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1. ABOUT DISTRICT

DISTRICT Solutions sarl is a **Spin-off Design-Build** and **R&D** engineering firm. Officially founded in 2016, it is the result of a cumulative experience of its CEO and founder Dr. Eng. Michel Chalhoub who acts in the engineering field since 1999. The firm is focused on a diversity of projects in Digitalization & Structural Health Monitoring, Non Destructive Testing, Structural Design, Supervision & Management, Value engineering, and Execution.



Our experience in **Non-Destructive Testing** is focused on built heritage, especially on masonry and timber structures.

Our **DESIGN** experience covers the development of architectural and structural solutions for contemporary buildings, and geotechnical solutions related to soil and rock mechanics projects.

Our **DESIGN & BUILD** solutions are associated with the renovation and restoration of buildings, with a special emphasis on **Built Heritage**. Our services include architectural and damage surveys, seismic assessment of individual buildings and urban areas, retrofitting, and more.



Our **RESEARCH** activity results from specific case studies requiring innovative solutions and advanced numerical modeling of masonry structures and rock masses.

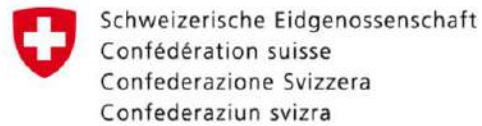
Our **CLIENTS** belong to the private sector, NGOs, embassies, ministries, and international organizations.

Our **KEY STAFF** is composed of multicultural senior and young professionals, with PhDs and Masters from world-class universities and programs, in engineering, architecture, and restoration of Built Heritage.

We perform in several countries, and our projects are distributed in Europe, South America, the Middle East, North and East Africa, and the Gulf region.



2. A SELECTION OF OUR CLIENTS



3. DIGITAL SURVEY, HBIM & STRUCTURAL HEALTH MONITORING



Tripoli Citadel – Tripoli – North Lebanon



Laser scanning point cloud output





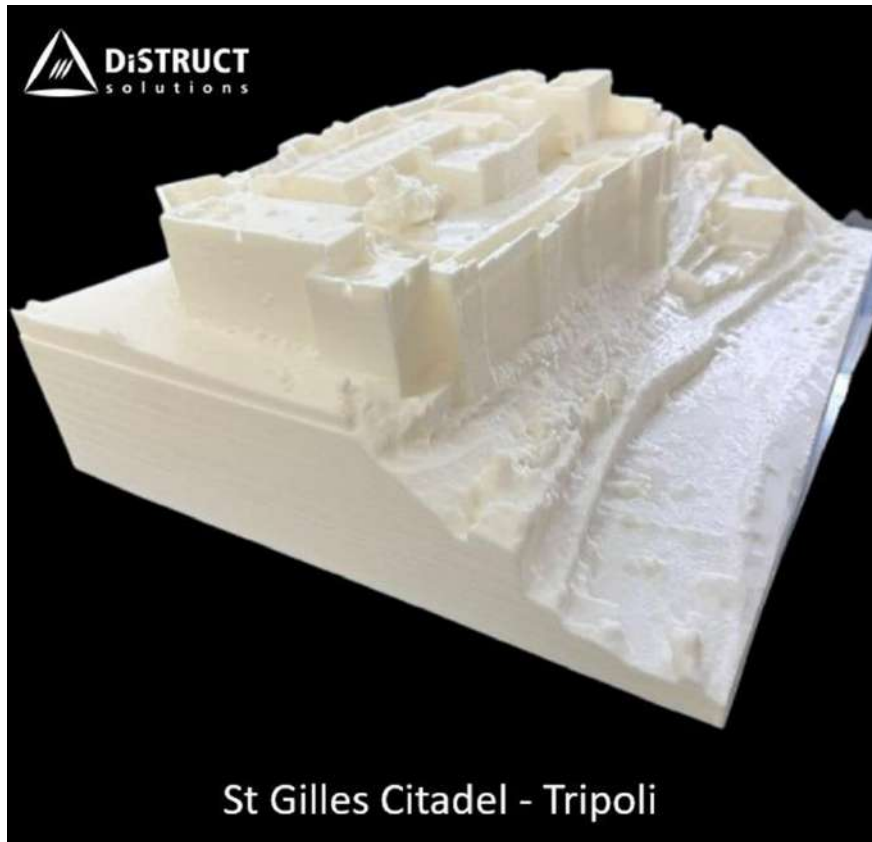
3D Model photogrammetry output





3D model, Orthomosaics, Photogrammetry Output

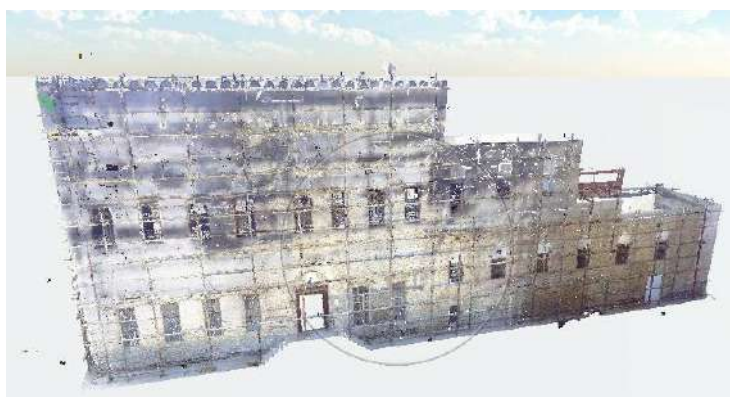




3D printed model

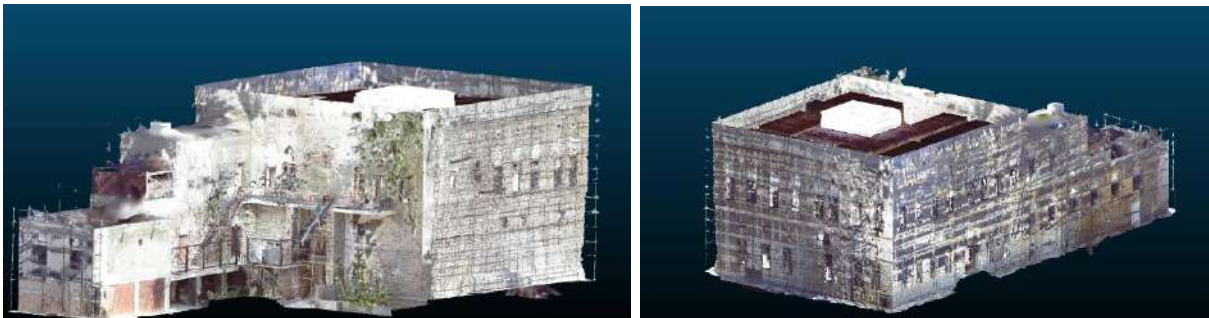


Omani French Museum – Muscat – The Sultanate of Oman



Point clouds Laser scanning output





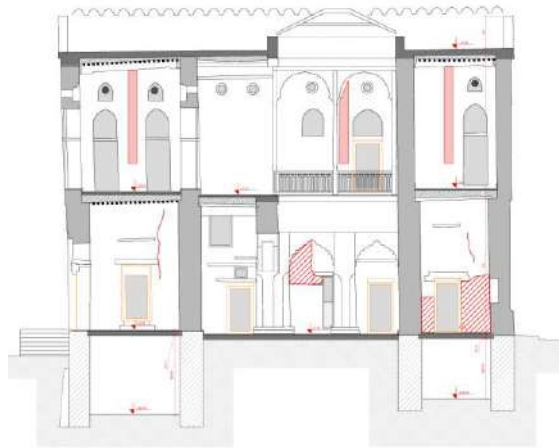
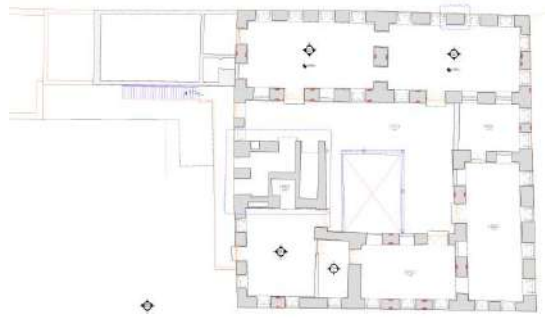
3D model and sections by Laser scanning



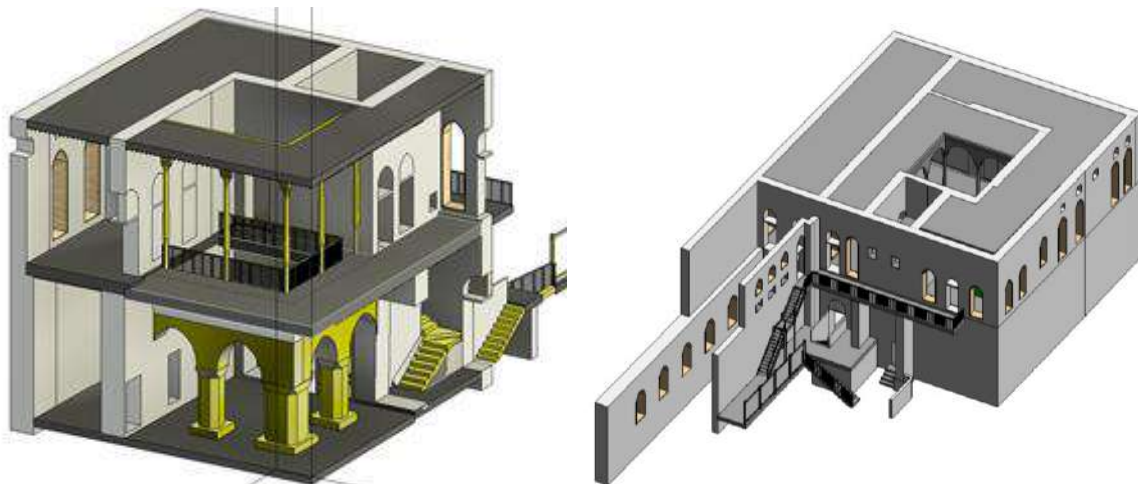


3D model and sections by Laser scanning



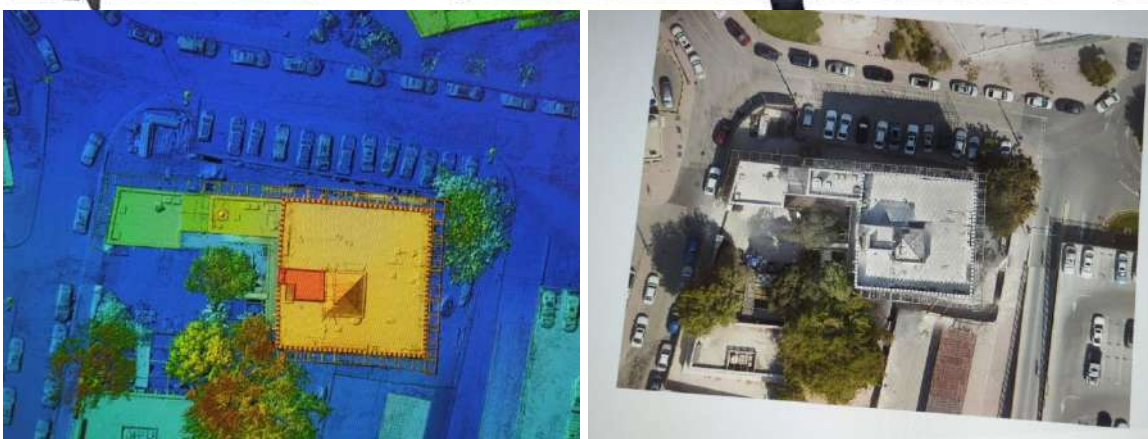


From scan to as built



BIM Model





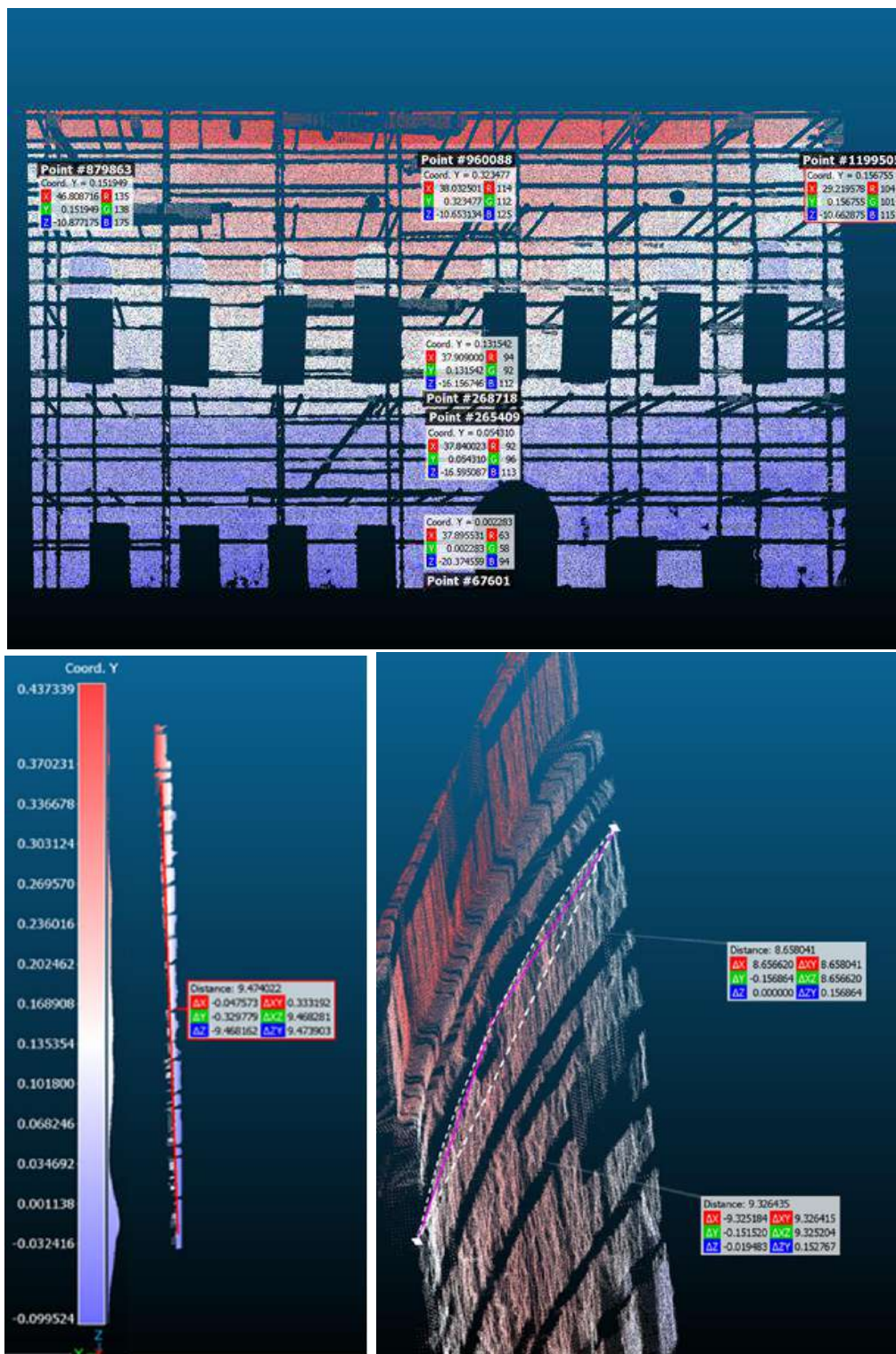
Orthomosaic, DEM, 3D model: Photogrammetry





3D model: Photogrammetry

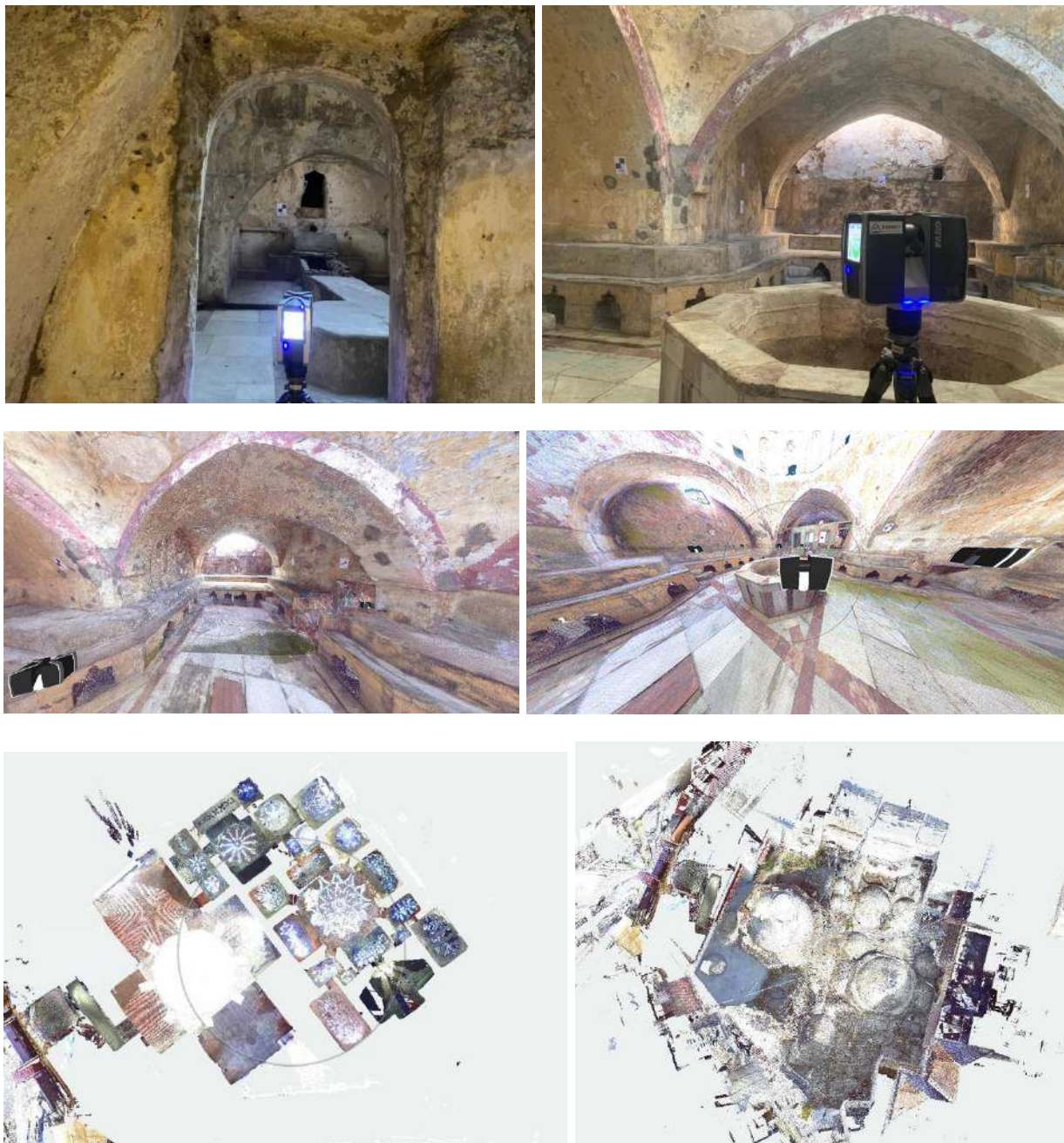




Structural deviation detected by laser scanning output (tilting & bulging of the main façade)

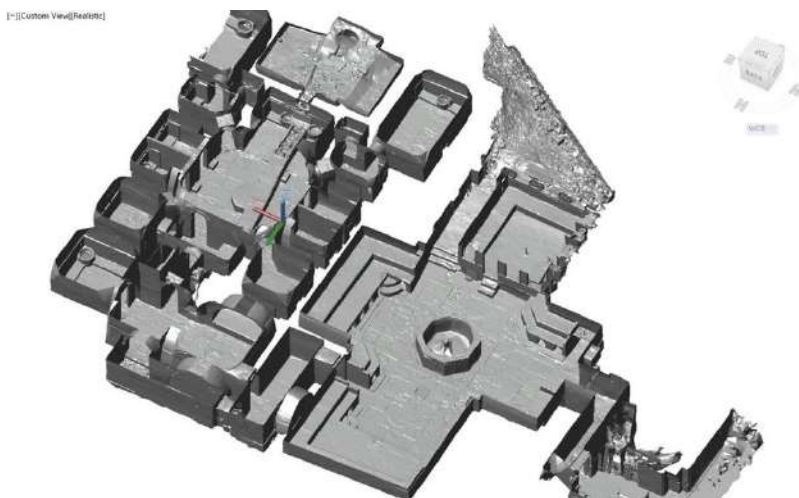
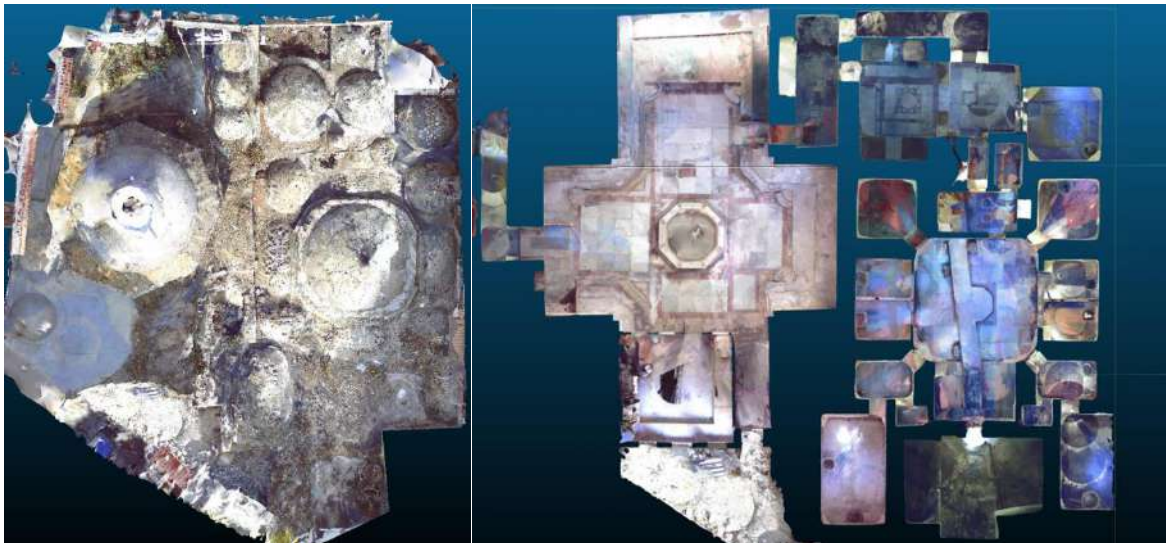


