ²	16%	Mancanza.JPG	Caduta e perdita degli strati di intonaco con preliminari saggi per la composizione della malta idonea per colorazione e granulometria. Applicazione di due o più strati di intonaco, successiva pulitura e revisione cromatica dei bordi.
Vegetazione	Presenza di licheni, muschi e piante.	1,67 m ²	2%	Vegetazione.jpg	Tinteggiatura a calce e velatura superficiale.
Totali		100,47 m ²			



Abaco dei degradi				
Tipo del Degrado	Descrizione del Degrado	Superficie	%	Immagine del Degrado
Presenza di muffe	Deposito stratiforme, compatto e generalmente aderente al substrato, composto da sostanze inorganiche o da strutture di natura biologica	74,97 m ²	75%	Deposit.jpg
Lacuna	Caduta e perdita di continuità delle superfici (parte degli strati di intonaco più esterni).	7,66 m ²	8%	Lacuna.jpg

Abaco dei degradi				
Tipo del Degrado	Descrizione del Degrado	Superficie	%	Immagine del Degrado
Mancanza	Caduta e perdita degli strati di intonaco con conseguente messa in luce del paramento murario.	16,17 m ²	16%	Mancanza.JPG
Vegetazione	Presenza di licheni, muschi e piante.	1,67 m ²	2%	Vegetazione.jpg



GEOPHYSICAL SURVEY RELATED TO MASONRY STRUCTURES

03

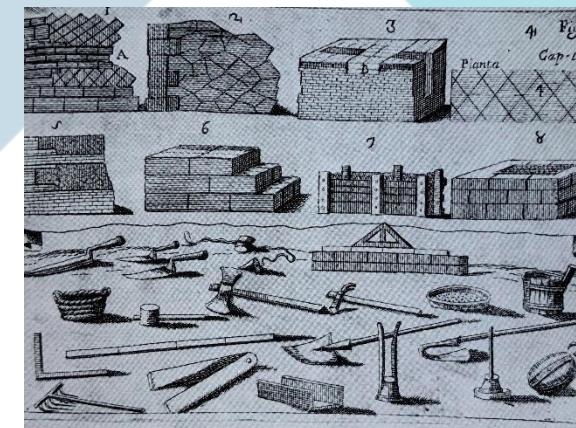
POTENTIAL SOLUTIONS

Let's return to the potential solutions

- **CONSULTATION OF HISTORICAL LITERATURE AND MANUALS**



These documents provide explanations of masonry techniques



- **SURVEY OF EXPOSED MASONRY PARTS**

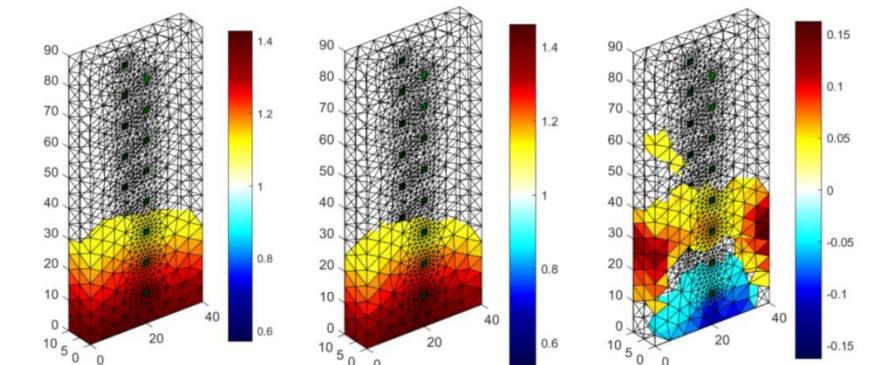


Uncovered or open portions of masonry, often resulting from earthquakes or prolonged degradation, as opportunity to identify ancient construction techniques



- **INTEGRATED SURVEY TECHNIQUES**

Combined use of photogrammetry, laser scanning, and geophysical surveys can provide accurate data that, once interpreted, can be incorporated into the HBIM model



INTEGRATED SURVEY TECHNIQUES

In collaboration with the geophysics laboratory of ISPC in Naples we applied the Georadar, techniques which utilizes the transmission of electromagnetic waves and Geoelectric techniques, to investigate

- the internal structure of masonry,
- identification of the thickness of various materials present and
- detecting internal cracks or voids that are not immediately visible.



Diagnostic program for the study of the consistency of masonry structures and deterioration.

1. Georadar investigations on **elevation masonry** for the identification of non-evident or hidden data
2. Georadar investigations on **vaulted structures**
3. GPR and ERT investigations on the **ground along the facade**
4. Georadar investigations on **known masonry** to verify the correspondence of tomographic anomalies with the geometric material characteristics of the sampled cases