Hamмам Al Nouri – Tripoli – North Lebanon



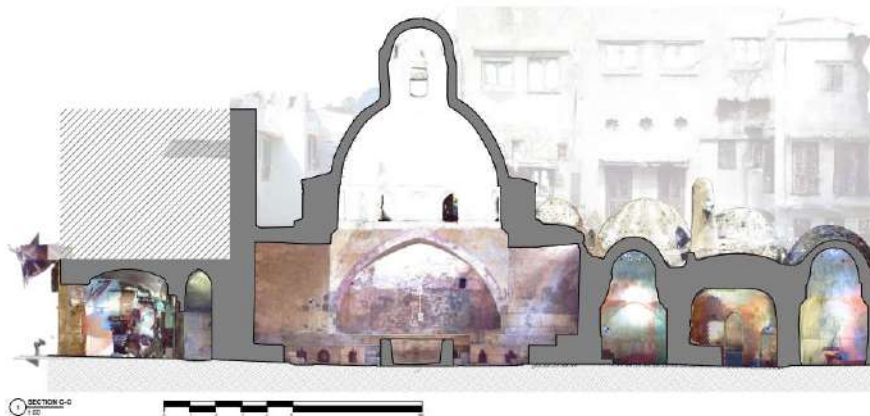
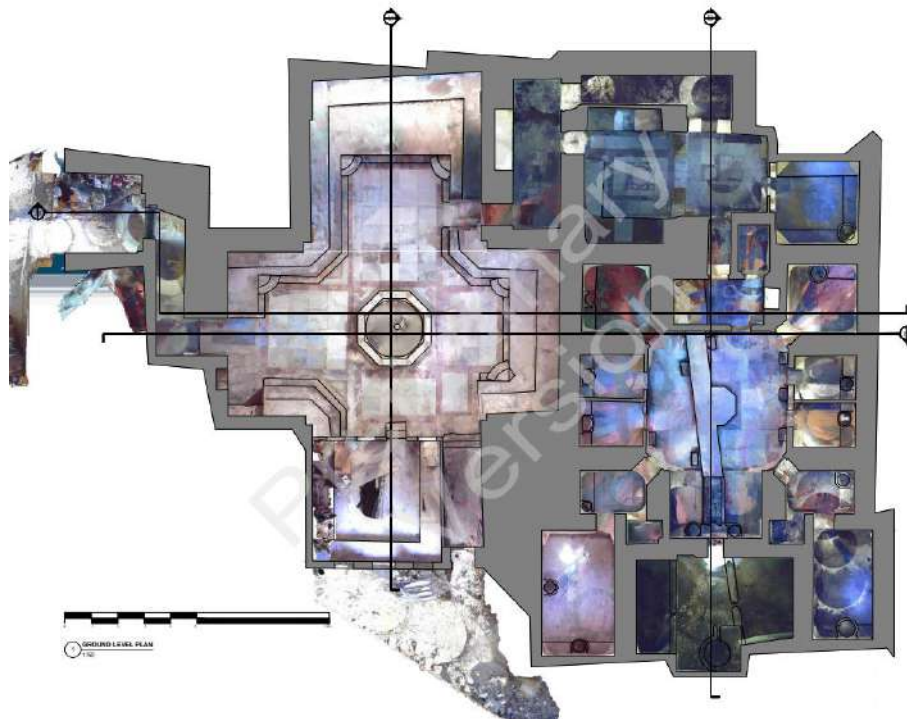
Laser scanning point cloud output





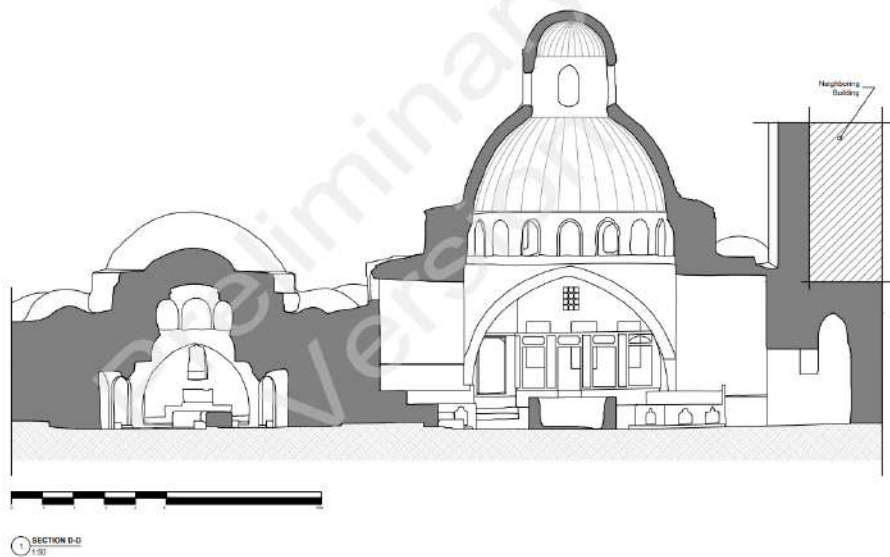
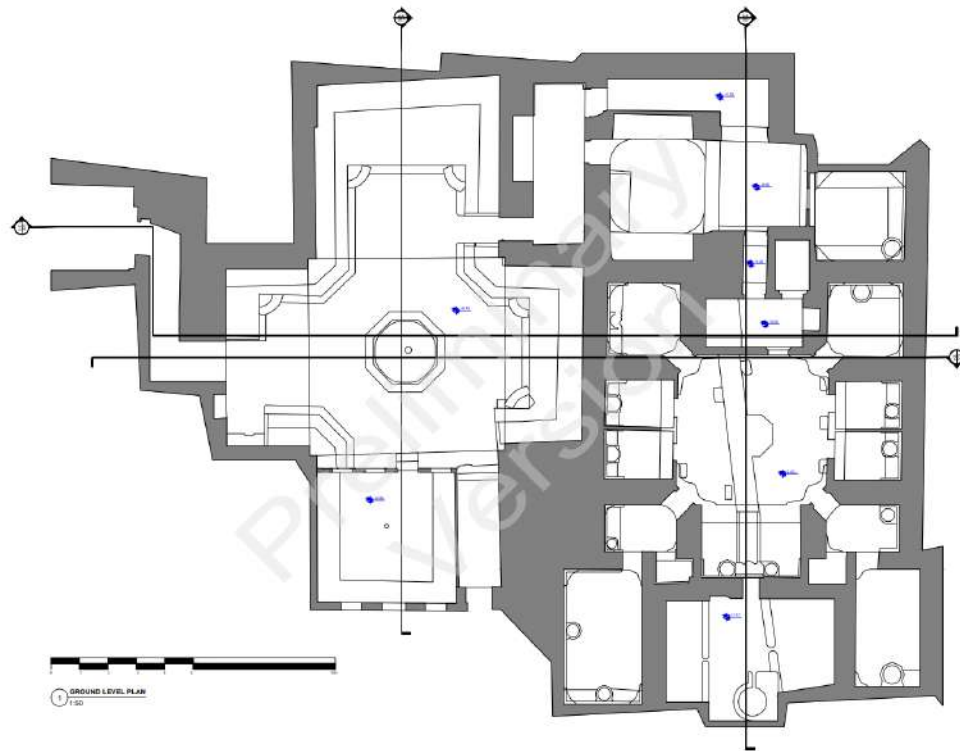
3D Model and sections by Laser scanning to HBIM





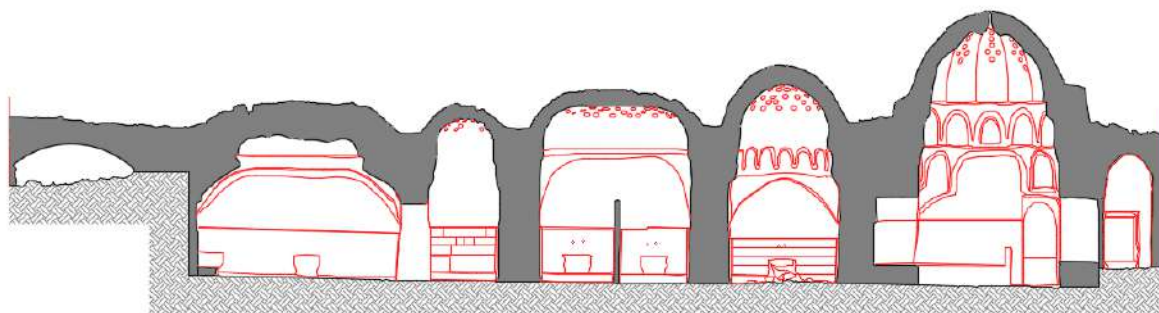
From scan to as built



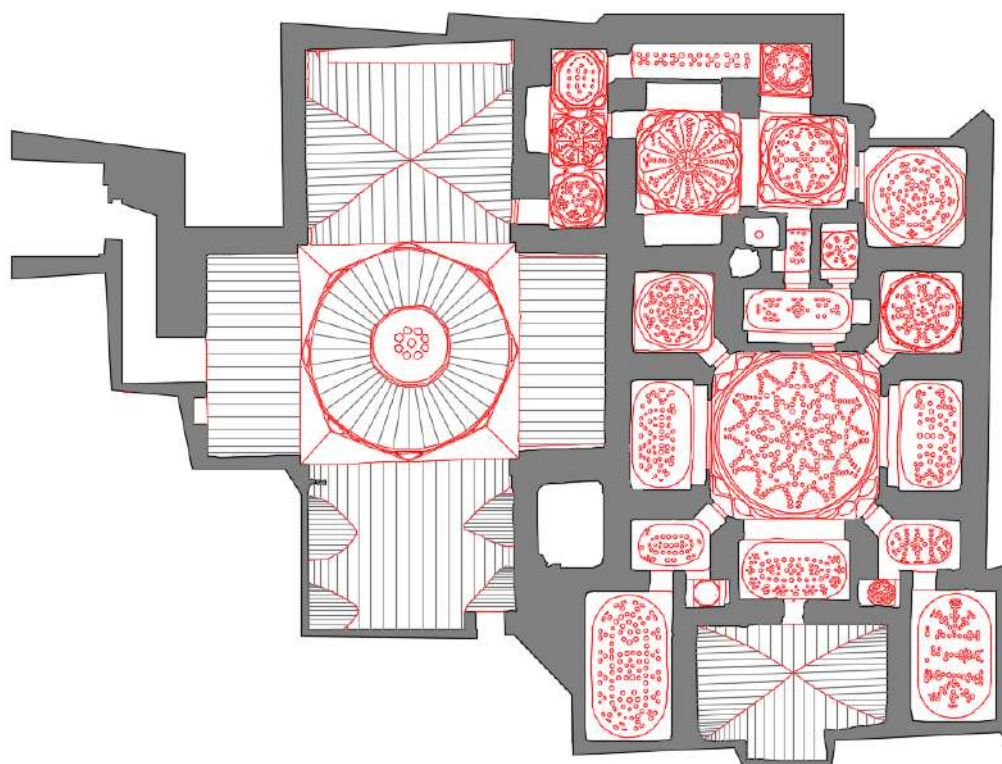


From scan to as built





SECTION Y-Y
1:50



REFLECTED CEILING PLAN
1:50

From scan to as built





3D Model photogrammetry output





3D Model photogrammetry output





3D Printed Model



ST Leba Church – Hasroun – North Lebanon



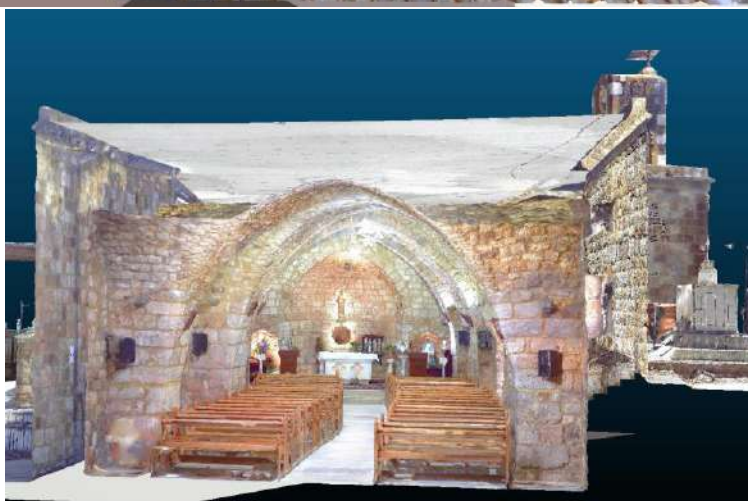
Laser scanning point cloud output





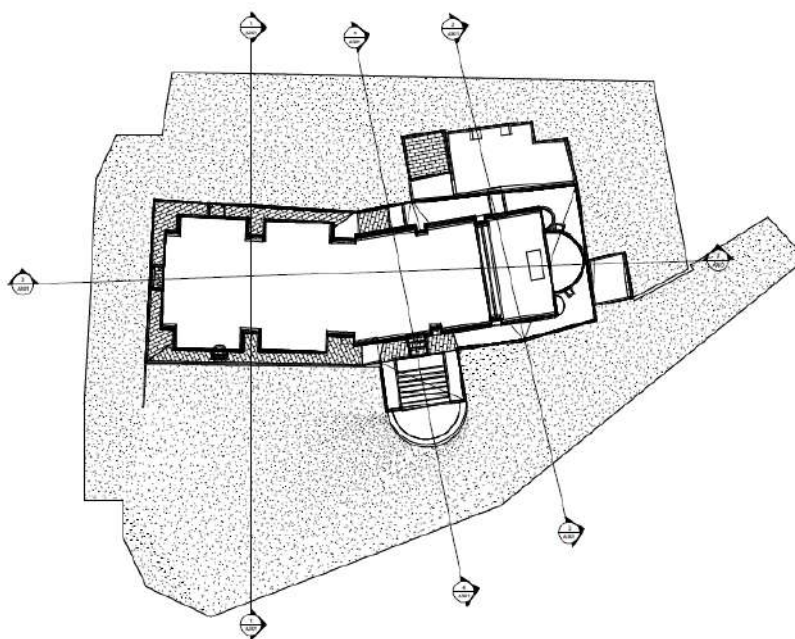
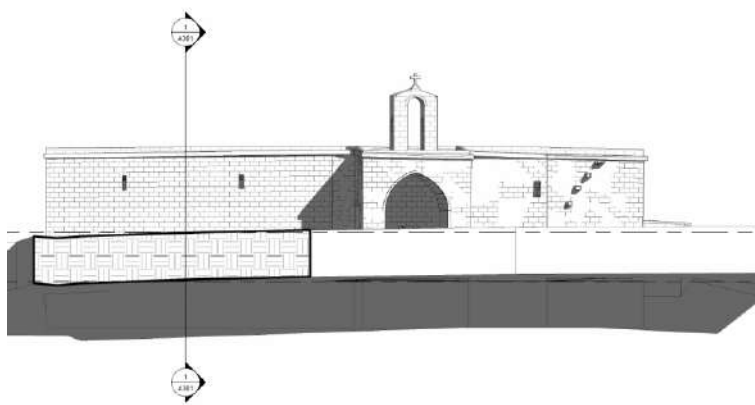
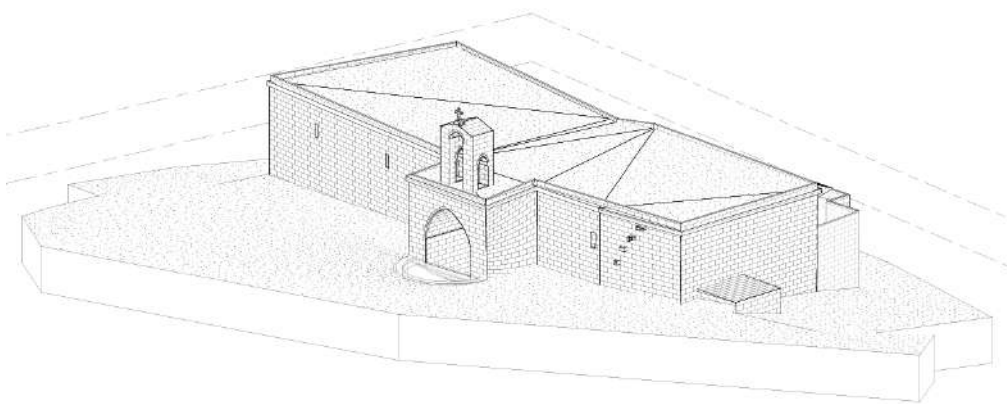
3D Model and sections by Laser scanning





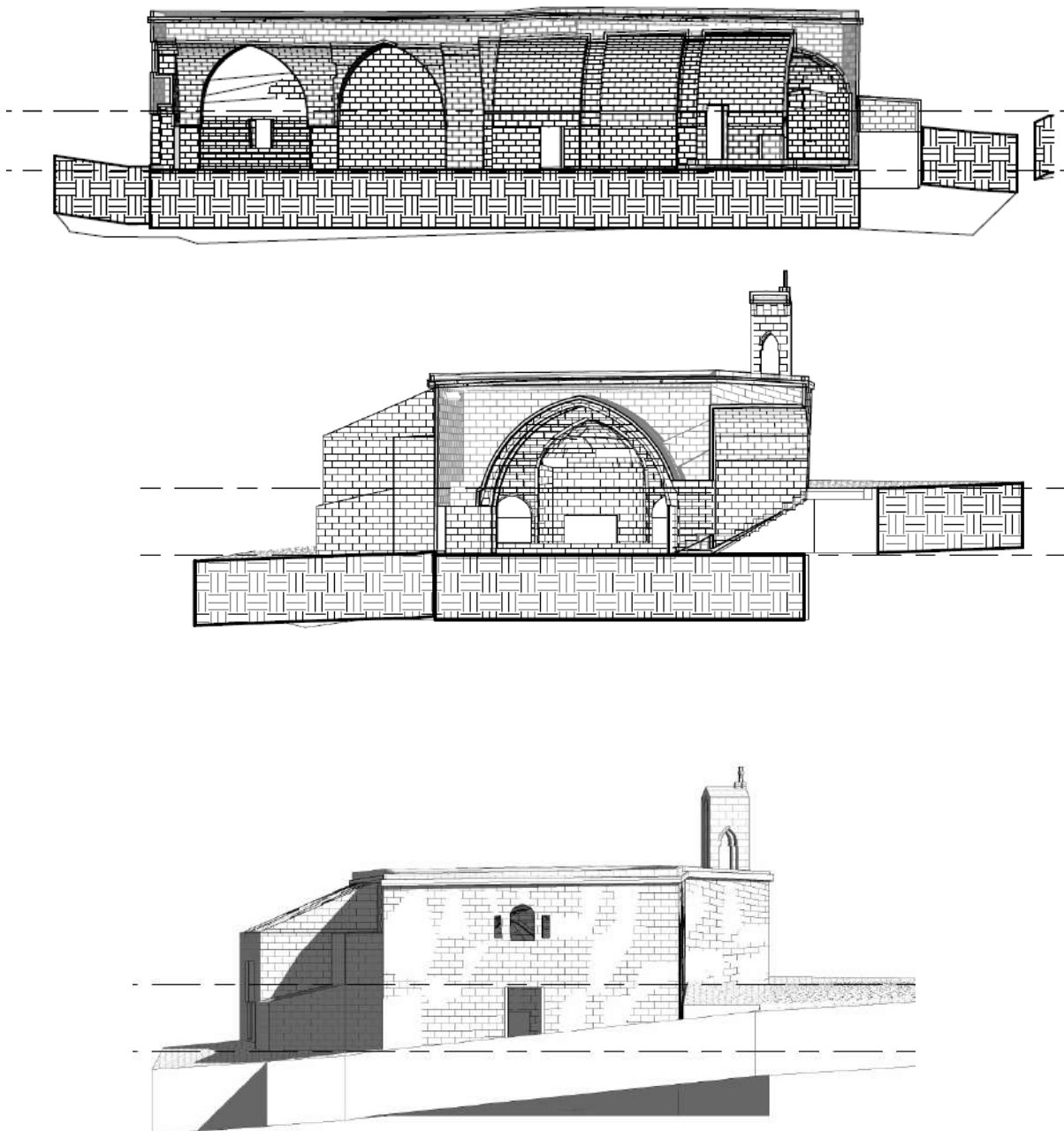
3D Model and sections by Laser scanning





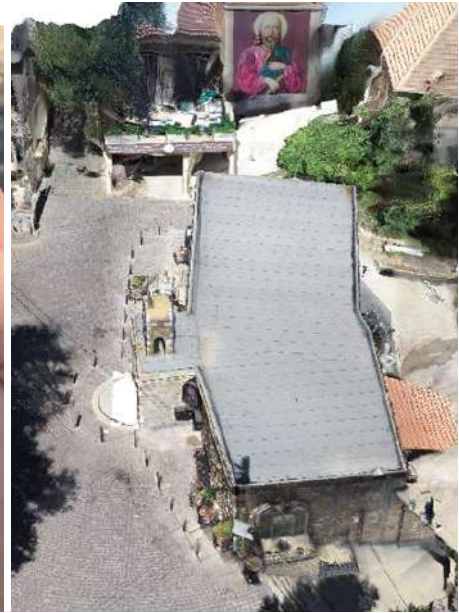
From Scan to HBIM





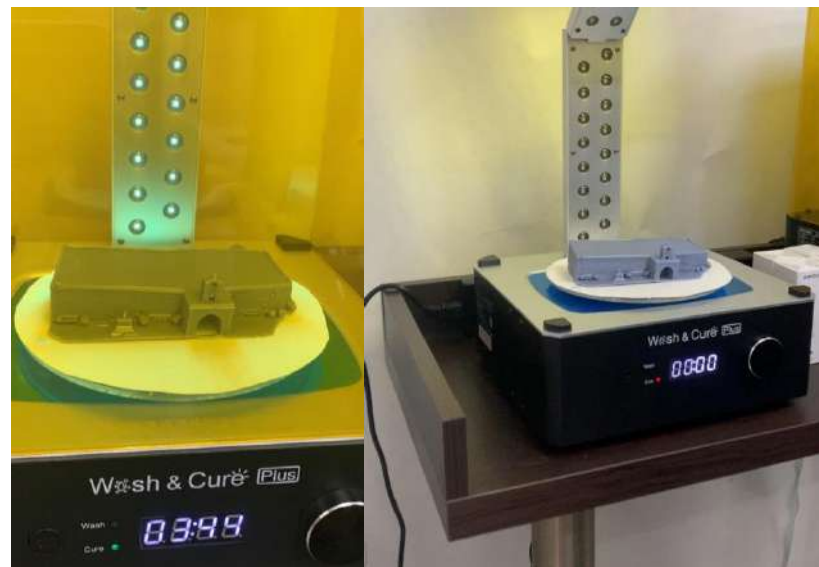
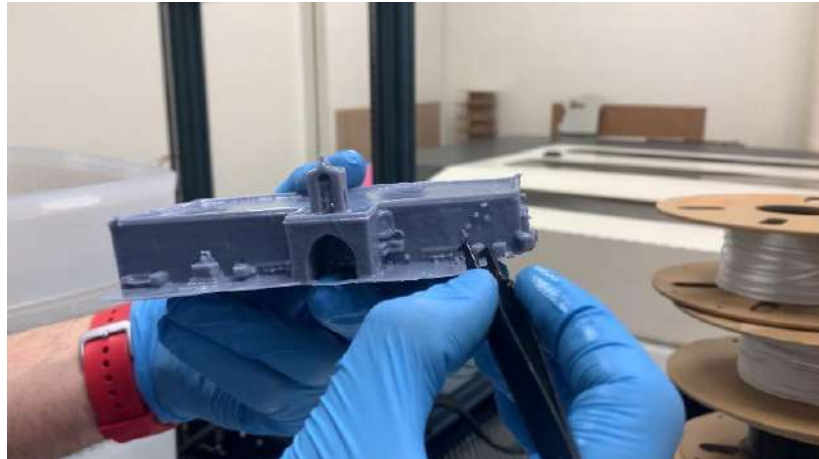
From Scan to HBIM





3D Model by Photogrammetry





3D Model Printing

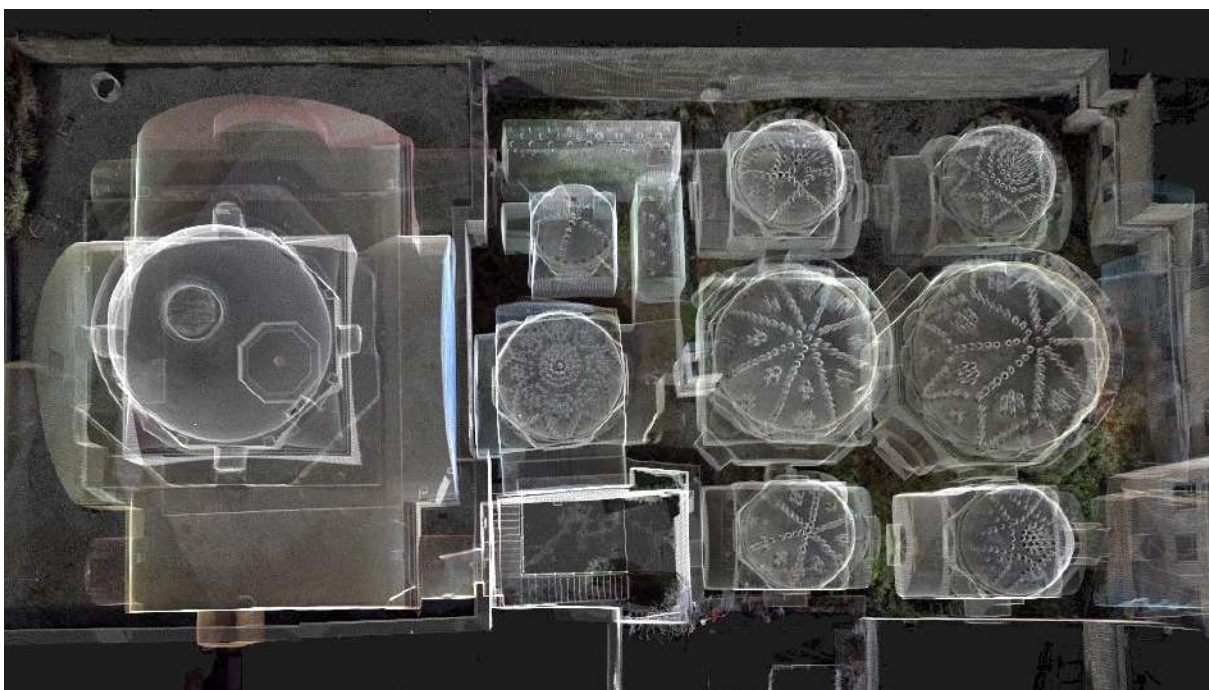
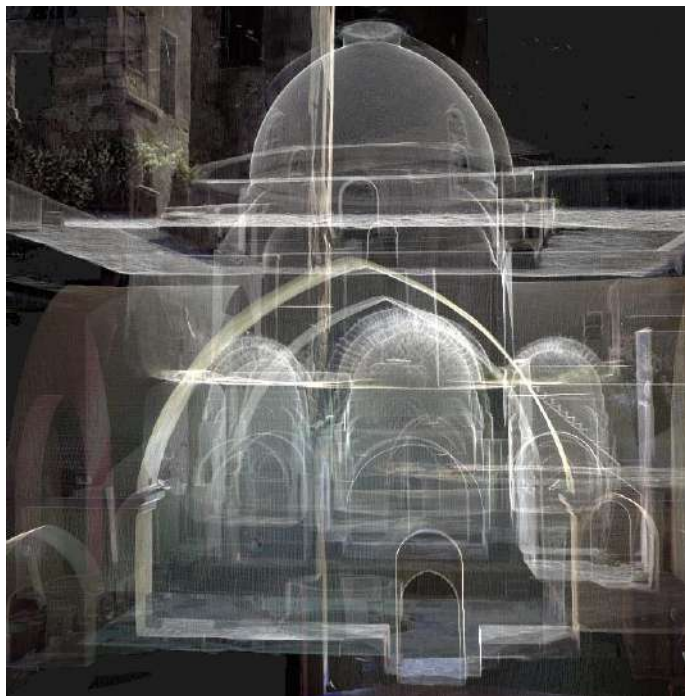




Virtual Reality through headset device



Hamam Ezz Al Din – Tripoli – North Lebanon



Laser scanning point cloud output





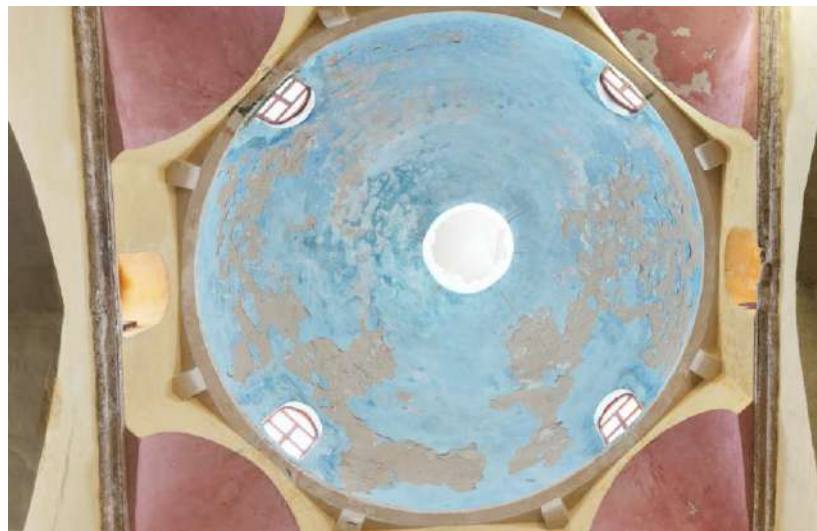
3D Model by Photogrammetry





3D Model by Photogrammetry





3D Model by Photogrammetry





Virtual Reality through headset device

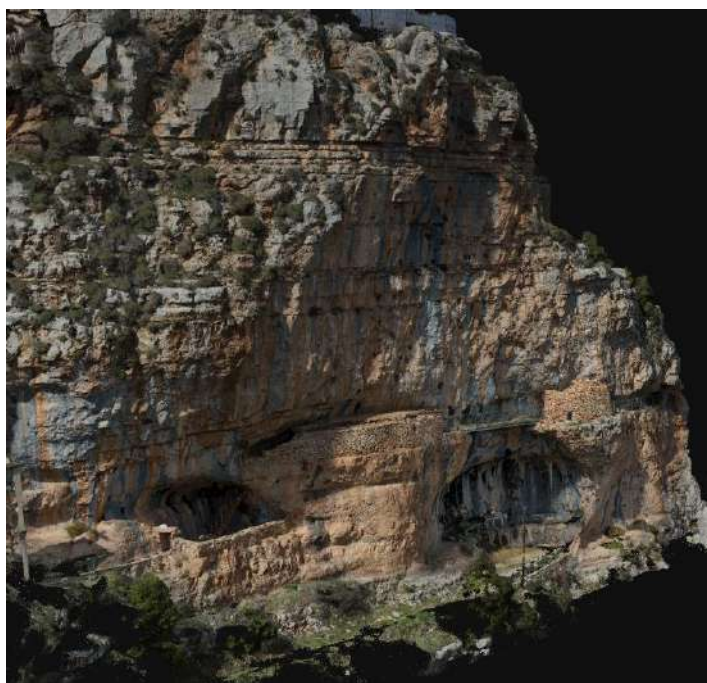


St Simon Monastery – Berkasha – North Lebanon



Drone Shots





3D model by photogrammetry

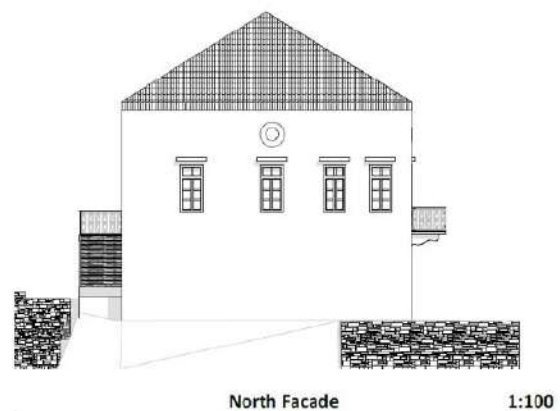
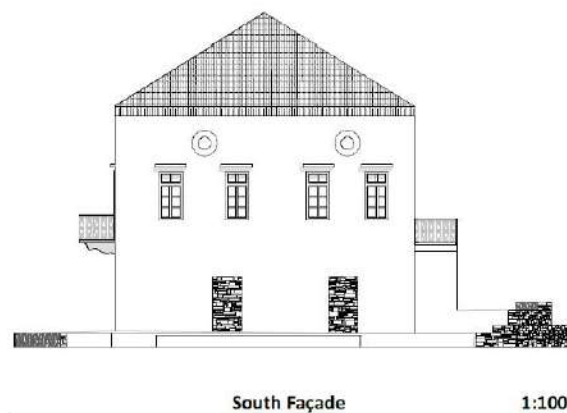
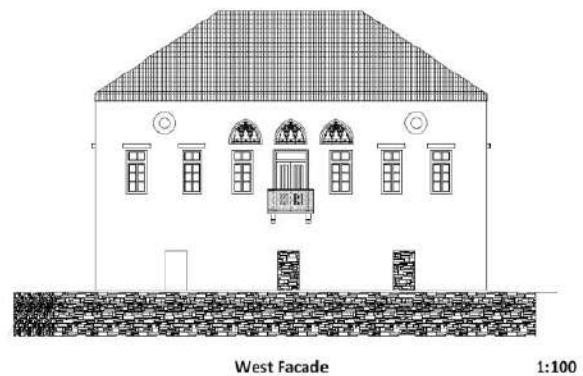
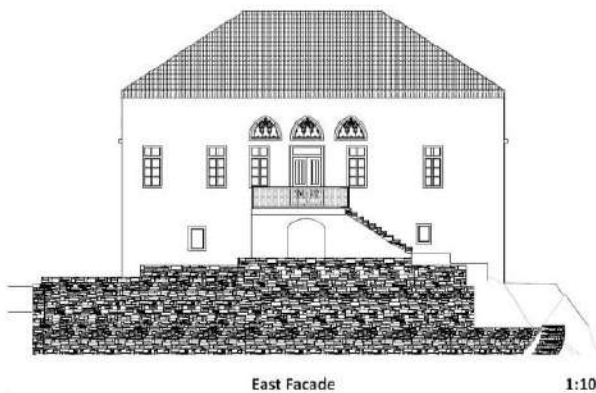
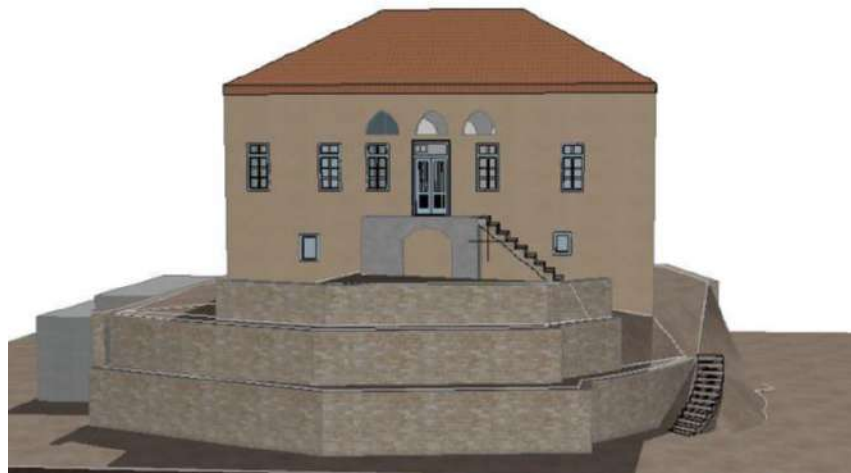


Jbeil House – Byblos – North Lebanon



Laser scanning point cloud output

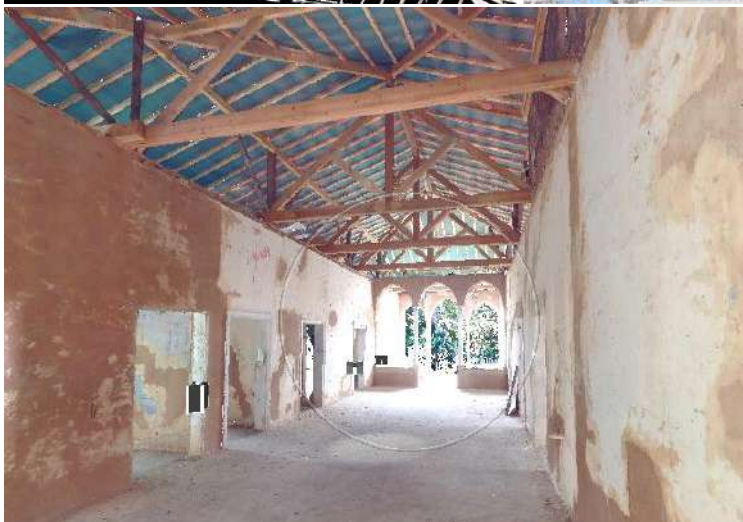




From Scan to HBIM

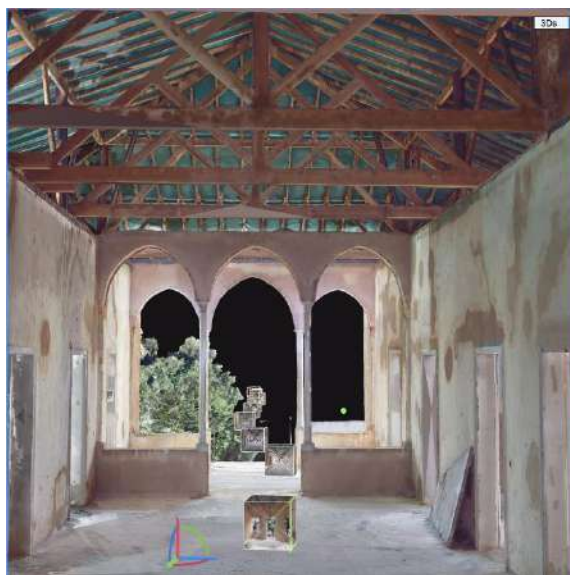


Rmeil 360 – Beirut



Inner views and Attic - Point clouds - Laser scanning





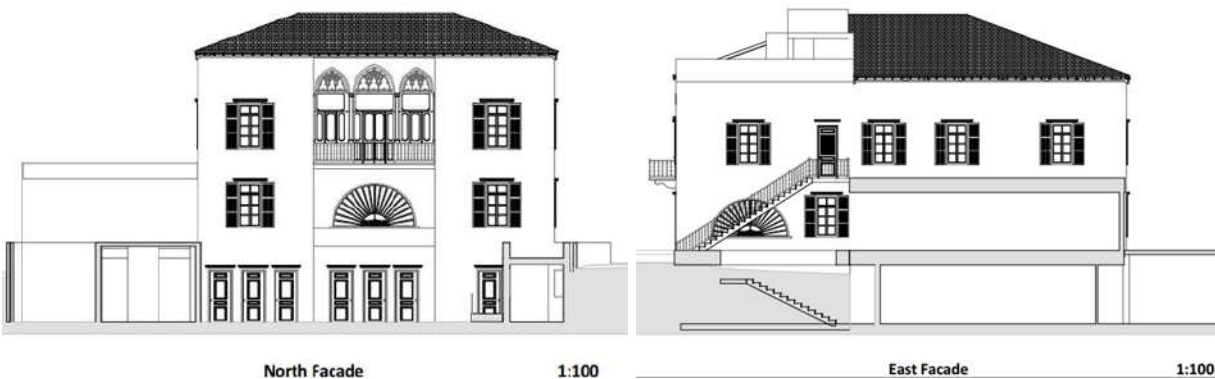
3D Model and 3D sections by Laser scanning