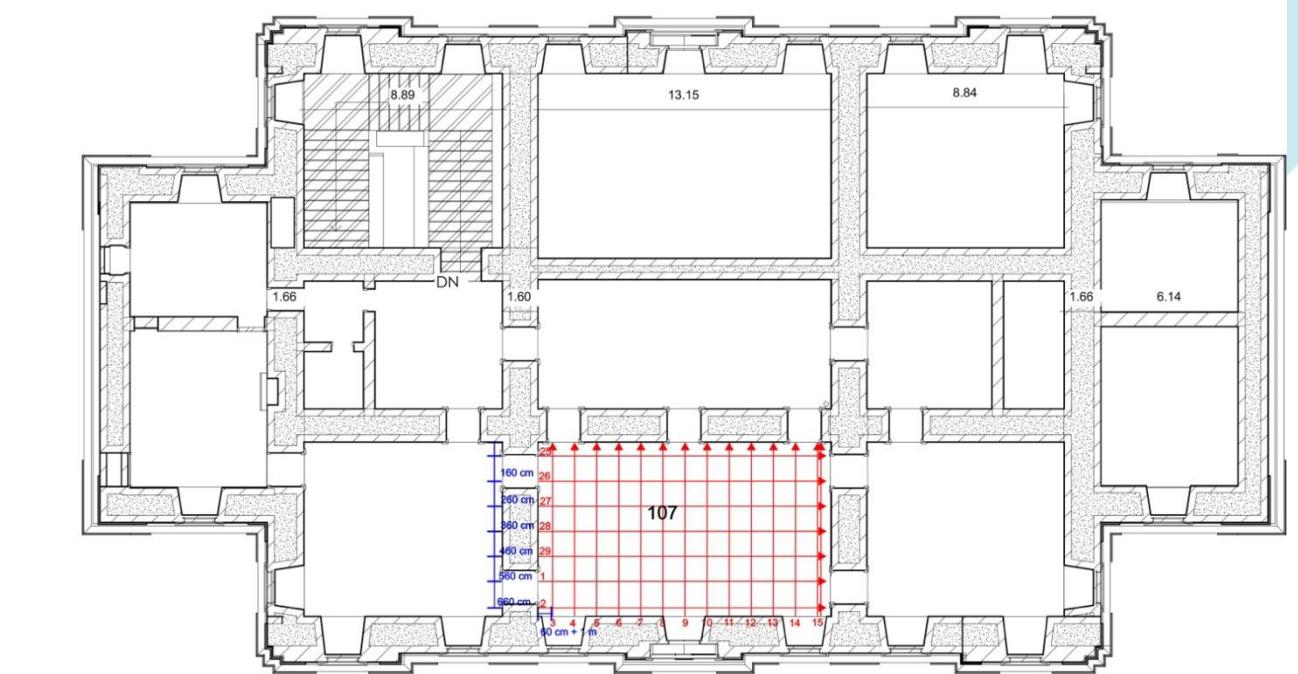
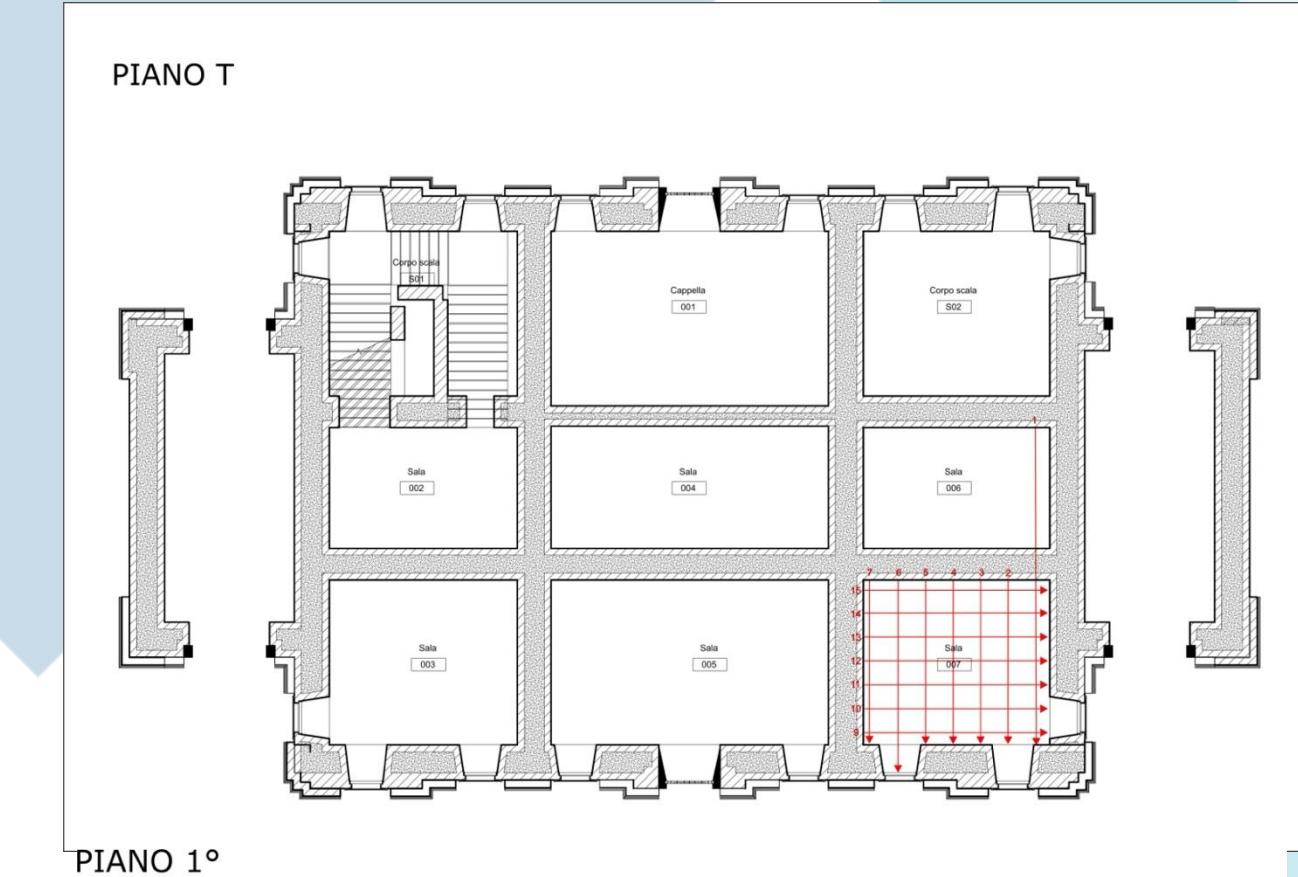
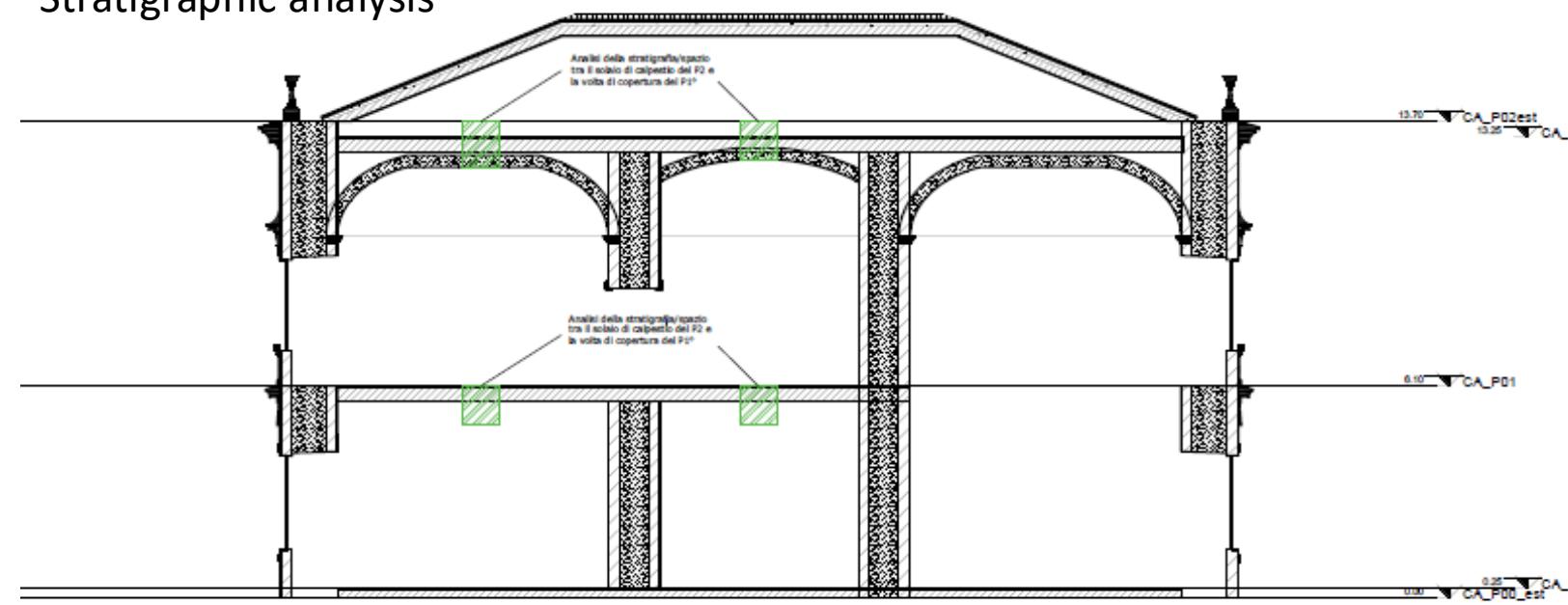