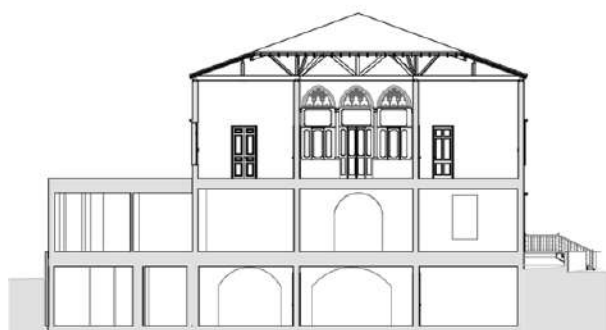
3D model: Photogrammetry





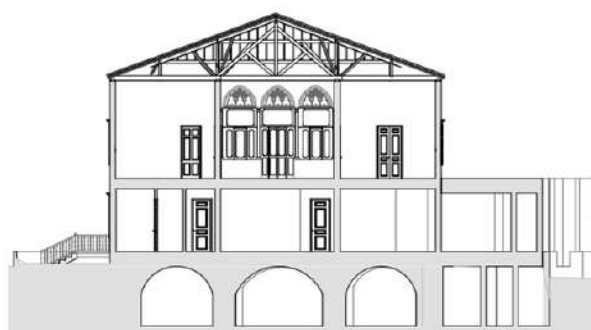
From scan to HBIM





Section AA

1:100



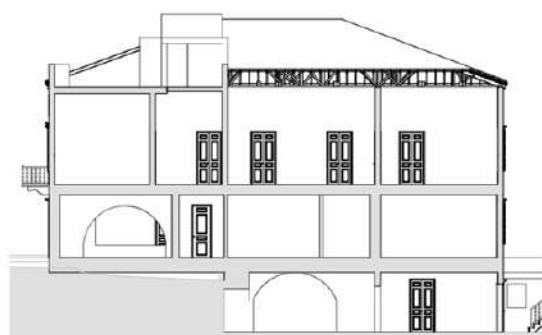
Section CC

1:100



Section BB

1:100



Section DD

1:100

From scan to HBIM

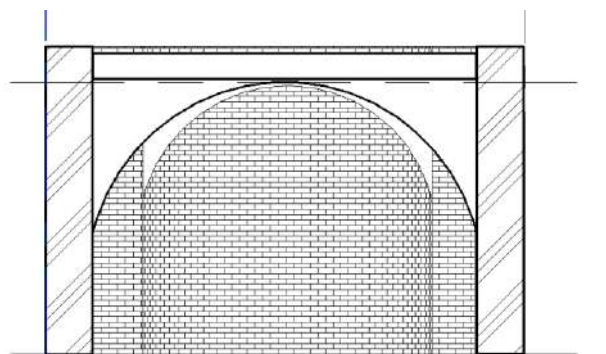
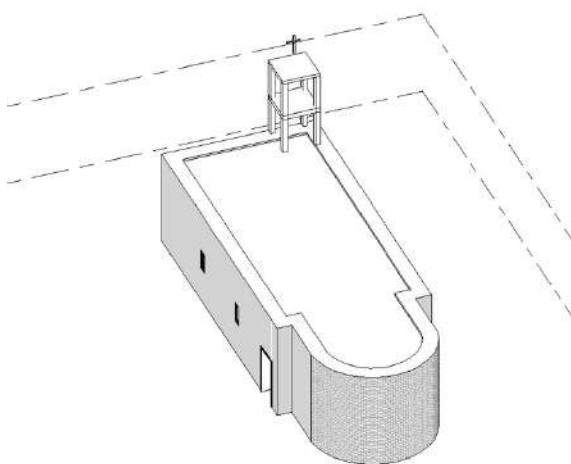
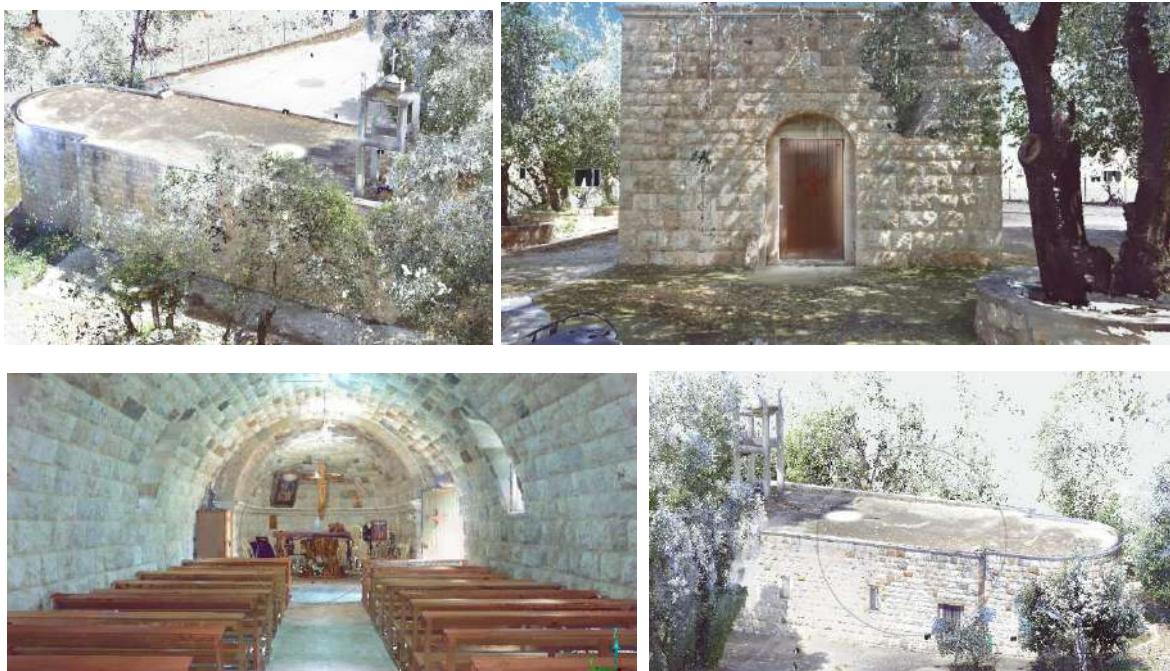
St Georges Church – Besebel – North Lebanon



3D model Photogrammetry



ST Eberyan Church – Kferzaina – North Lebanon



Laser scanning point cloud output/HBIM





3D Model and sections by Laser scanning



Hadid 124 – Tripoli – North Lebanon



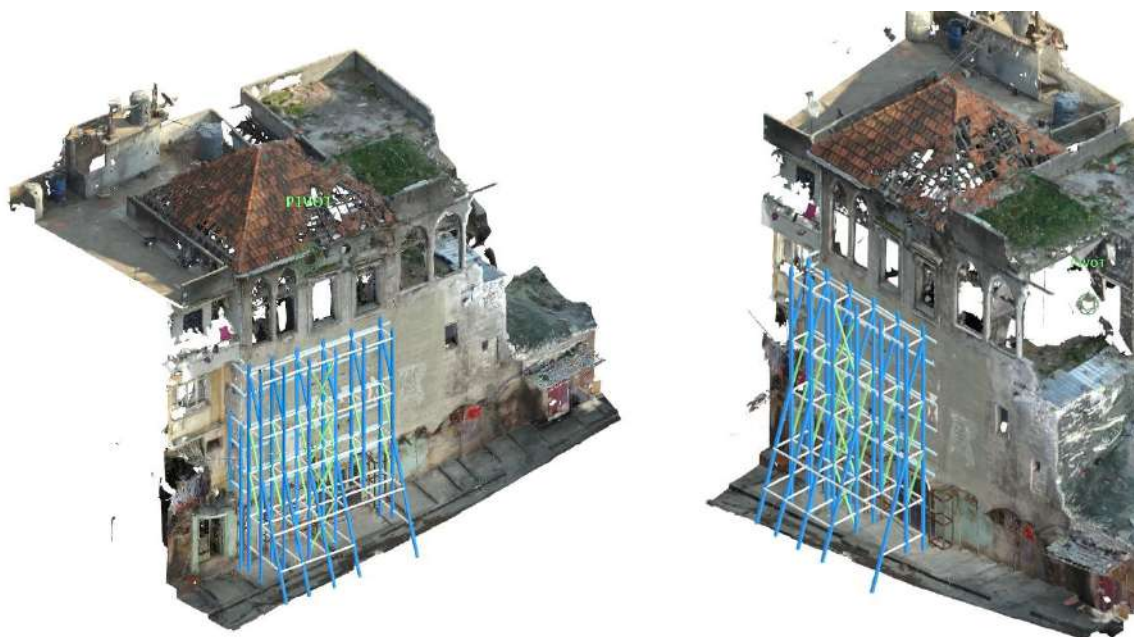
3D point clouds by combination of laser scanning and photogrammetry





3D Model by combination of laser scanning and photogrammetry





Scan to Required Intervention for built heritage at risk



Scan to 4D and 5D Simulation



Old city of Tripoli – North Lebanon Structural Assessment on GIS for structural health monitoring



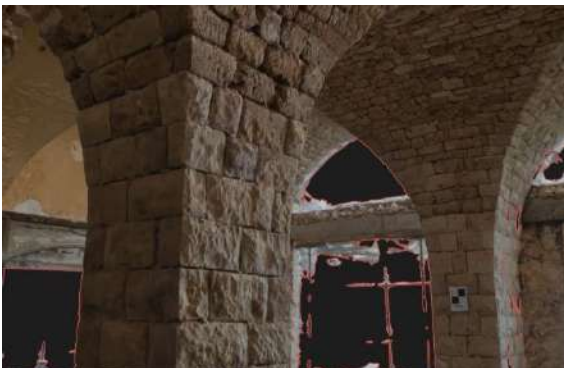
Field Structural assessment results and data on GIS



Ashrafieh 726 – Beirut – Lebanon



3D point clouds by combination of laser scanning and photogrammetry



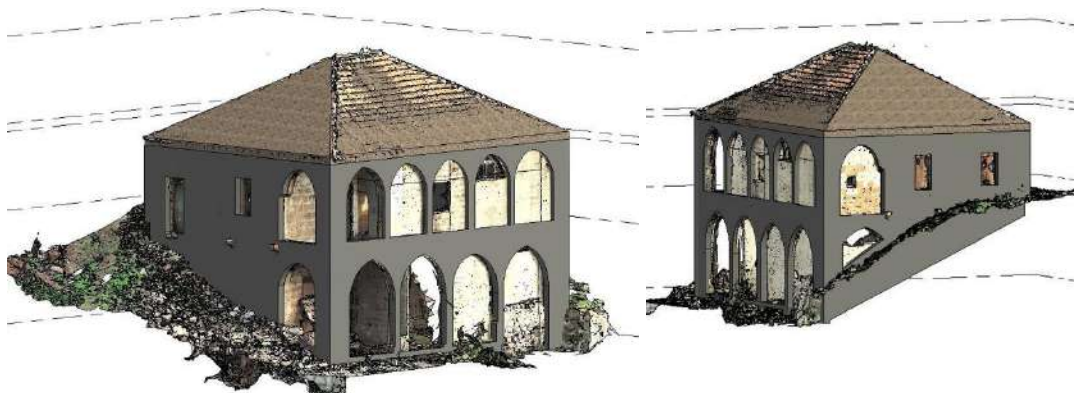
3D Model by combination of laser scanning and photogrammetry



Bayt Hasroun – North Lebanon



3D Model photogrammetry



BIM Model



4. NON-DESTRUCTIVE TESTING



Aleppo Citadel - Syria: Entrance main Tower and bridge



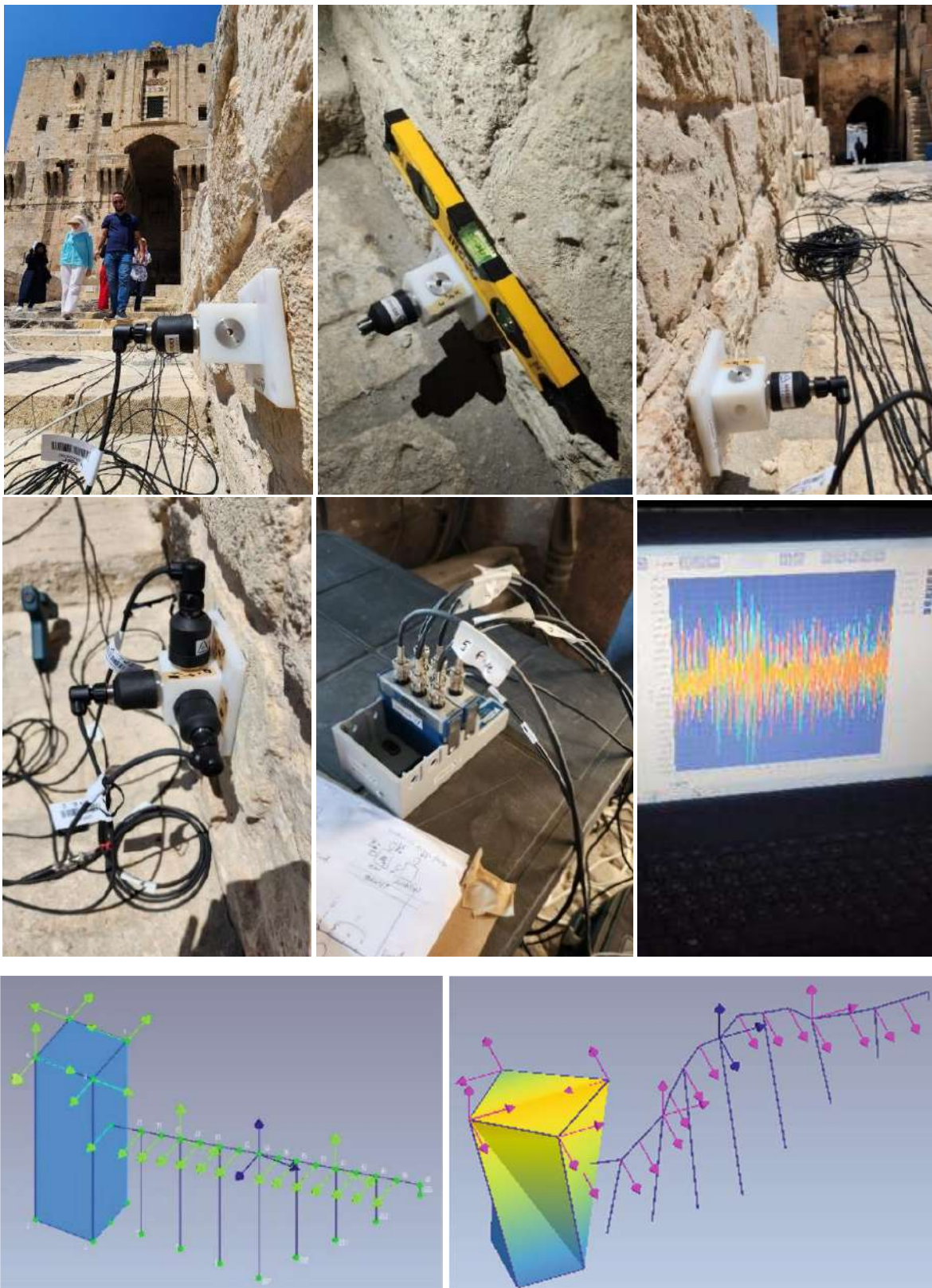
Sonic testing for masonry pillars



Endoscopy for masonry pillars



Experimental dynamic identification



The house of Wonders – Zanzibar

Photos before the different collapses



Historic photos

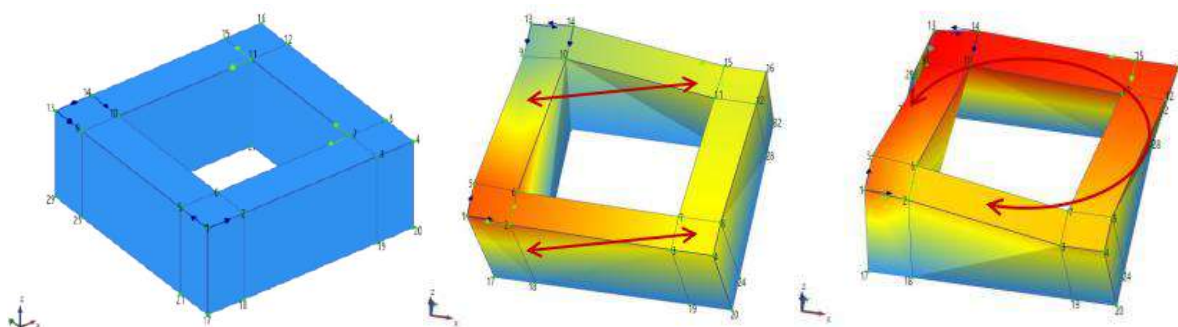
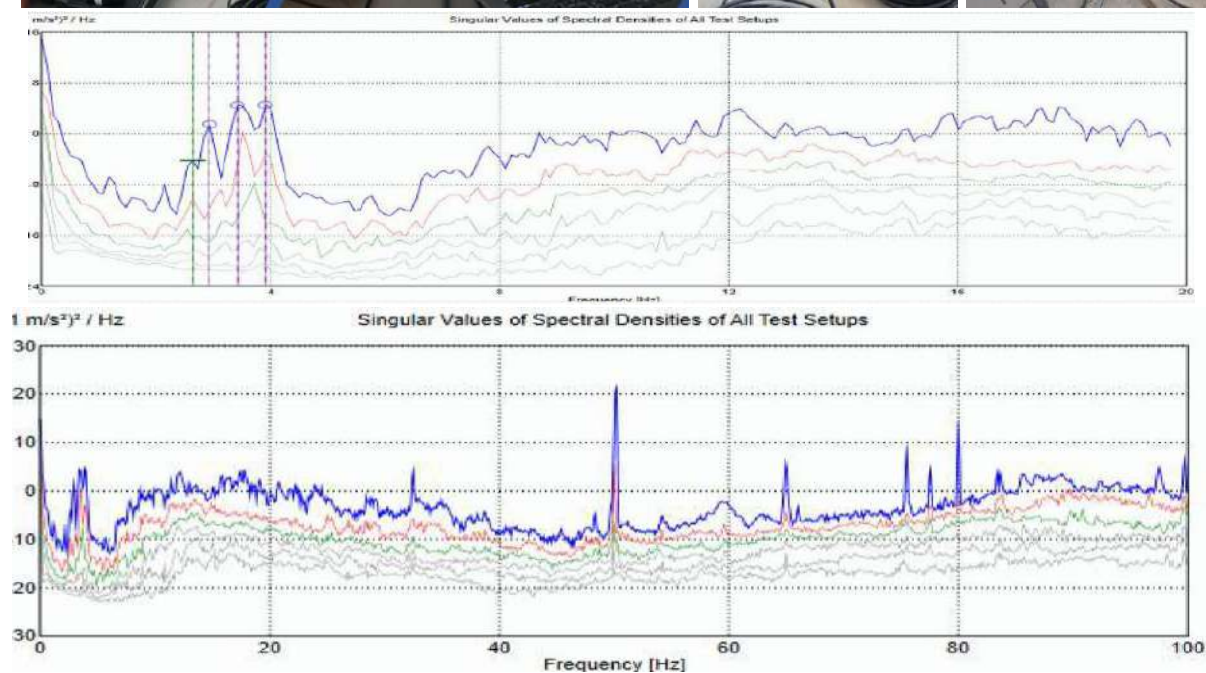