Geophysical acquisitions for diagnostic purposes on the vaults

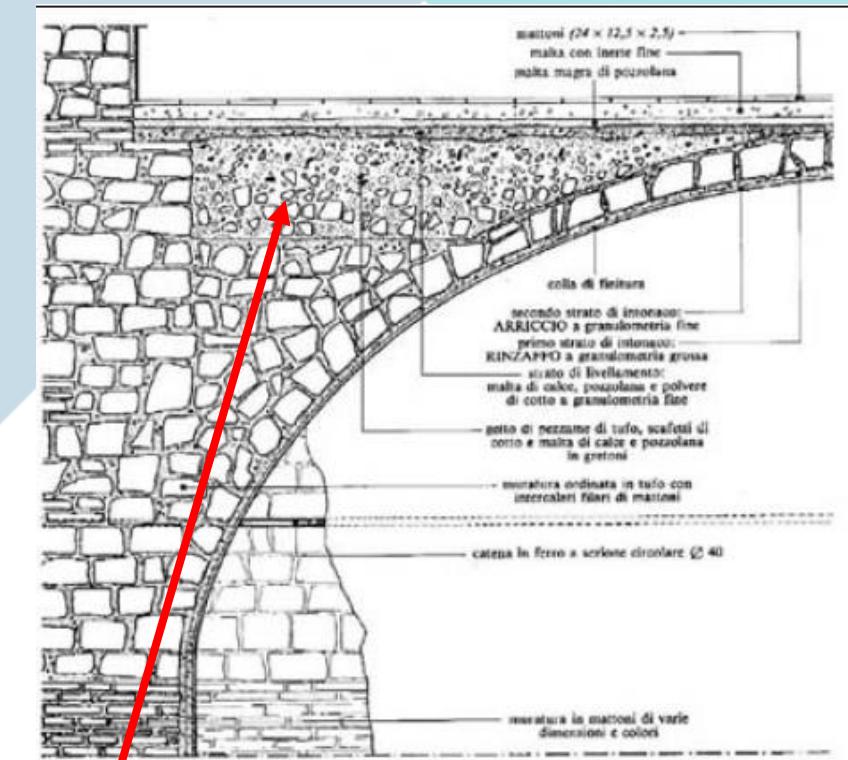
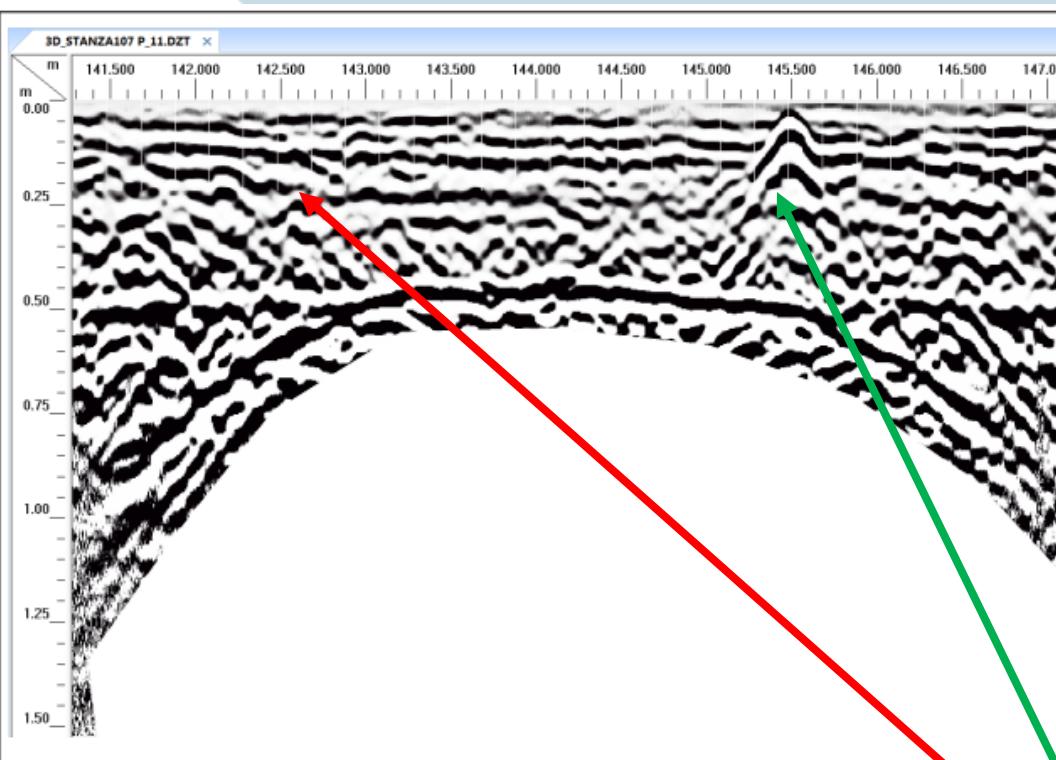
High-frequency GPR (Ground Penetrating Radar) survey (900 MHz) on the floors in some rooms on the ground floor, first floor, and attic.

SEZIONE TRASVERSALE

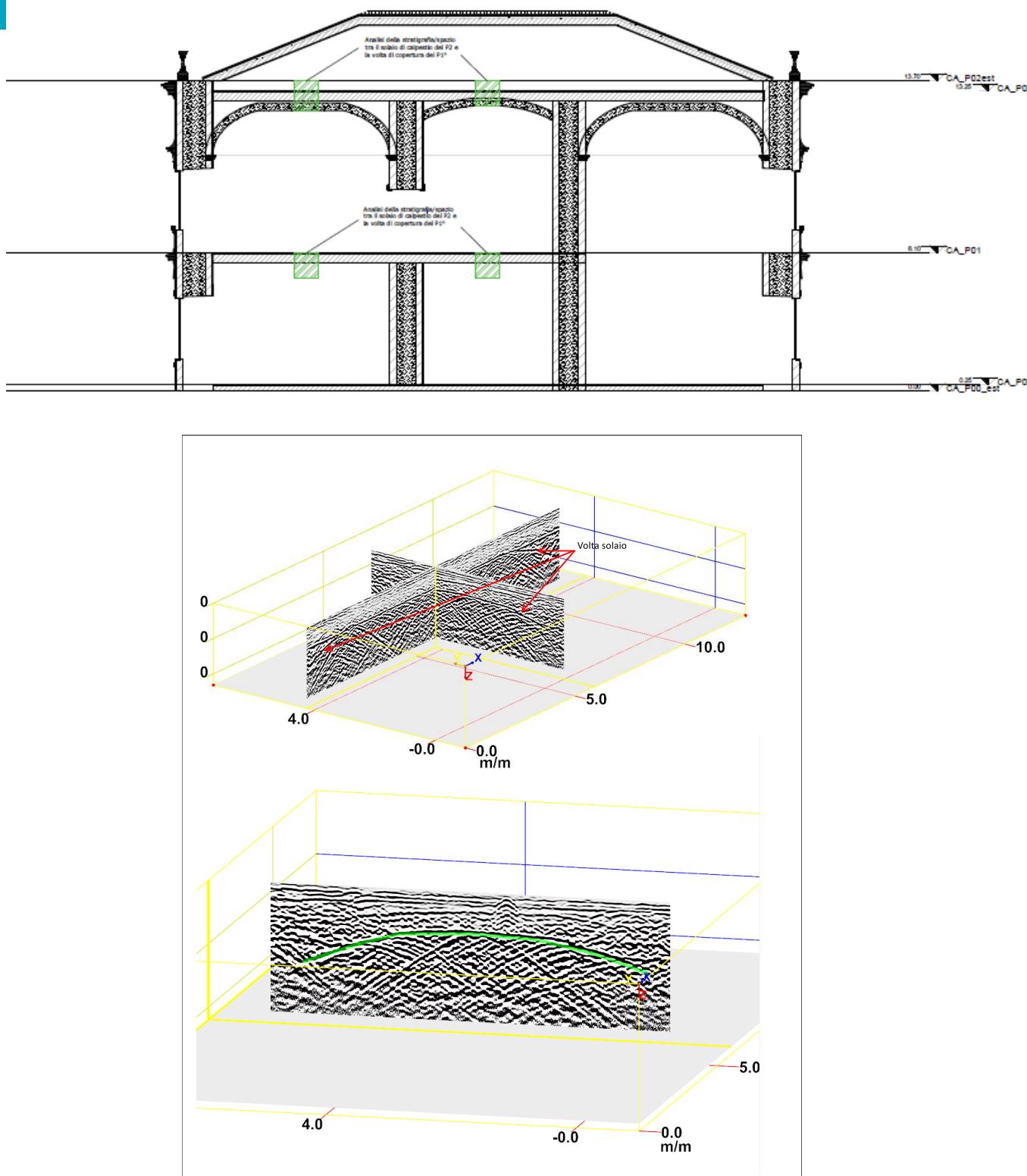
Stratigraphic analysis



SURVEY OF VAULTS



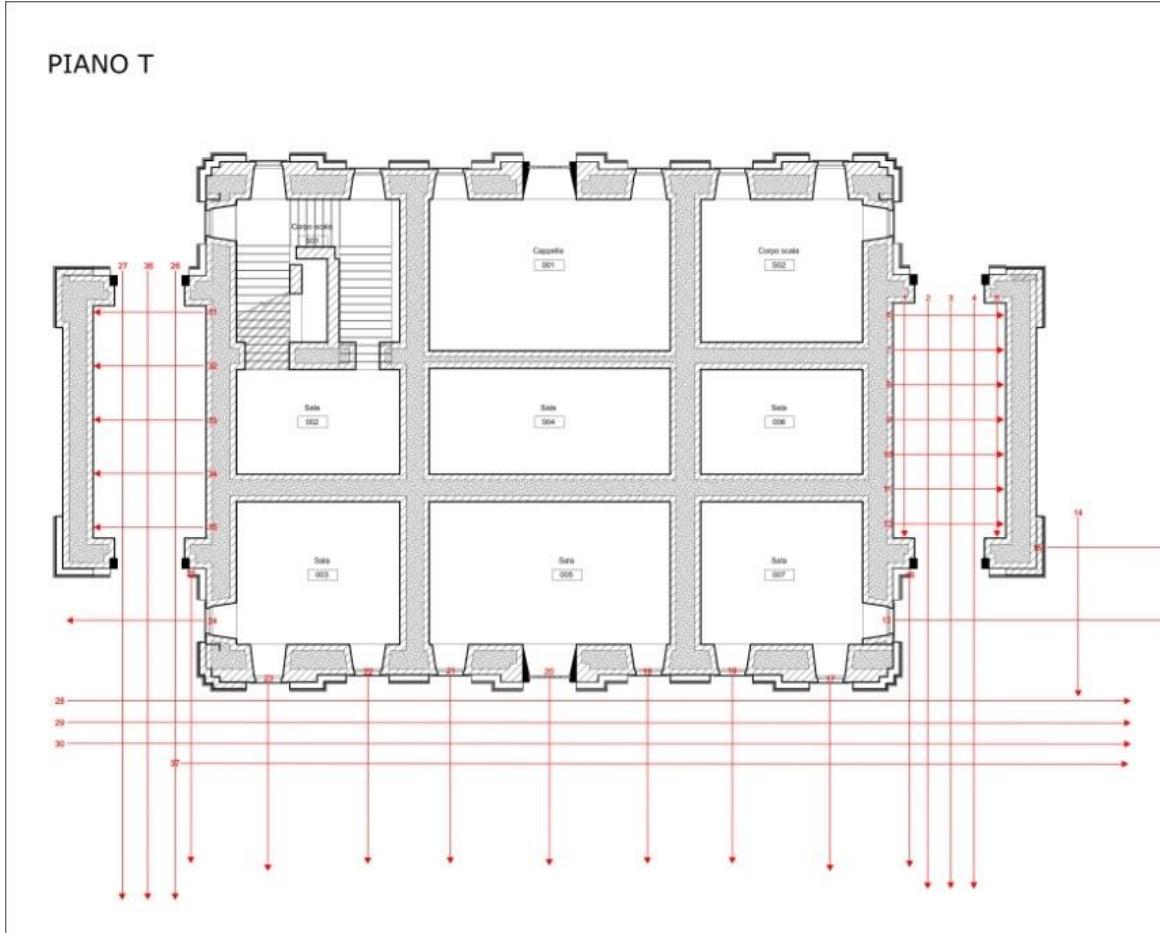
- Detail of the ceiling vault at first floor. There are:
 - infill elements present within the first 50-60 cm
 - and diffracted events related to service systems