Photos after multiple partial collapses

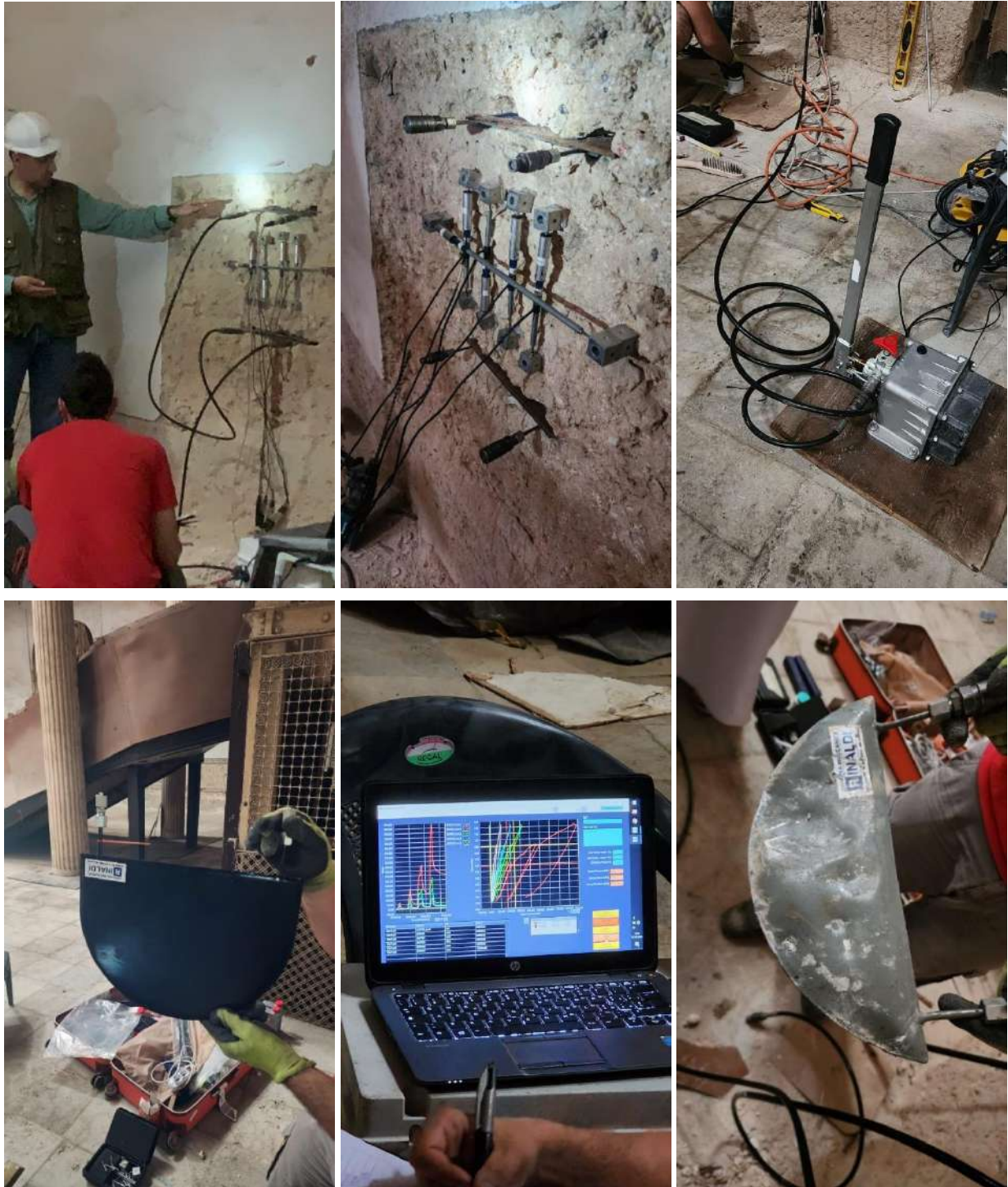


Non-destructive testing campaign

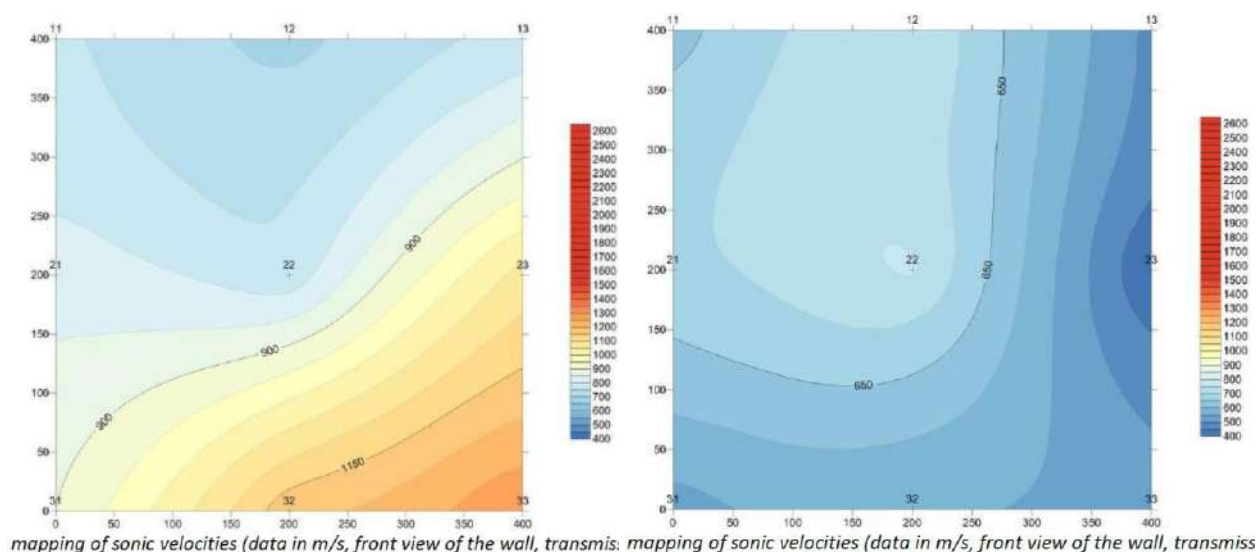
Experimental dynamic identification



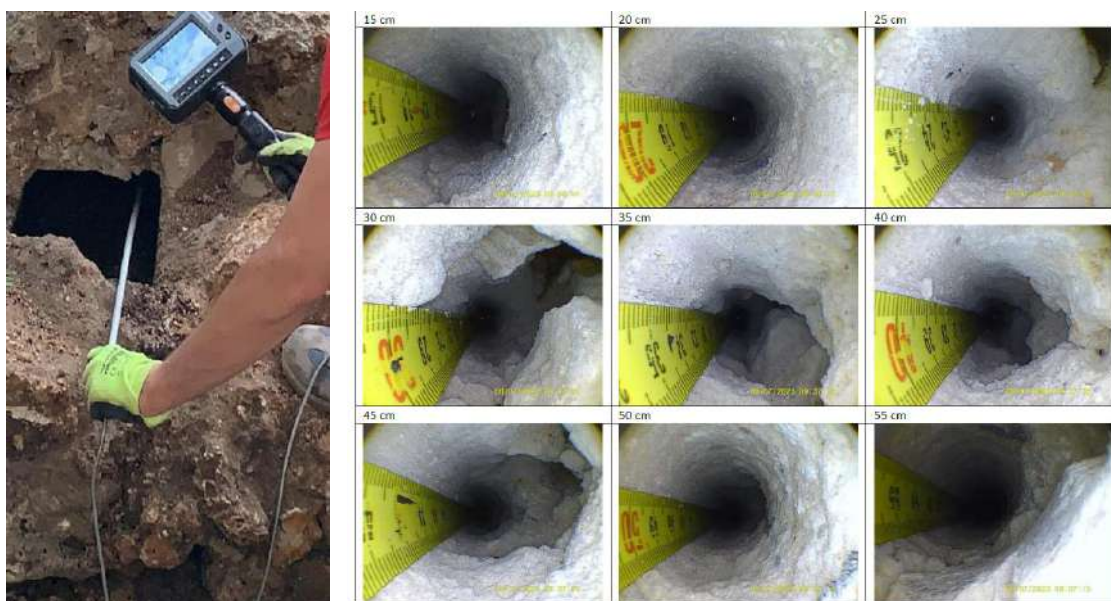
Double flat-jack on lime concrete walls



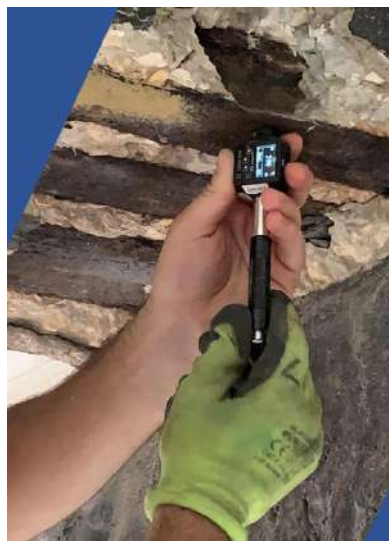
Sonic on foundations and walls



Endoscopy on foundations and walls



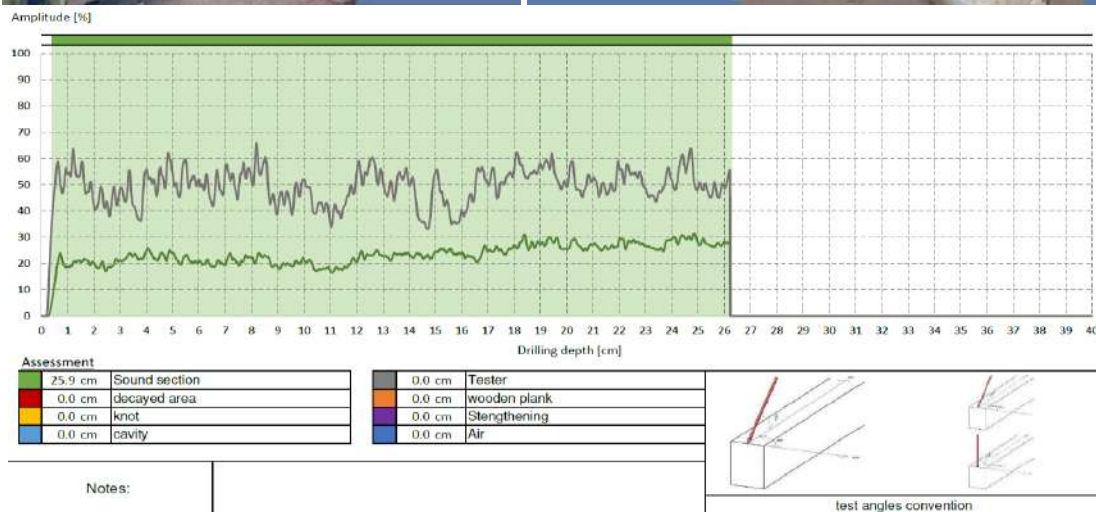
Hardness test on Iron



Schmidt hammer on concrete



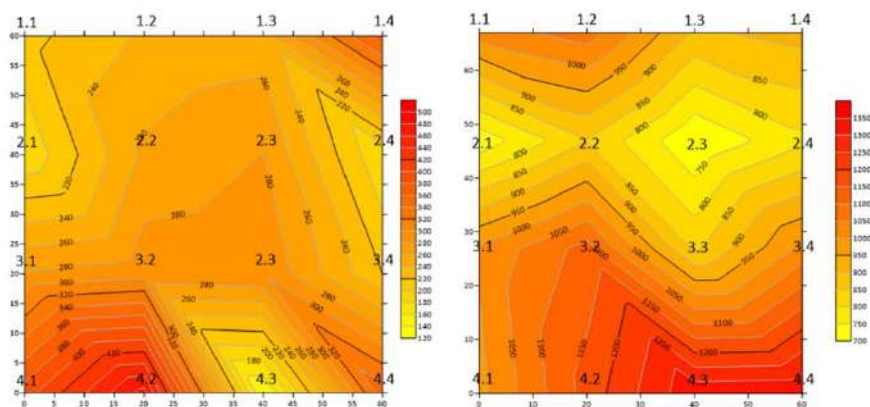
Resistograph on wooden elements



Omani French Museum- Sultanate of Oman



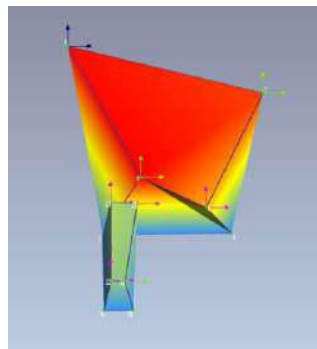
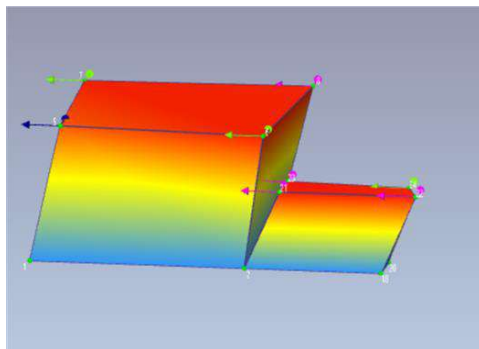
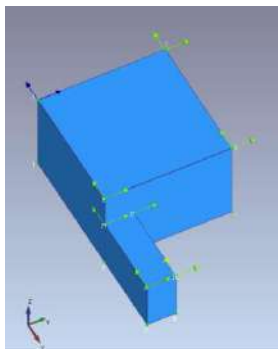
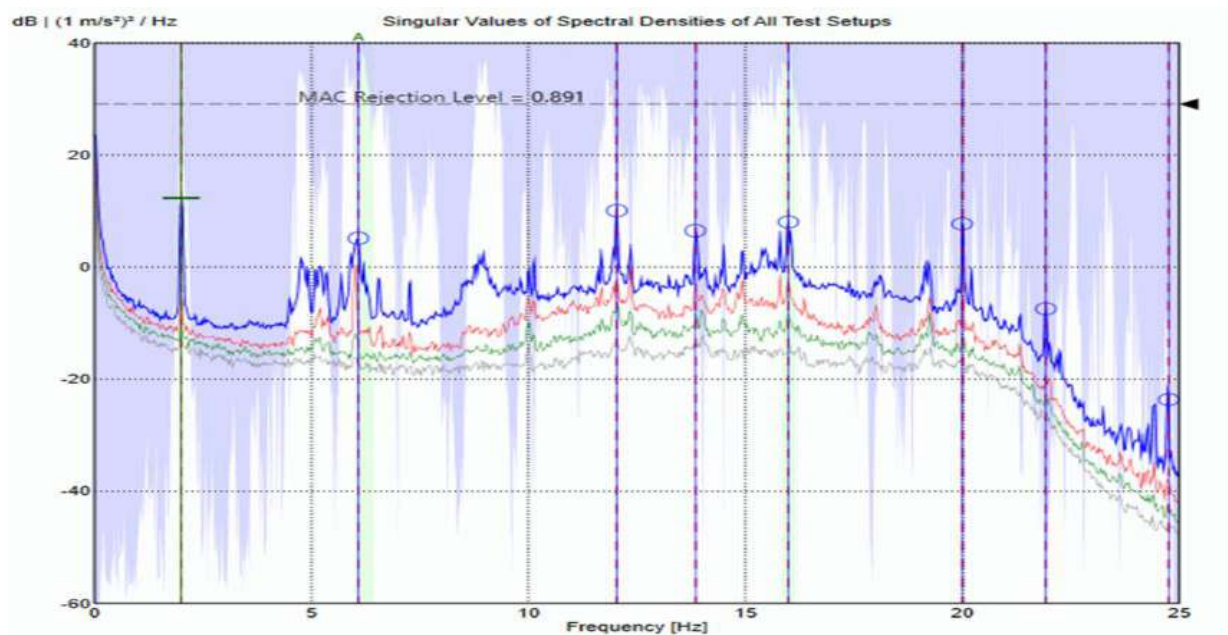
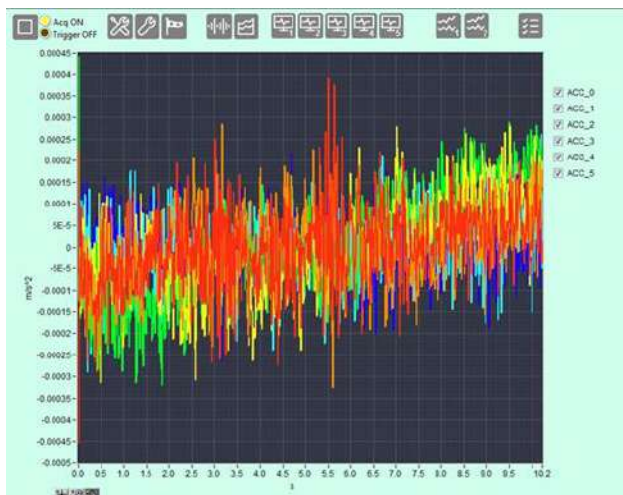
Sonic on foundations and walls



Endoscopy on foundations and walls



Experimental dynamic identification

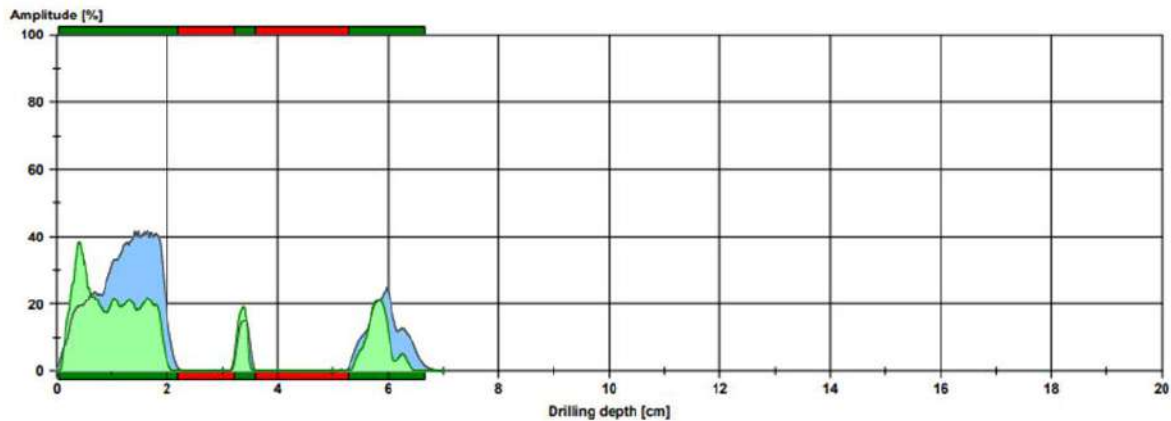


Drilling resistance on wooden elements



Measuring / object data

Measurement no.:	10	Speed	: 1500 r/min	Diameter:	
ID number	: RH.09	Needle stats:	---	Level	: First
Drilling depth	: 7.00 cm	Tilt	: -29°	Direction:	
Date	: 27.01.2024	Offset	: 57 / 272	Species	: Beam
Time	: 14:39:19	Avg. curve	: off / off	Location	: Room 5
Feed	: 25 cm/min			Name	:



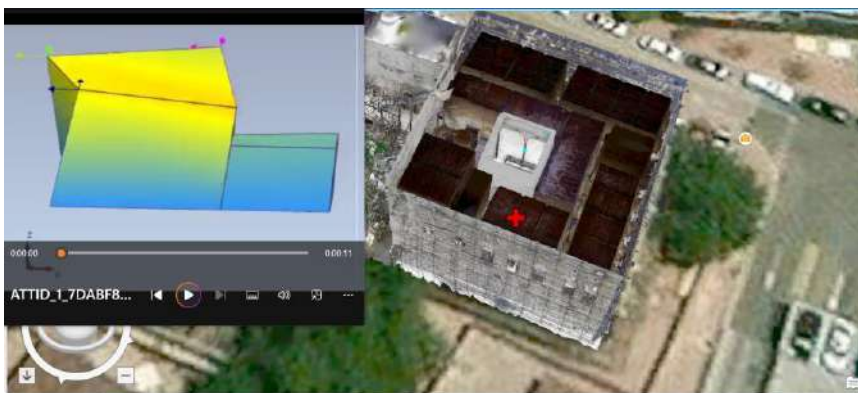
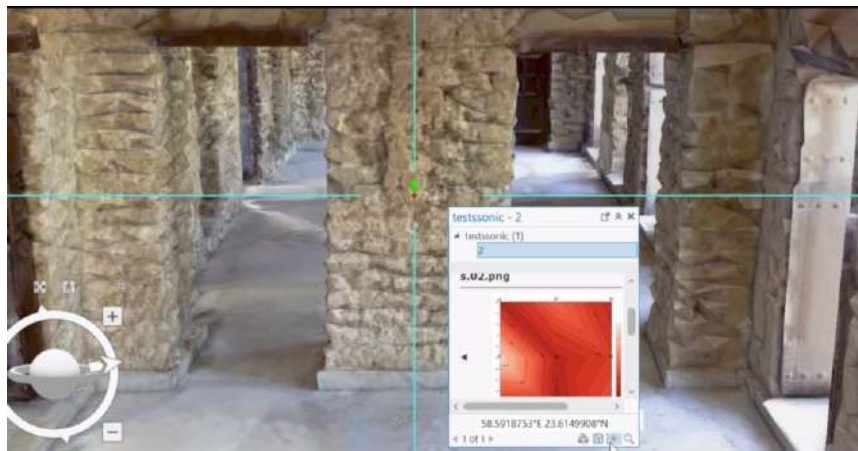
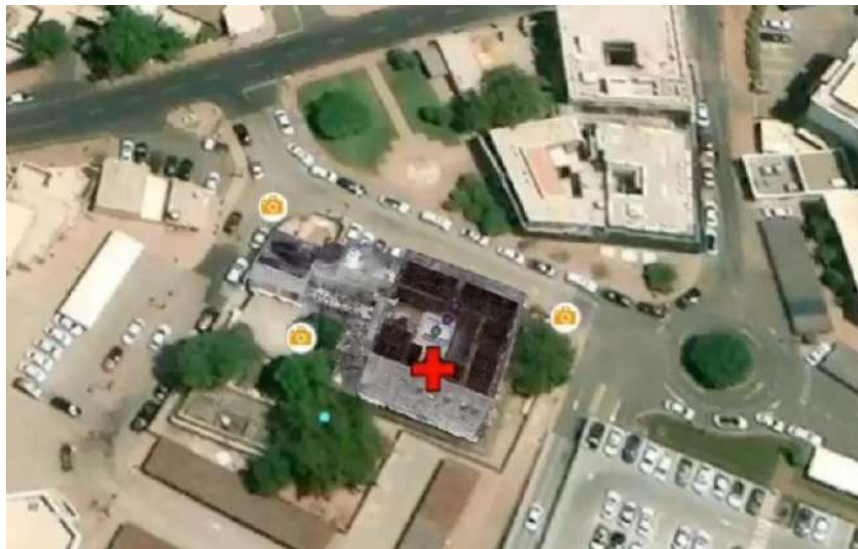
Assessment

From 0.03 cm to 2.19 cm	: Sound Section
From 2.19 cm to 3.22 cm	: Decay
From 3.22 cm to 3.60 cm	: Sound Section
From 3.60 cm to 5.28 cm	: Decay
From 5.28 cm to 6.66 cm	: Sound Section

Comment



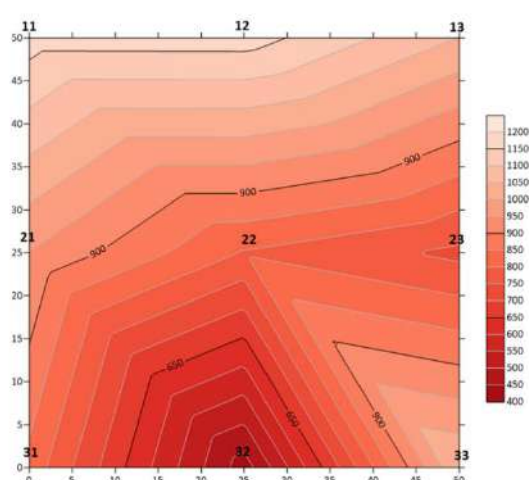
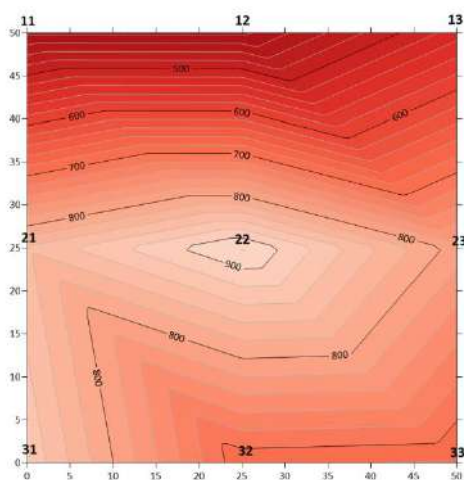
Testing results documented on the digital model for built heritage remote sensing on GIS



Bait Al Sahel - Zanzibar



Sonic on foundations and walls



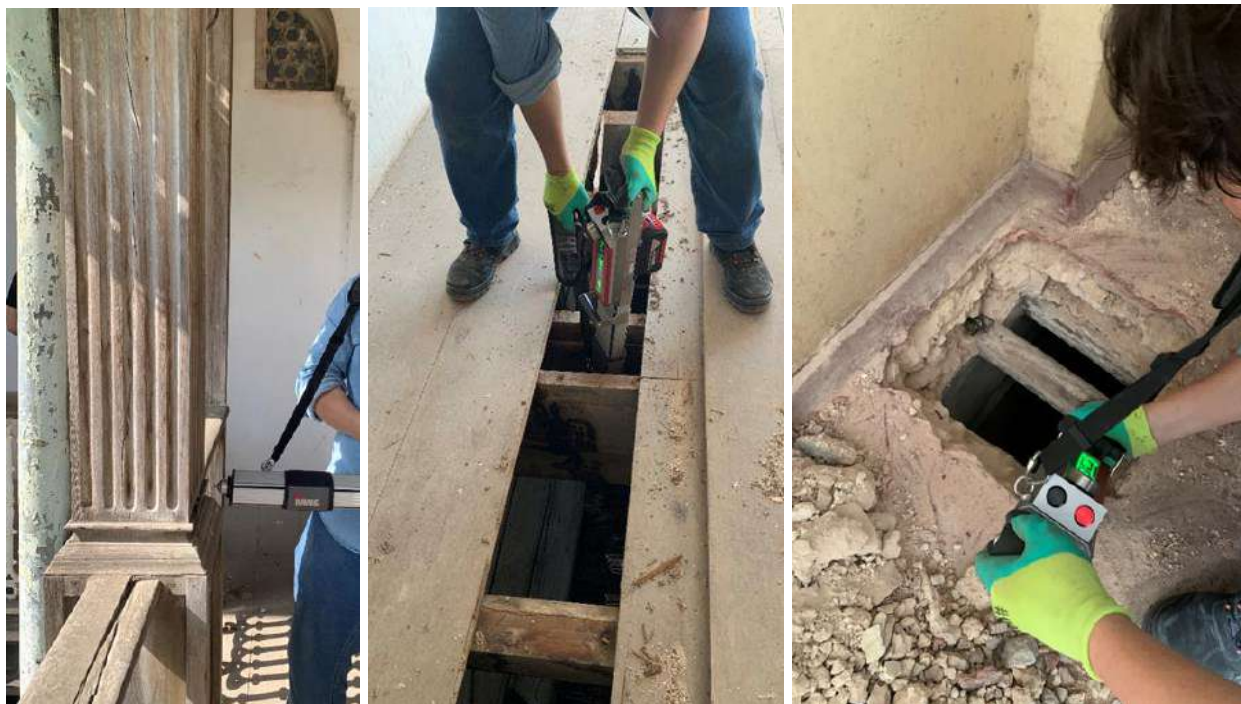
Endoscopy on foundations, walls, columns, and slabs



END.01			
0 cm	5 cm	10 cm	15 cm
			
20 cm	25 cm	30 cm	35 cm
			
40 cm	45 cm	50 cm	55 cm
			
60 cm	65 cm	70 cm	73 cm
			

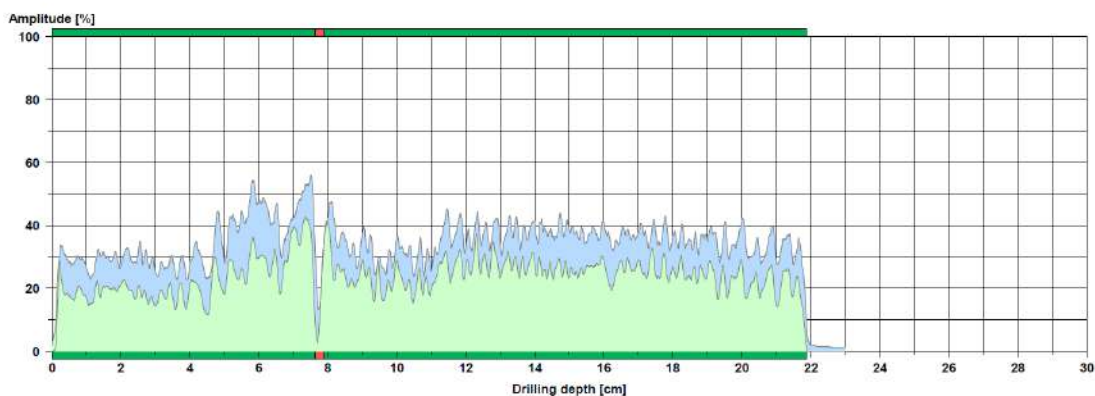


Drilling resistance on wooden elements



Measuring / object data

Measurement no.:	5	Speed	: 1500 r/min	Diameter:	
ID number	: RH.05	Needle state:	—	Level	: F1
Drilling depth	: 23,00 cm	Tilt	: 0°	Direction:	
Date	: 15.12.2024	Offset	: 72 / 399	Species	: COLUMN 22.5 x 22.5
Time	: 15:19:49	Avg. curve	: off / off	Location	: 1.16
Feed	: 100 cm/min			Name	: BAIT AL SAHEL



Assessment

From 0,00 cm to	7,63 cm	: Sound Section
From 7,63 cm to	7,88 cm	: Decay
From 7,88 cm to	21,87 cm	: Sound Section

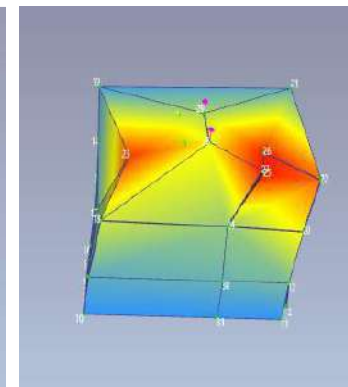
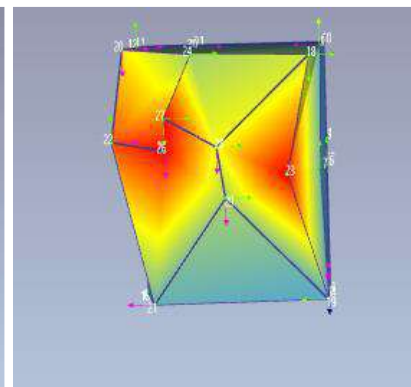
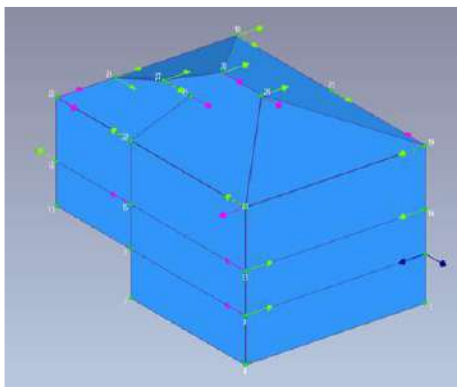
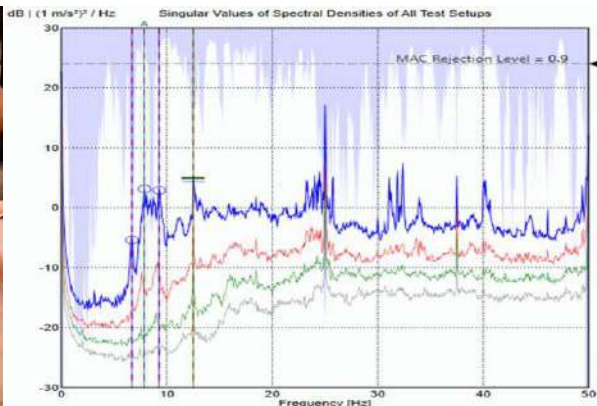
Comment



Rmeil 360 - Beirut - Lebanon



Dynamic identification – Operational Modal Analysis



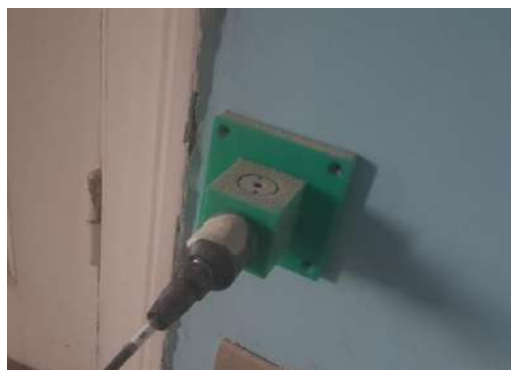
Endoscopy for masonry walls



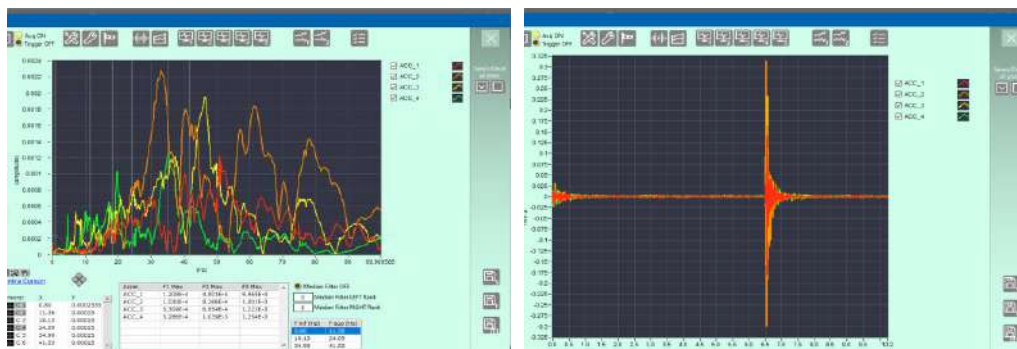
Resistograph for wooden elements



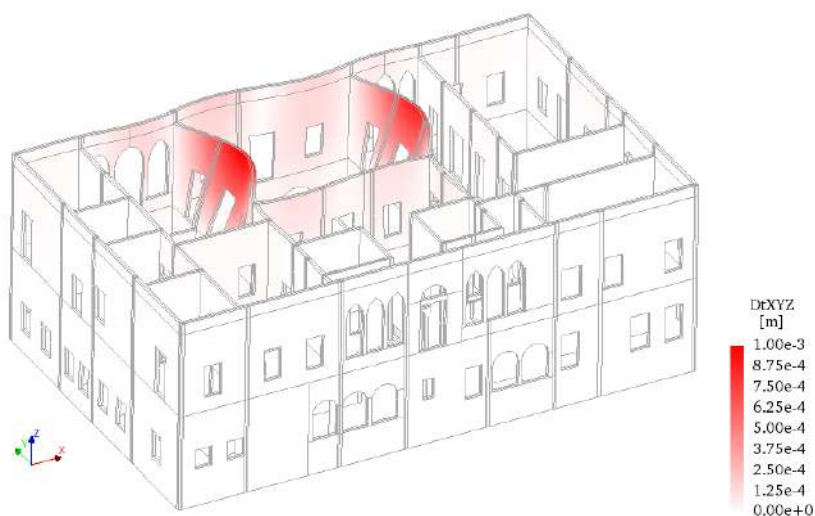
Dynamic identification test of the Greek Orthodox Archbishopry - Beirut – Lebanon (Before Restoration)



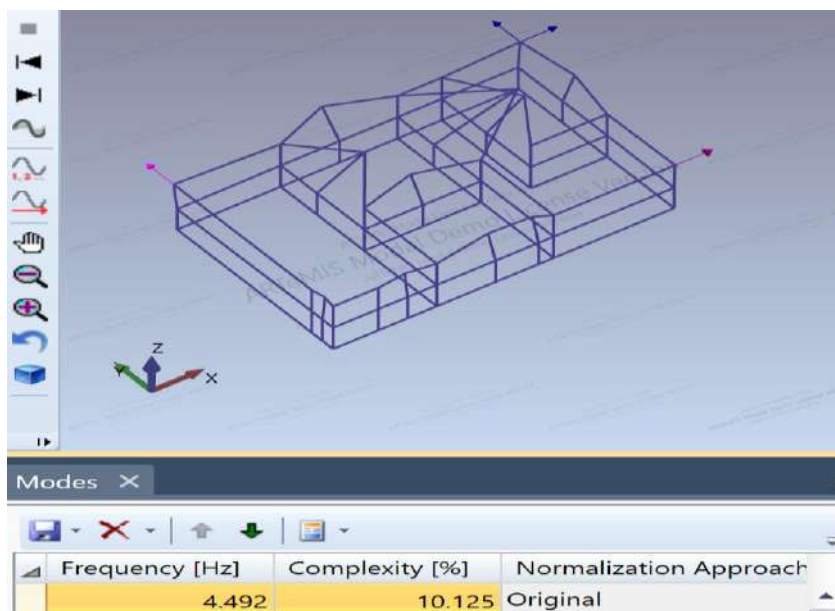
Data acquisition



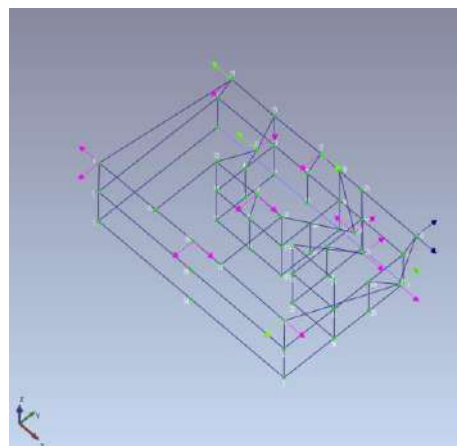
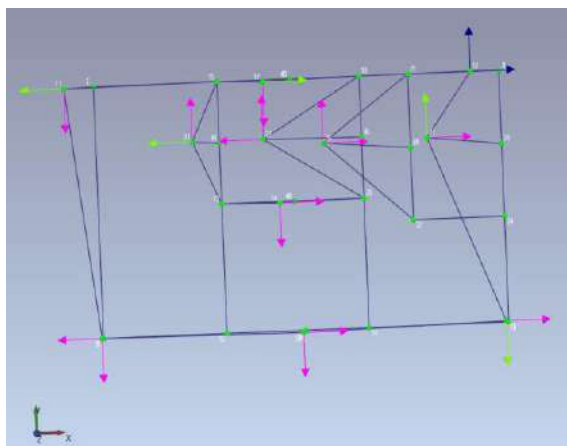
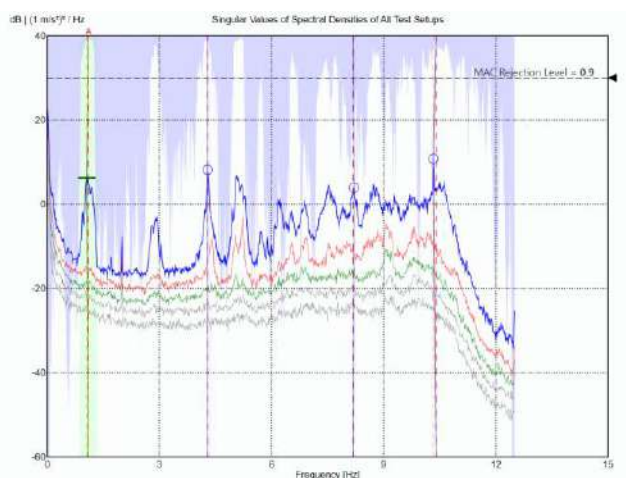
Numerical mode shapes



Experimental mode shapes



Dynamic identification and Drilling resistance test of the Greek Orthodox Archbishopry - Beirut – Lebanon (During Restoration)

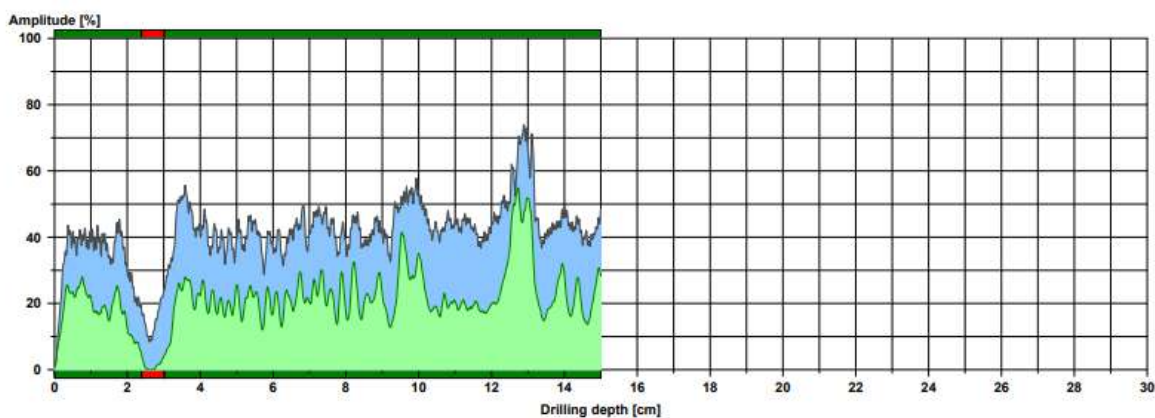


Resistograph/ Drilling resistance test for wooden elements



Measuring / object data

Measurement no.:	2	Speed	: 1500 r/min	Diameter:	
ID number	: A1	Needle state:	—	Level	:
Drilling depth	: 15,00 cm	Tilt	: -90°	Direction:	
Date	: 31.07.2024	Offset	: 93 / 259	Species	: Joist 15*7.5 cm
Time	: 10:35:41	Avg. curve	: off / off	Location	: Room 1
Feed	: 200 cm/min			Name	:



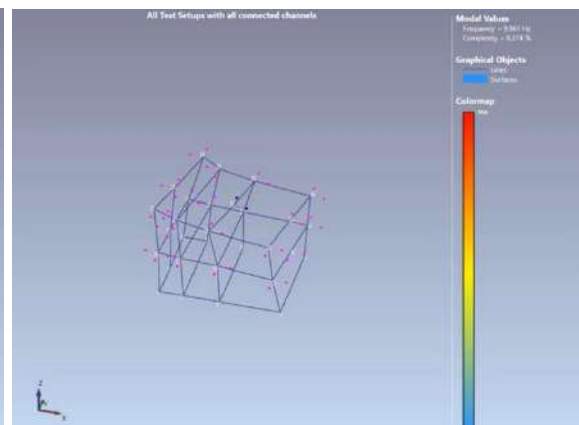
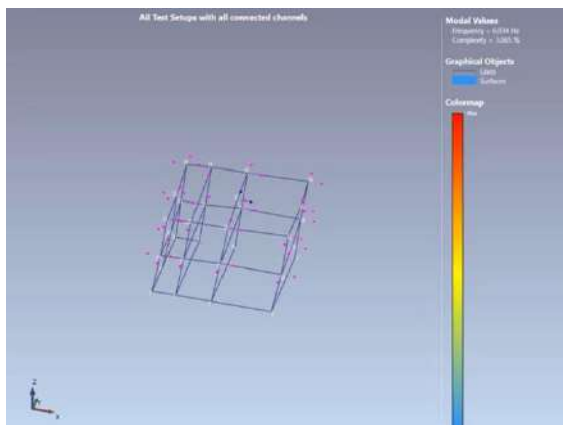
Assessment

From 0,00 cm to	2,39 cm	: Sound Section
From 2,39 cm to	3,02 cm	: Decay
From 3,02 cm to	15,00 cm	: Sound Section

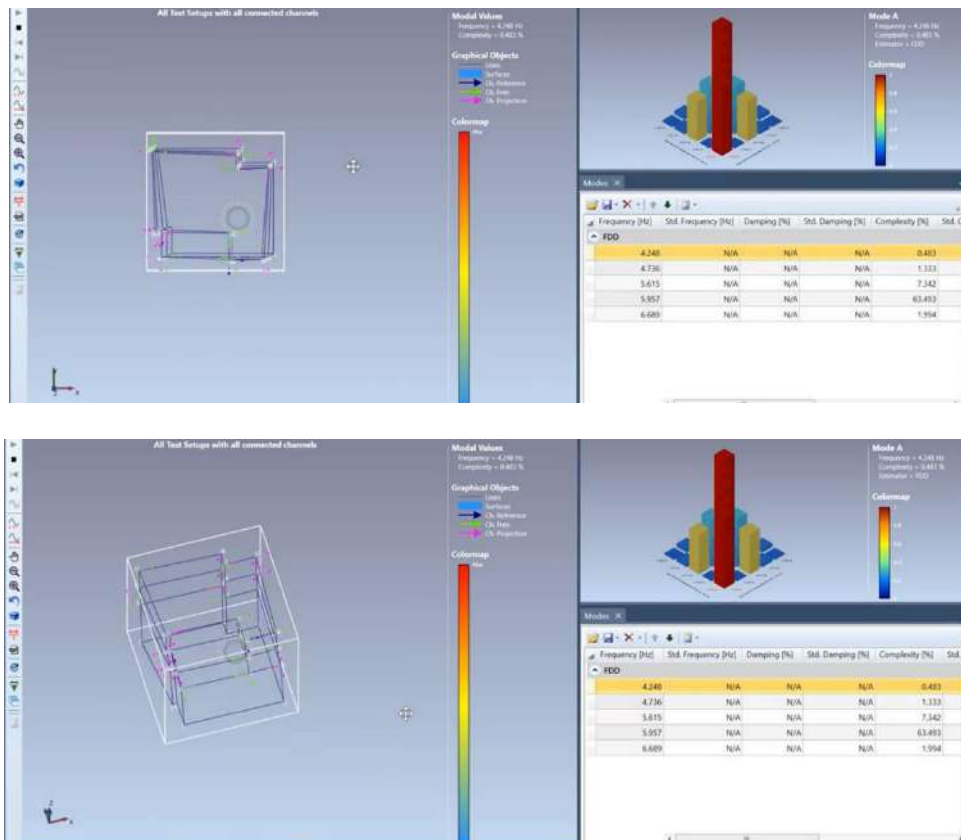
Comment



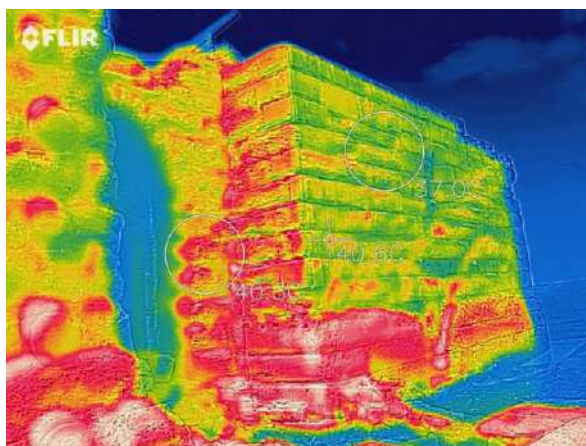
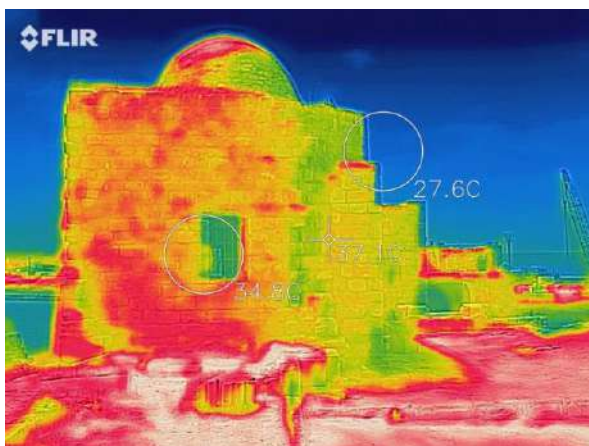
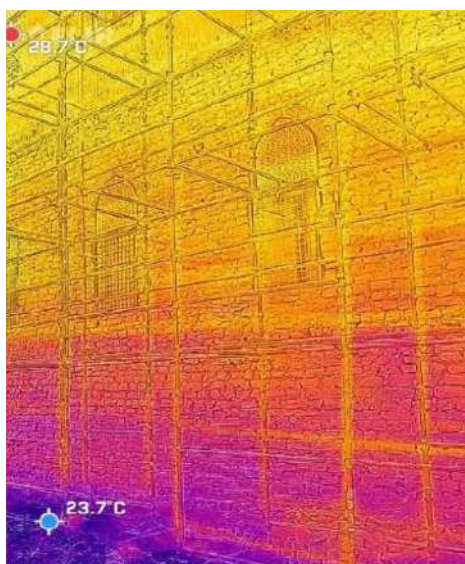
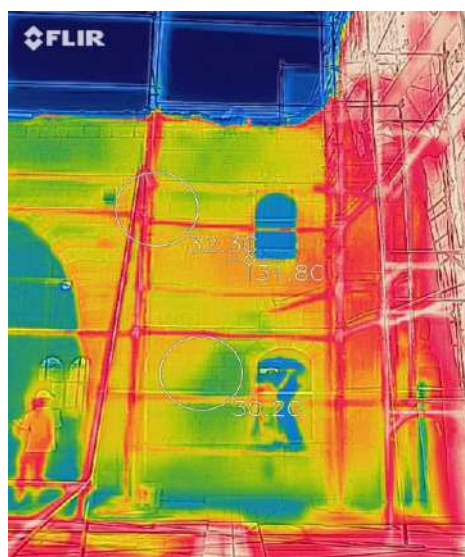
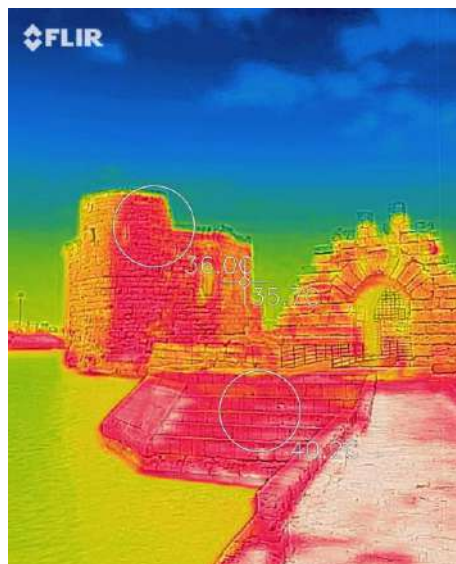
Dynamic identification test of Rmeil 264 - Beirut – Lebanon (During Restoration)