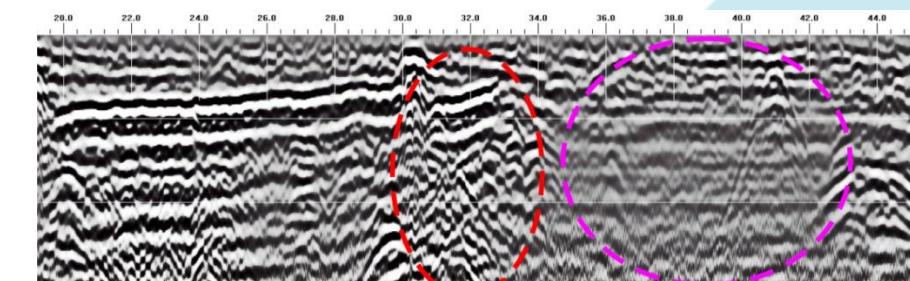
The interpolation of the 3D GPR grids at 900 MHz allowed the identification of the flat areas from the curved ones in the floor, distinguishing the horizontal part (white area) from the curved part (black area).

Survey on the perimeter of the external facade

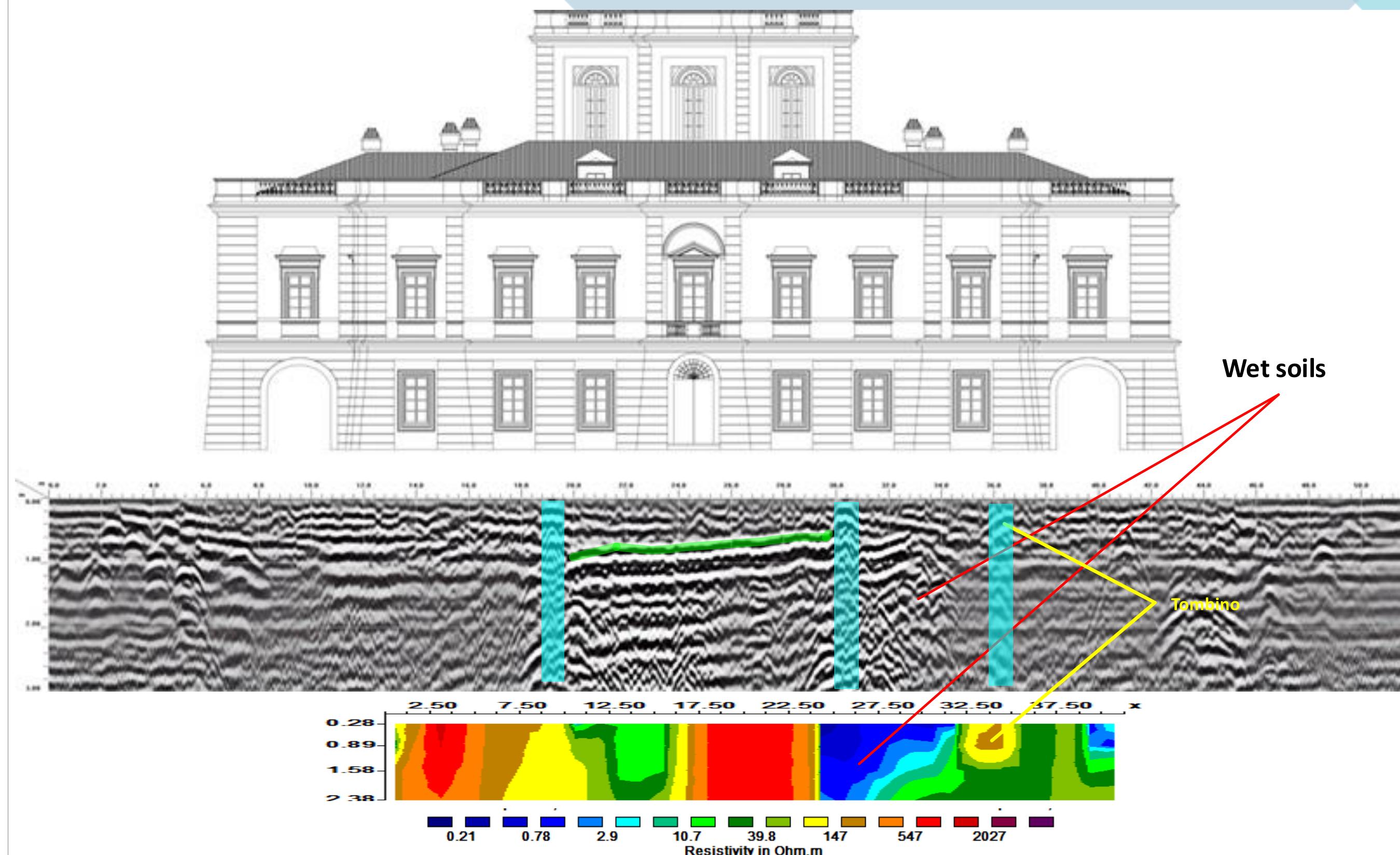
- GPR and geoelectric surveys were carried out on portions of the external terrain to detect possible subsidence or areas of water infiltration



Grid created along the perimeter of the facade



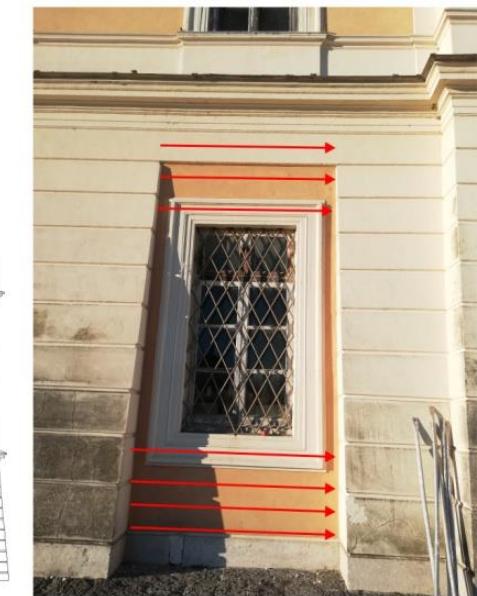
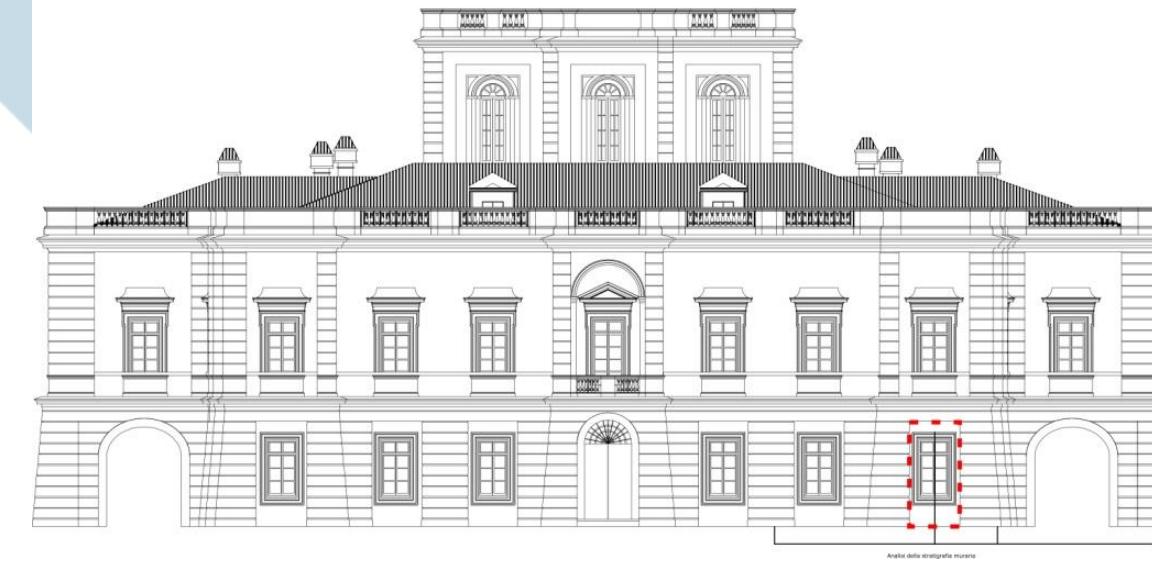
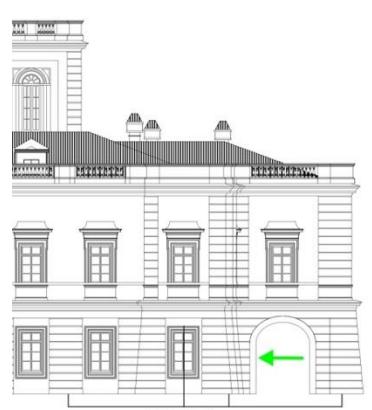
GPR and ERT survey on the ground perimeter of the external facade



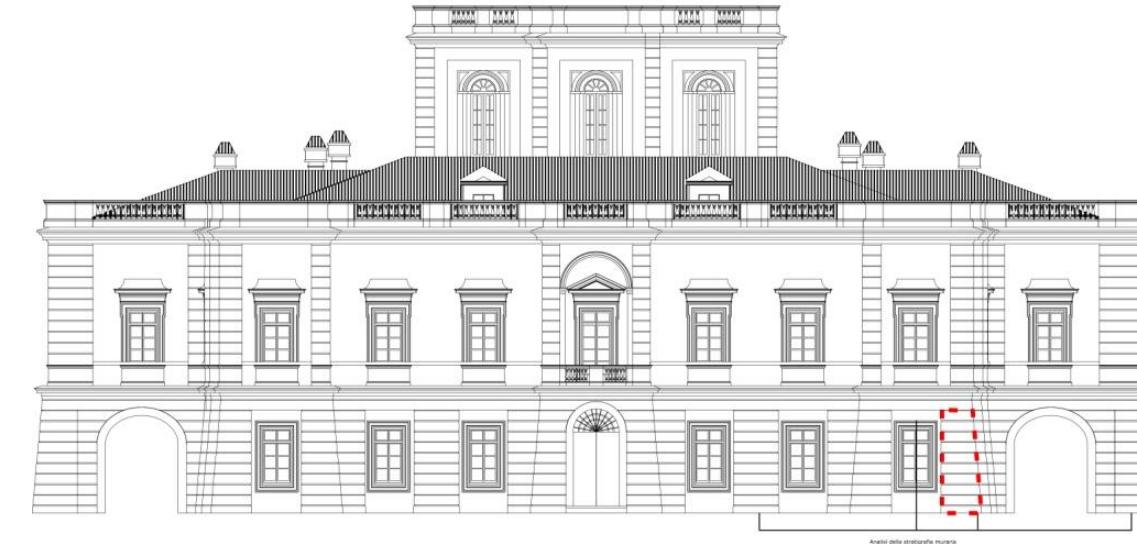
GPR ON MASONRY OF WALLS

Areas on the right side of the building selected to collect data on the material composition and the presence and extent of degradation (e.g., humidity)