Dynamic identification test of 694 Building- Beirut – Lebanon (During Restoration)



Thermal imaging: Saida sea castle and Baz Palace – Deir AL Qamar , Lebanon



5. BUILT HERITAGE



5.1 Archeological sites

World heritage: Rehabilitation of Pedestrian Trail from Hasroun to Wadi Kadisha and restoration of S^t Asia Monastery (Contracting)

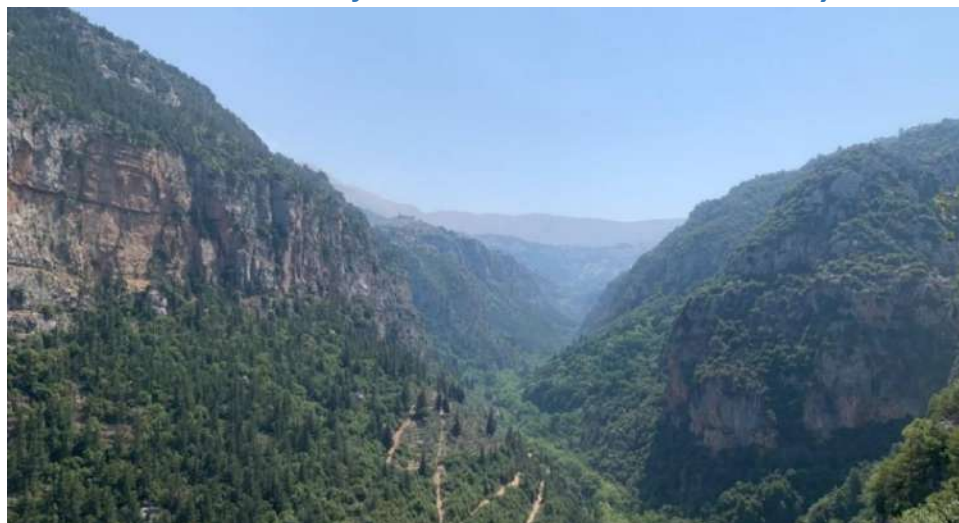
Restoration of S^t Asia Monastery



Restoration of S^t Asia Monastery



Rehabilitation of the trail: Hasroun – Qadisha Valley



Rehabilitation of the trail: Hasroun – Qadisha Valley

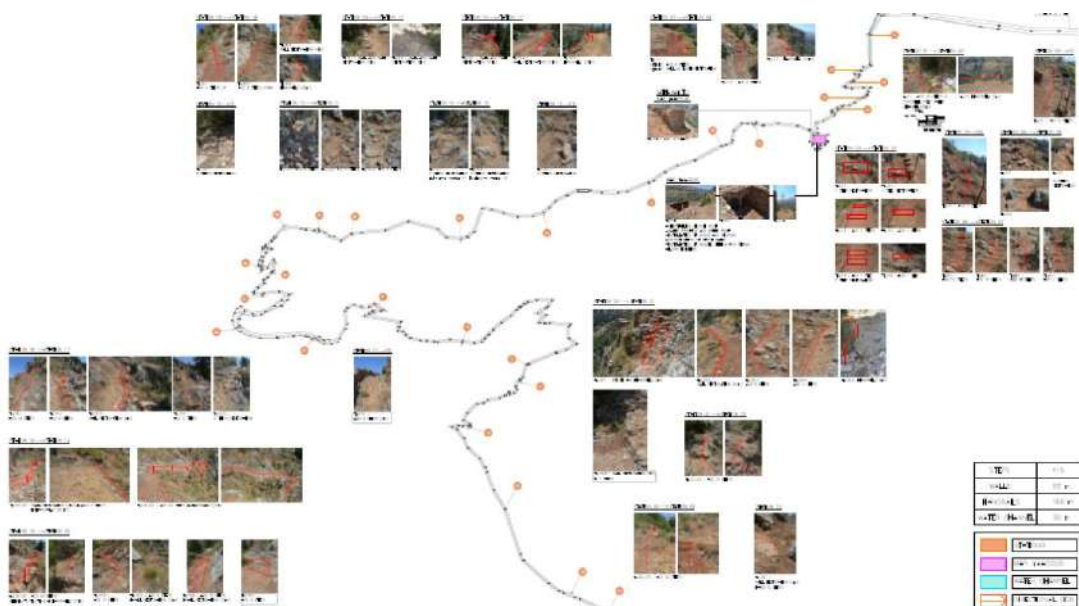


World Heritage - Lebanon

Rehabilitation of Pedestrian Trail Bcharreh - Wadi Kadisha and restoration of St James church (Contracting)



Trail leading from St James church- Bcharreh to Mar Alichaa- Holy Valley



Trail Key Plan





Panoramic station



Pedestrian bridge



St James Church before restoration



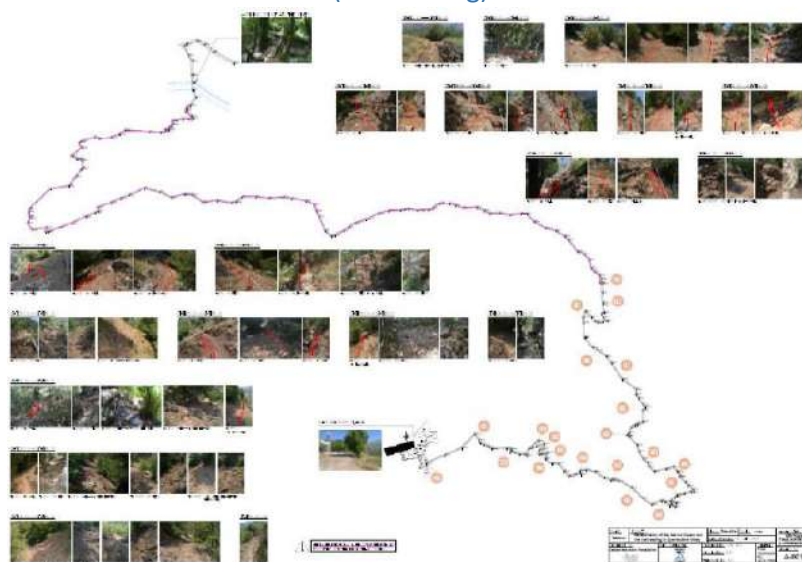
St James Church after restoration



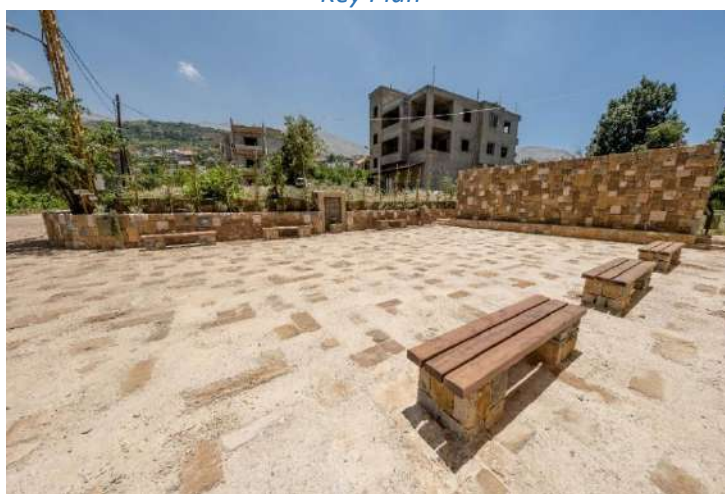
UNESCO World Heritage - Lebanon

Rehabilitation of Pedestrian Trail connecting Bazaoun to Wadi Qannoubine

(Contracting)



Key Plan



Plaza-Gathering point at the beginning of the trail

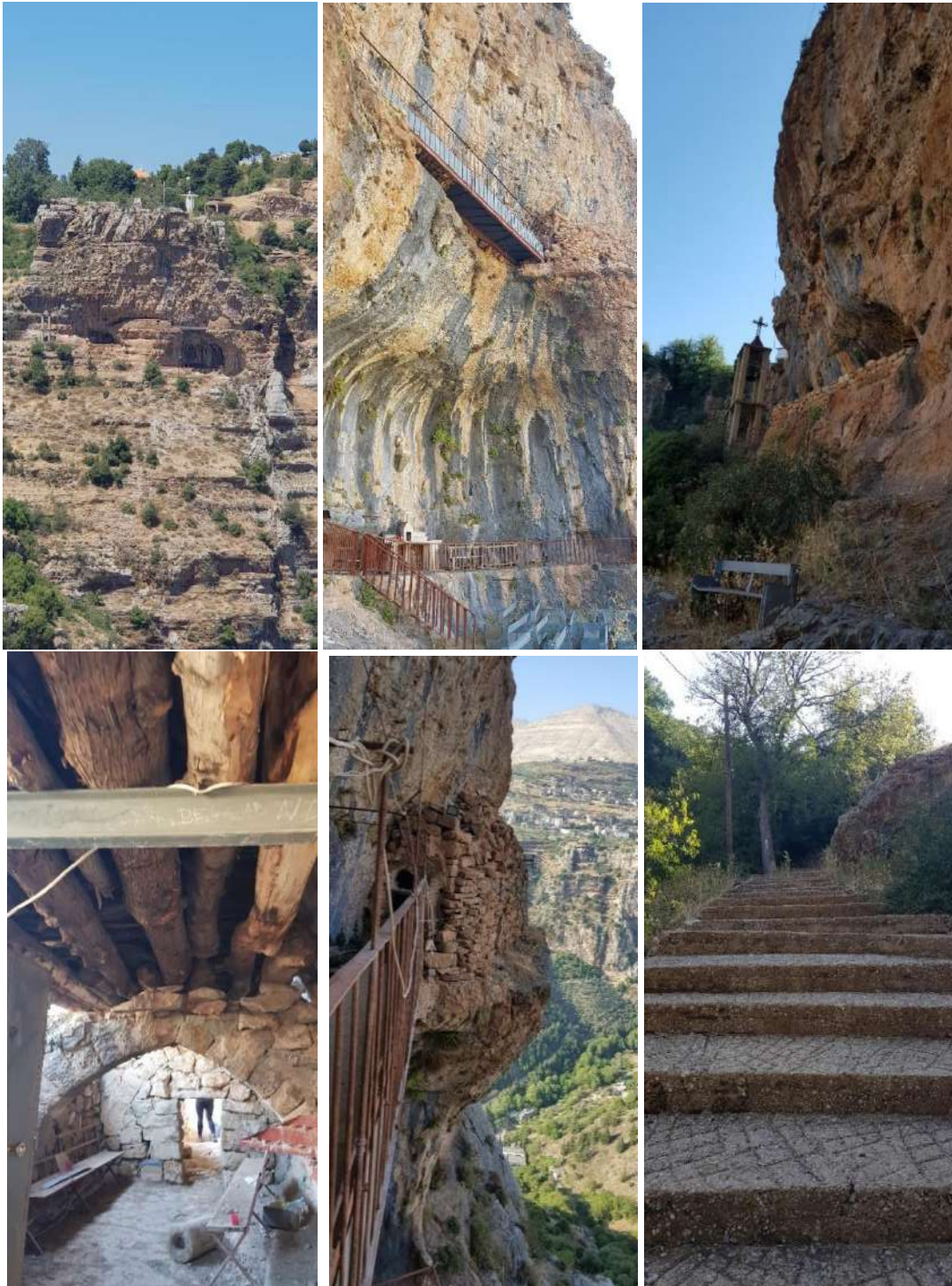


Some stations of the trail after rehabilitation



UNESCO World Heritage - Lebanon

Rehabilitation of St Semaan Monastery in Bkerkasha and the touristic trail - Wadi Qadisha (Contracting)



St Semaan Monastery before restoration





St Semaan Monastery after restoration



World Heritage - Lebanon

Rehabilitation of Hadath Al Jebbeh Water Mills and the Pedestrian trail (Contracting)



During execution





Mills restoration in progress



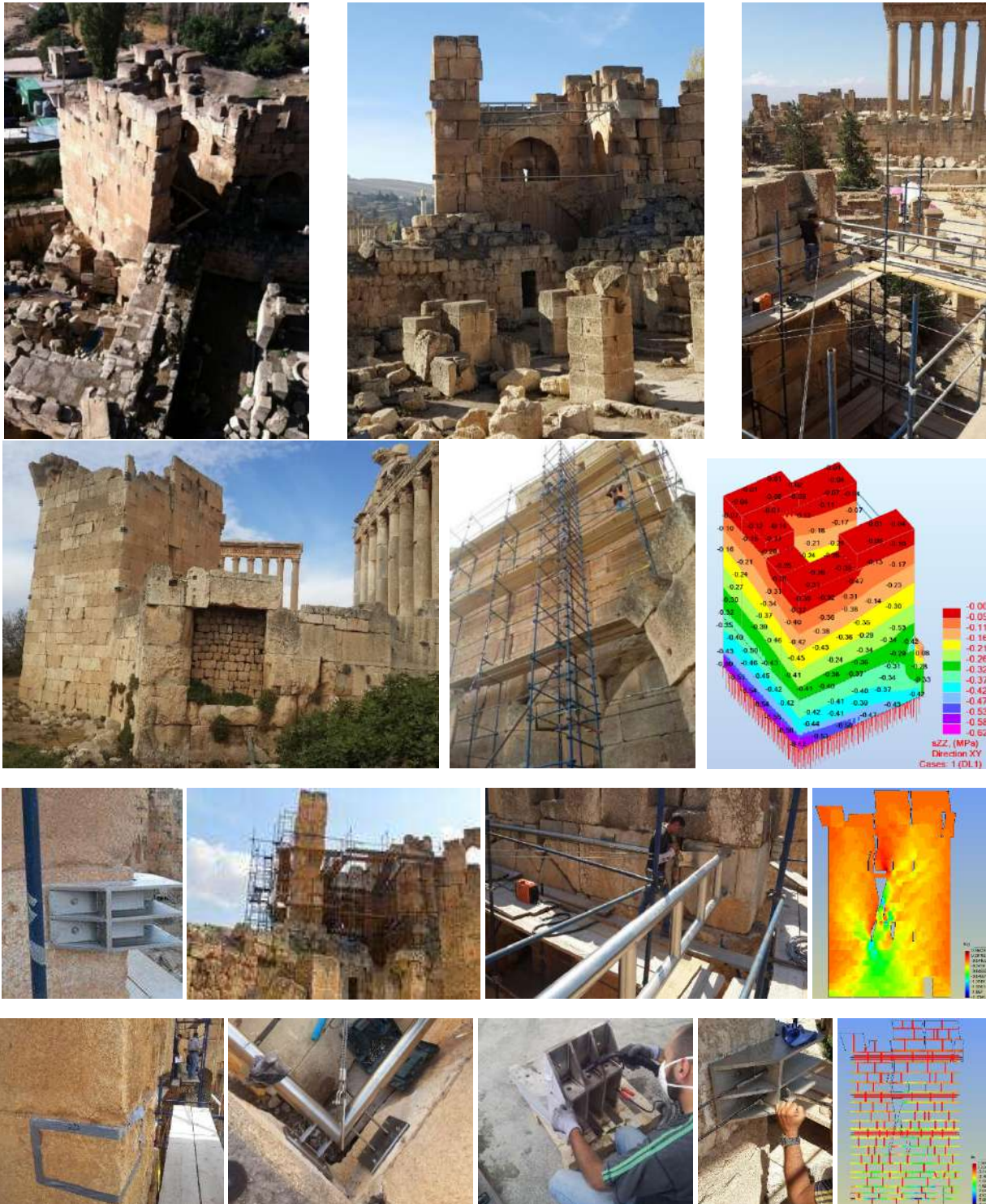
Hadath Al Jebbeh water mills - After restoration works



5.2 Seismic assessment & Retrofitting

World Heritage - Lebanon - Baalbek Temple - Arab Tower

Retrofitting (Design - build)

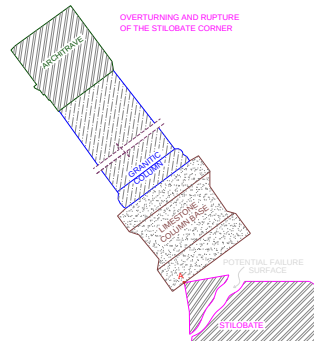
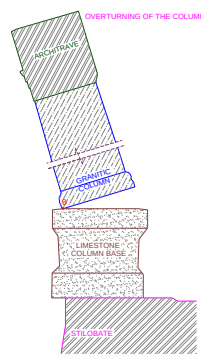
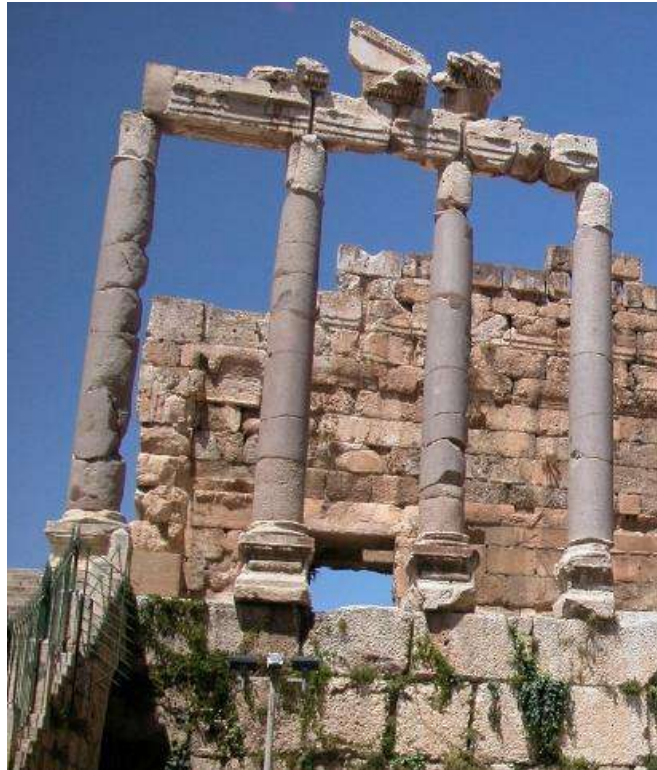




ARAB TOWER – BAALBEK: CONCEPT OF THE CONSOLIDATION SYSTEM AND DETAILS



UNESCO World Heritage – Lebanon Baalbek Temple – Propylaea – Retrofitting (Design build)



National Heritage - Lebanon

Saida Sea Castle - Restoration and Retrofitting

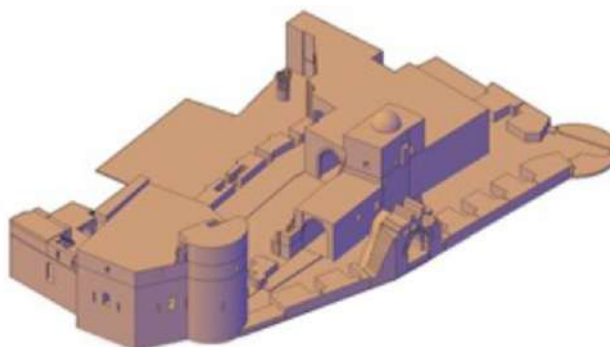
(Design – Build)



Rehabilitation work in the main entrance area

Main Gate consolidation

Consolidation of local structural elements: Arase treatment, injection of sealer cracks





Interior view of the dome in the Mosque



Walls of the main entrance



Consolidation of the demolished part of the vault





Final state of the consolidated vault



National Heritage - Lebanon Chehab Palace - Deir Al Qamar

Restoration and structural consolidation (Tender package & supervision)



Photogrammetry orthomosaic





Restoration of Hammam historic domes

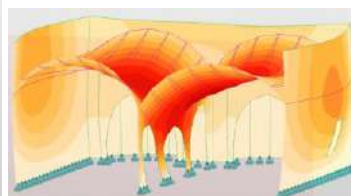
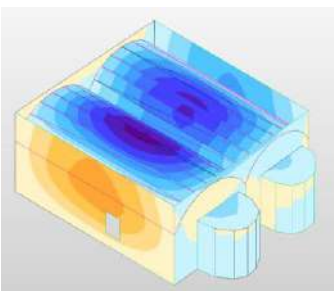