FRONTE INGRESSO PRINCIPALE



FRONTE INGRESSO PRINCIPALE



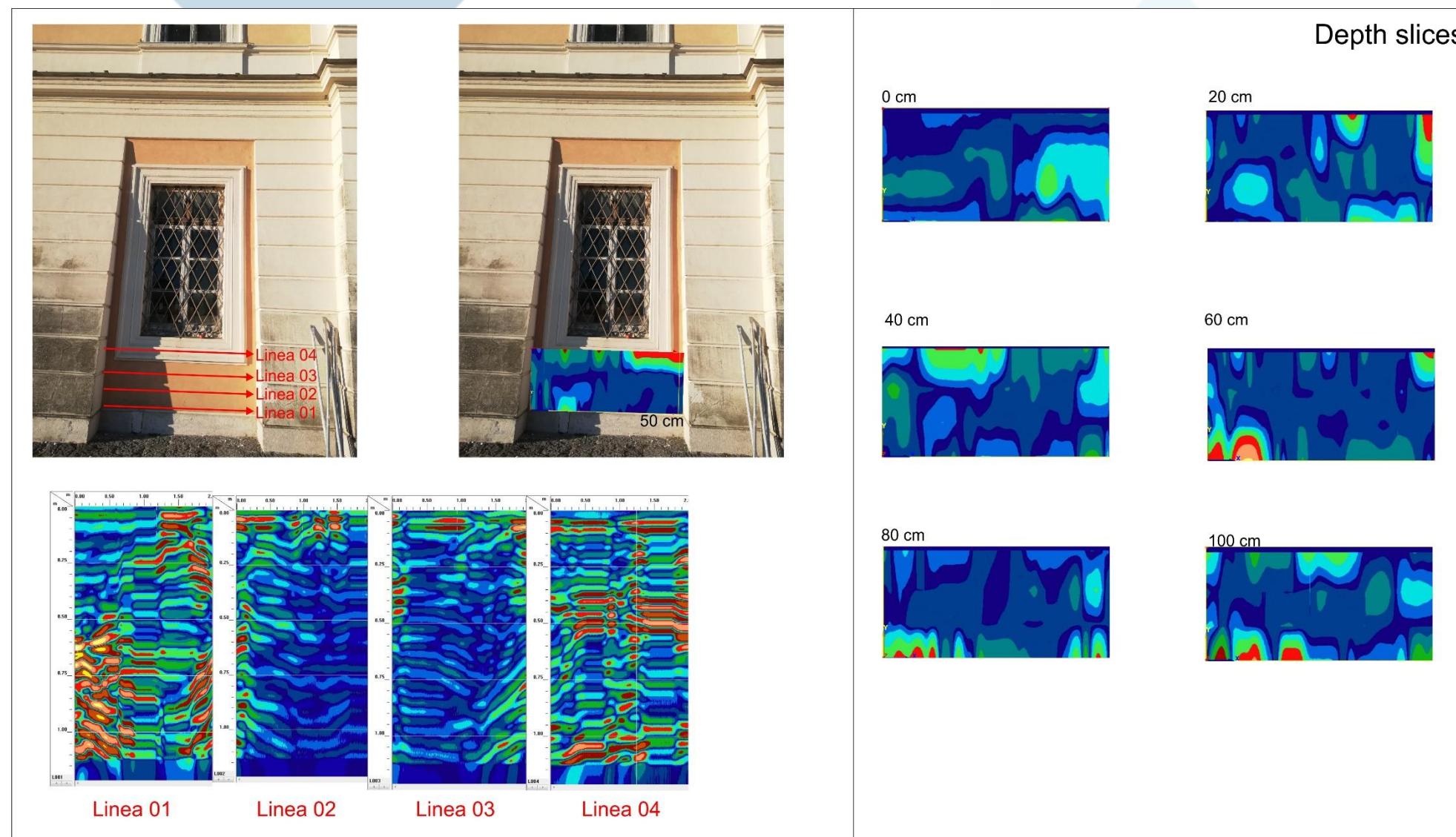
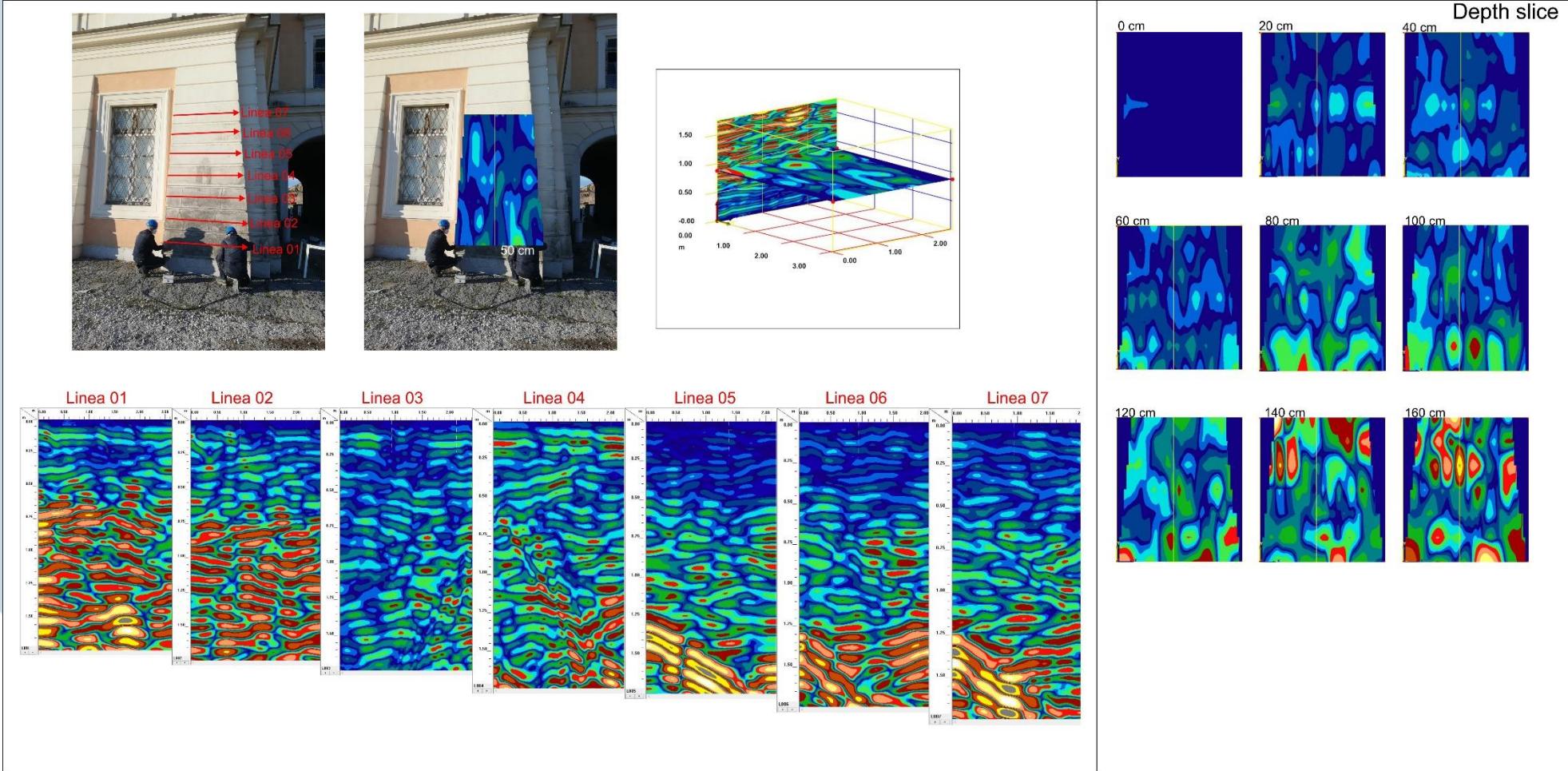
GPR ON WALLS

The interpretation of GPR data is often integrated with other sources of information, such as:

Historical or archaeological data: To confirm the identification of known structures or objects.

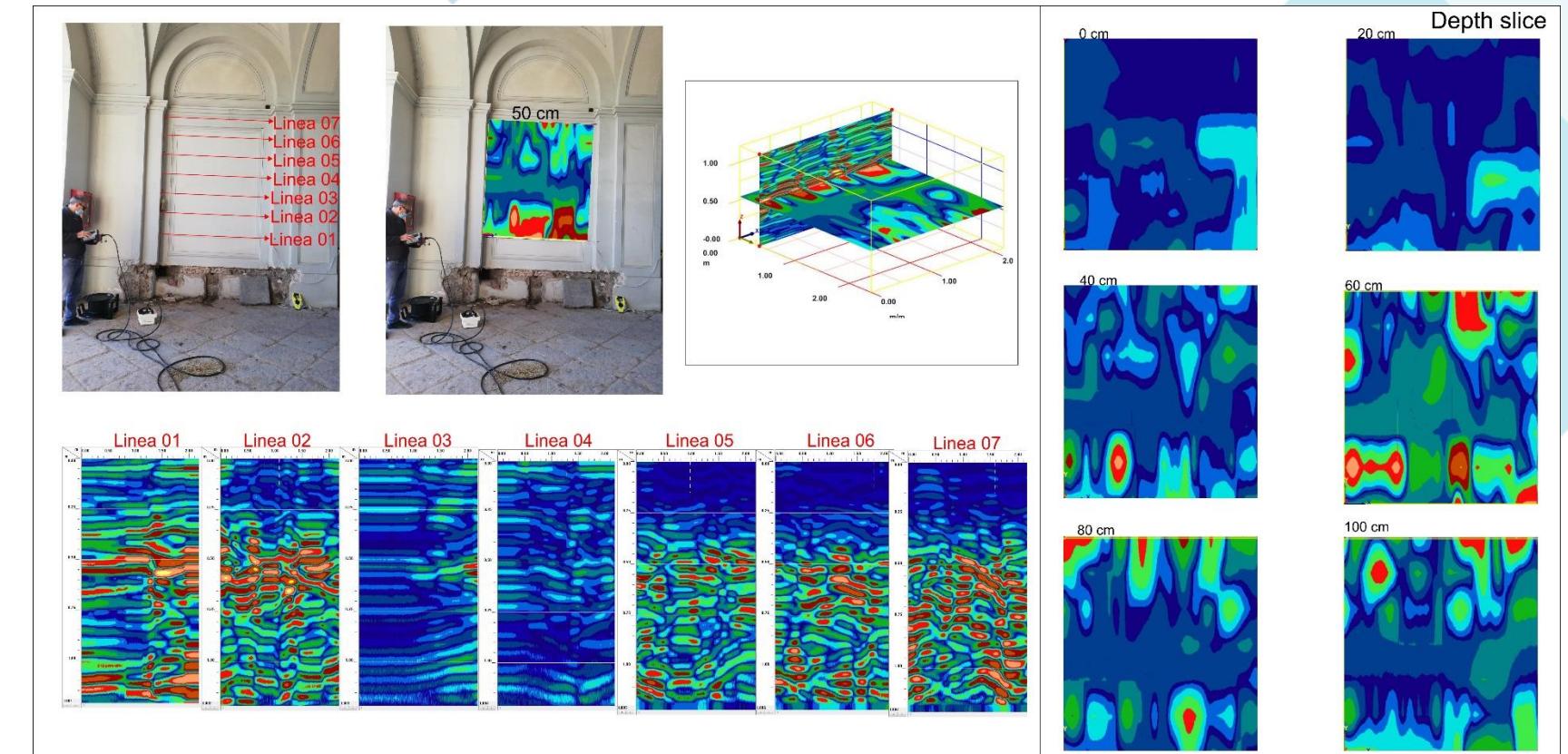
Complementary geophysical surveys: Such as seismic, magnetometric, or geoelectric surveys, to obtain a more complete view of the underground structure.

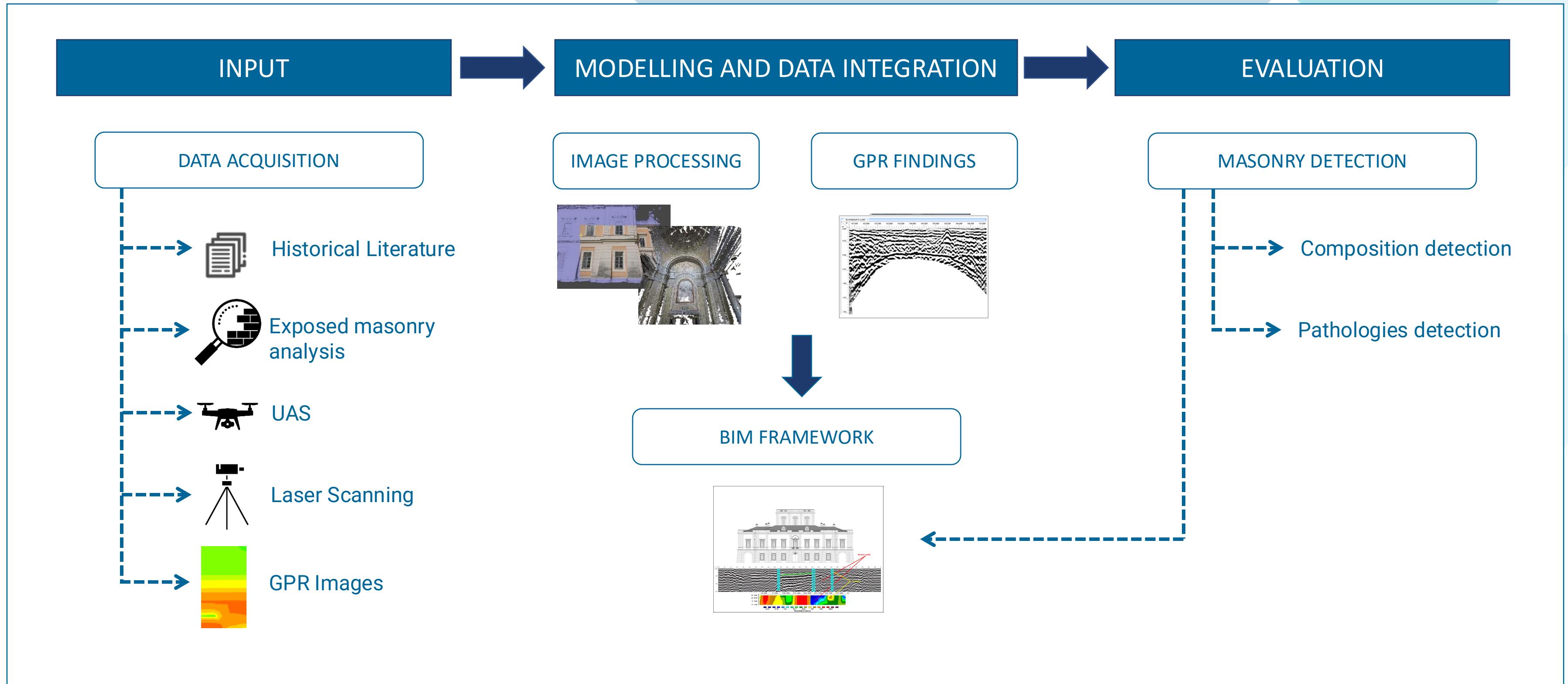
Local knowledge: Experts can compare the GPR results with local geological or structural knowledge to refine the interpretation.



GPR ON WALLS

- The GPR profiles acquired on the masonry have highlighted both structural variations and areas of possible humidity, which can be better interpreted and characterized through complementary geophysical surveys such as thermography or ultrasound the we are planned to integrate.







Thanks for your attention!

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