Excavation of the main court



National Heritage - Lebanon St Tehle Chamat - Jbeil

Archeology, restoration, retrofitting (Design and build)

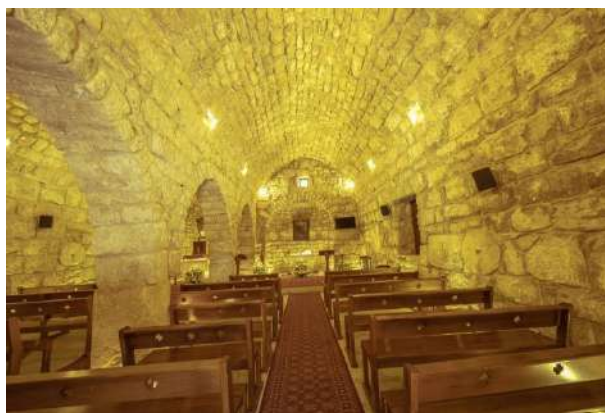


Finite Element Numerical Model



St Tehle Chamat - During execution





St Tehle Chamat - After structural restoration



National Heritage - Lebanon

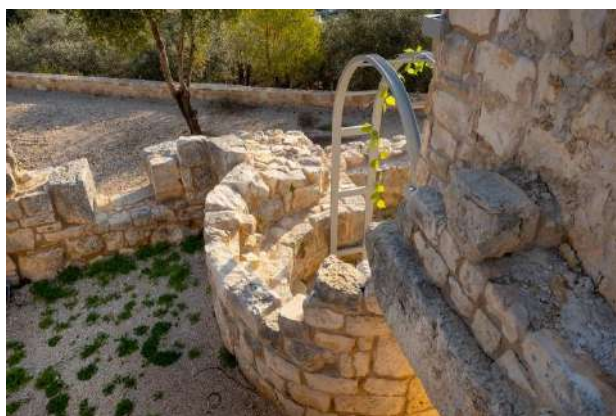
St Nicholas Behdaydet - Jbeil

Archeology, restoration, retrofitting (Design and build)



St Nicholas Behdaydet – During execution





St Nicholas Behdaydet – After restoration



National Heritage - Lebanon St Theodore Eddeh - Jbeil

Archeology, restoration, retrofitting (Design and build)



St Theodore Eddeh – During execution





St Theodore Eddeh – After restoration



National Heritage - Lebanon
St John Hardine - Batroun
Archeology, restoration, retrofitting (Contracting)



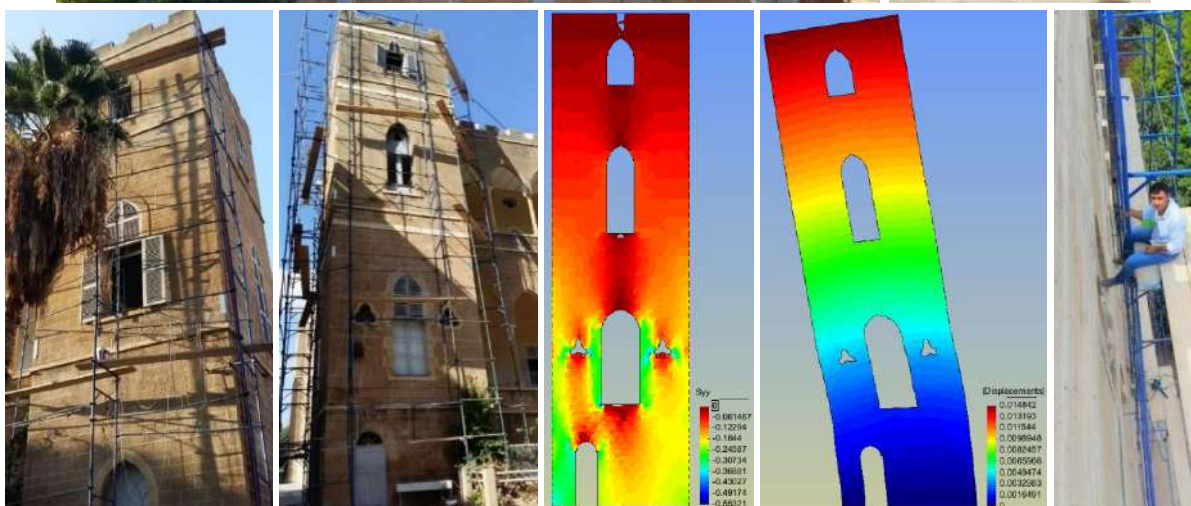
St John Hardine - During execution



St John Hardine - After restoration



National Heritage - Lebanon Nazareth Monastery Achrafieh - Beirut Retrofitting (Design build)



Rmeil 474 - Beirut : Structural restoration (Design build)



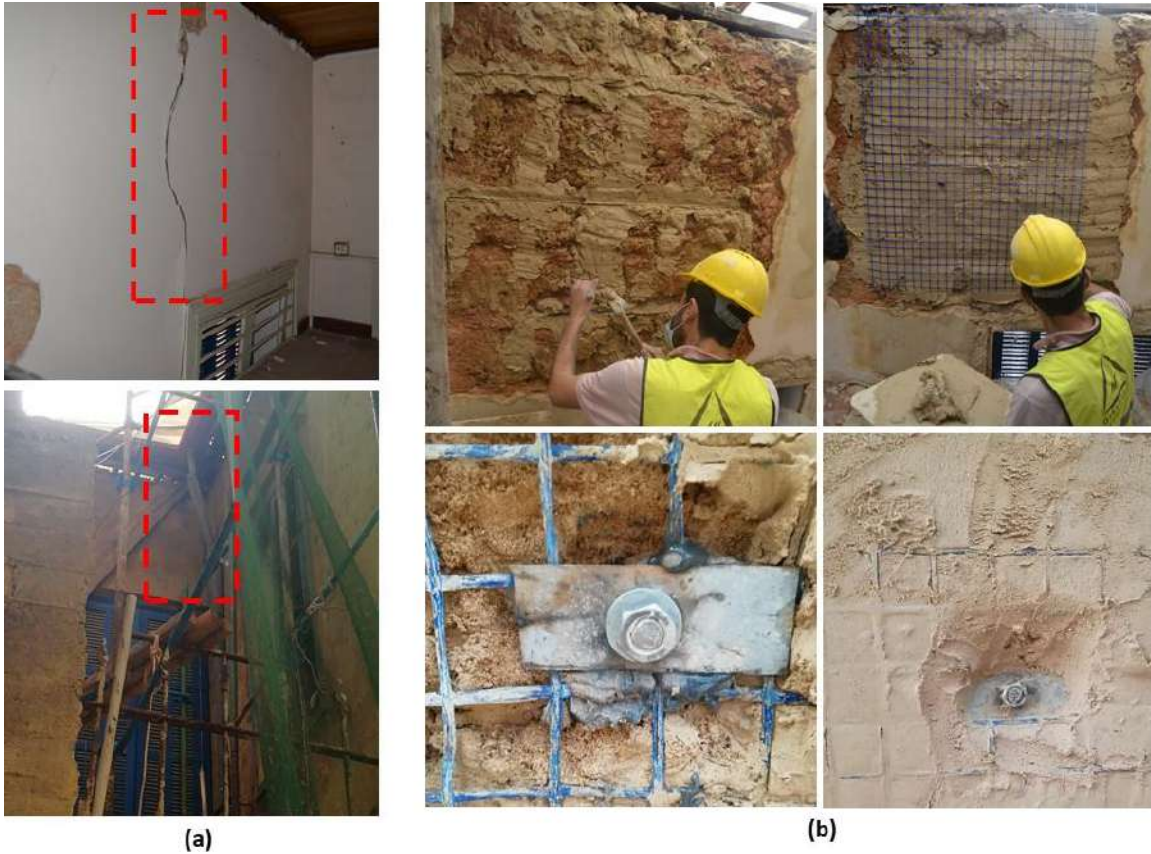
(a)



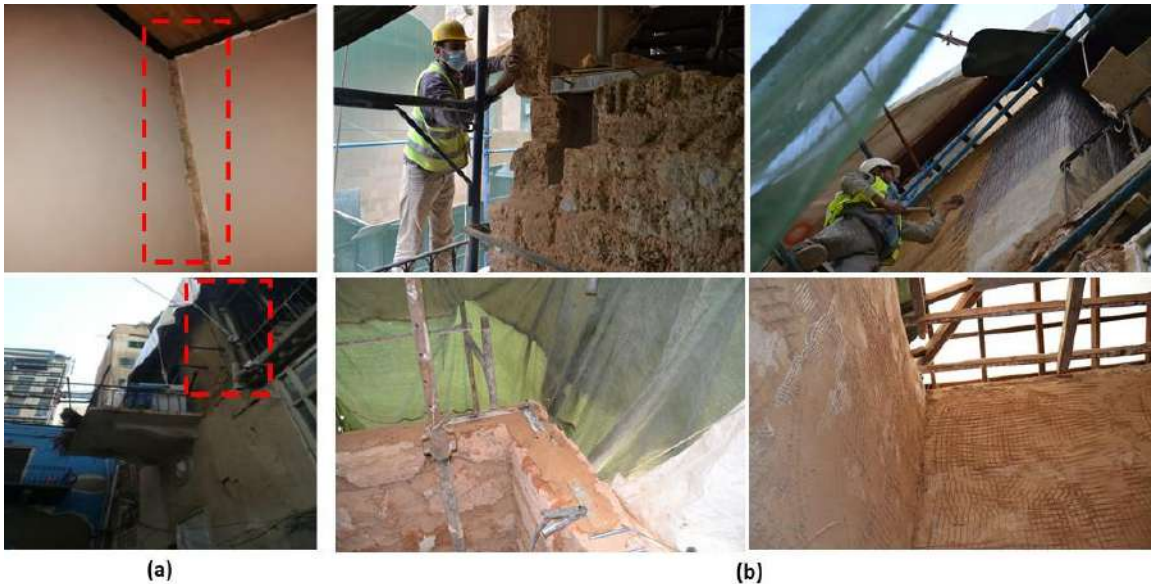
(b)

Exterior view of the building, (a)- damage due the Beirut blast 2020, (b)- After consolidation and restoration works





(a)- Internal and external views of detached wall-to-wall connection, (b)- Stitching using galvanized metal strips and threaded rods, structural mesh installation, deep repointing and plastering



(a)- Internal and external views of the detached corner, (b)- Corner consolidation and reinforcement using galvanized steel metal strips, deep repointing, double fiber mesh installation, and plastering





(a)- Deformed wall above arches, (b)- Wall consolidation: partial dismantling, remounting, deep repointing and plastering



Attic consolidation, (a) replacement of damaged timber elements, (b) Mesh installation to avoid water infiltration, (c) Red tiles installation





Re-plastering process



Repainting process



Consolidation & Restoration of Historic Buildings

Burj Abi Haidar Kindergarten - Beirut (Design build)



(a)



(b)



(c)

Exterior view of the building, (a)- Upon the blast, (b)- After consolidation and restoration works, (c)- Triple arch following the restoration work



Creating a happy space for the students





Attic Consolidation





Triple Arch Restoration



Finishing Works



Consolidation & Restoration of Historic Buildings- Site School Rmeil 360 - Achrafieh (Design build)



Dismantling and remounting walls



Stitching of structural cracks





Structural Plastering



Triple Arch Restoration

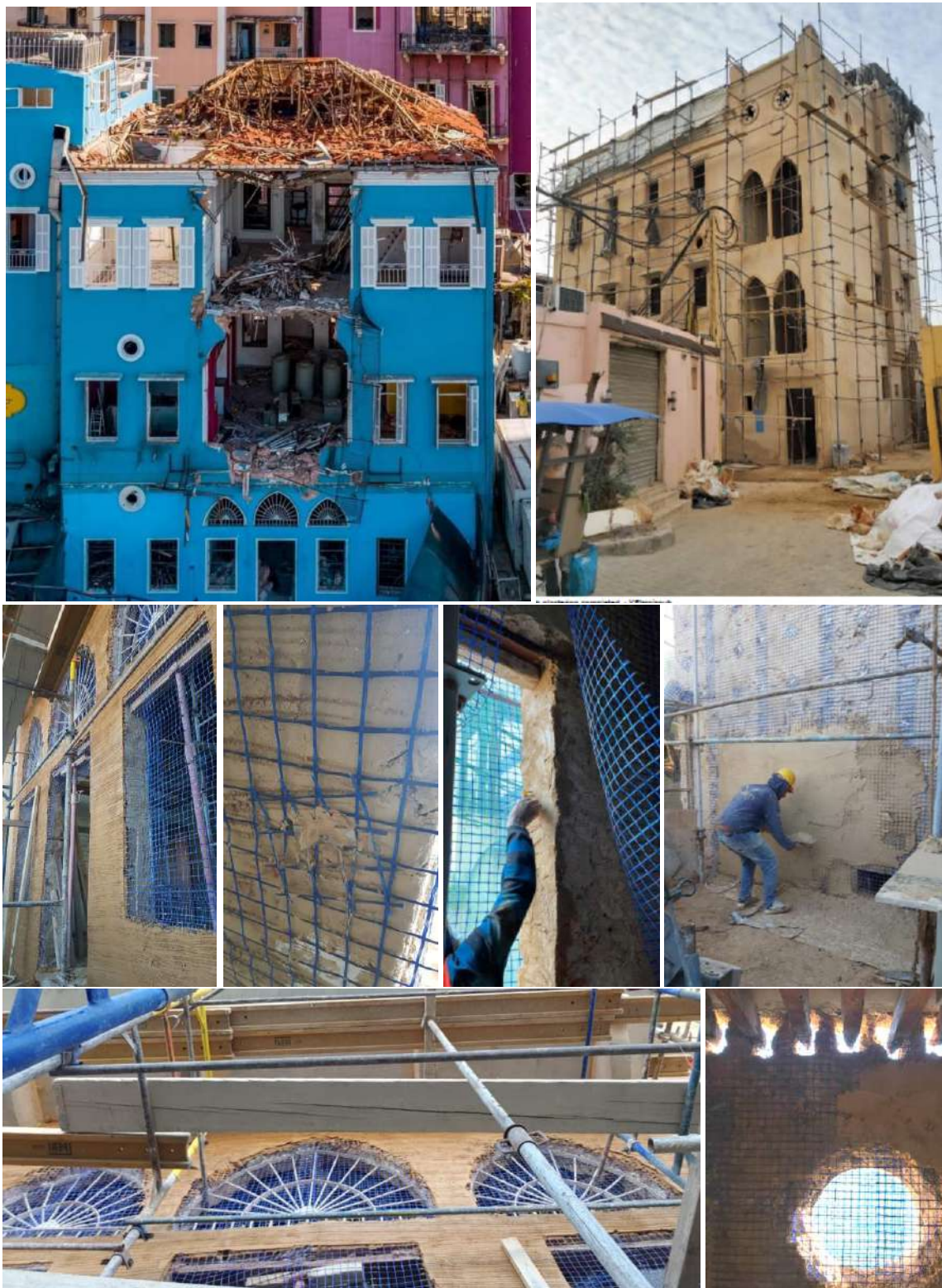




Attic Restoration



Medawar 479 - Beirut damaged by the Beirut Blast 2020 (Design & supervision)



Structural mesh





Wooden beam repair



Structural stitching



Foundation inspection pit

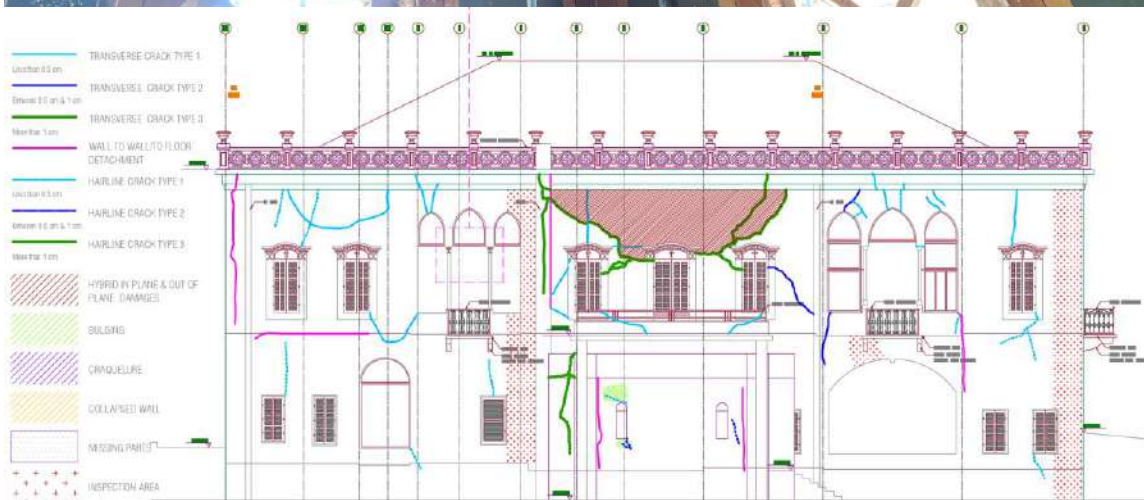


Wooden attic repair



Rmeil 356 - Beirut

Damage assessment and mapping



Damage assessment and mapping

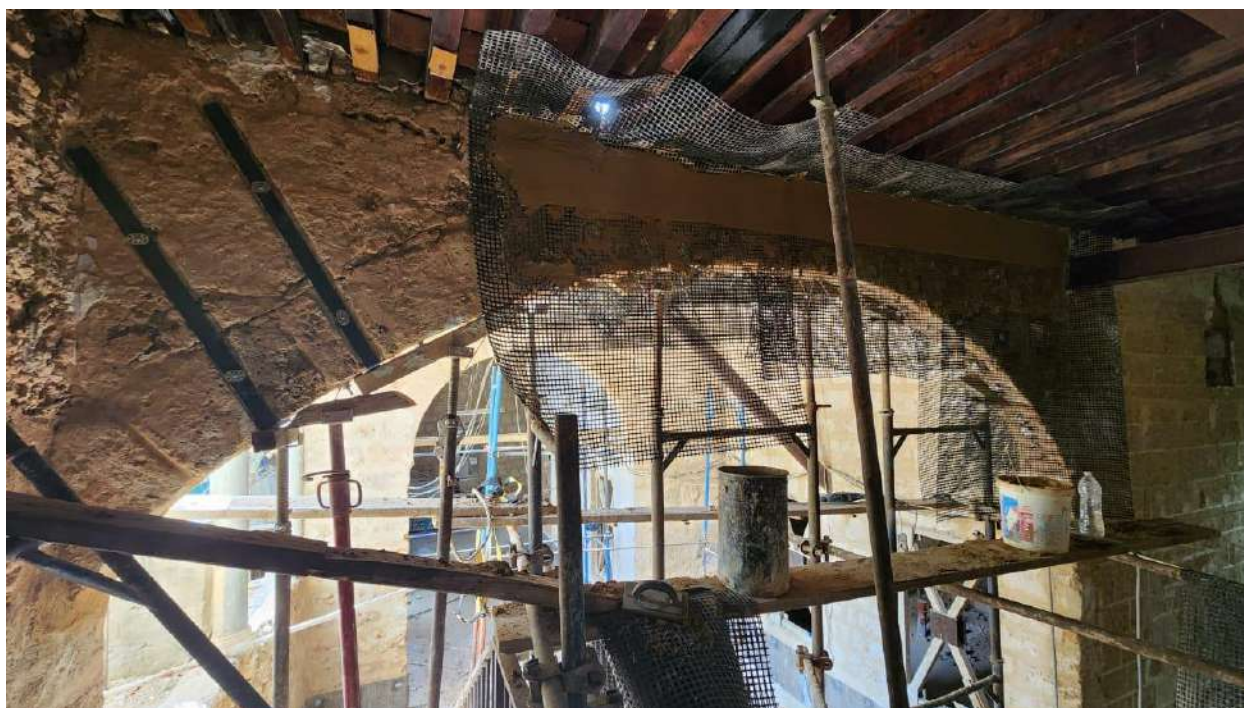




Inspection & Testing campaign: Material characterization



Restoration and consolidation



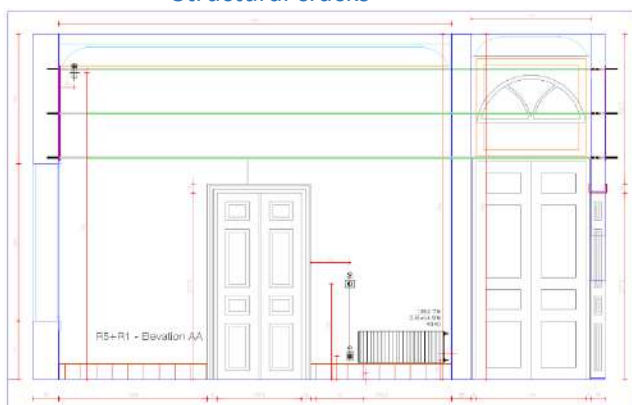
Seismic assessment & Retrofitting Beit Al Jabal – Douma (Design build)



Structural cracks

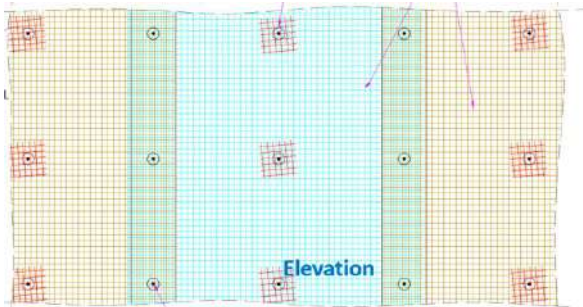


Cracks stitching



Tie rods wall strengthening





Structural plastering



Threaded rods for corners reinforcement



Strengthening a vault edge



5.3 Post-Disaster Massive Damage Assessment

World Heritage: Syria, Aleppo Citadel and the Old City – 2023 Earthquake



Entrance tower and bridge



Ayoubi Minaret – Aleppo Citadel

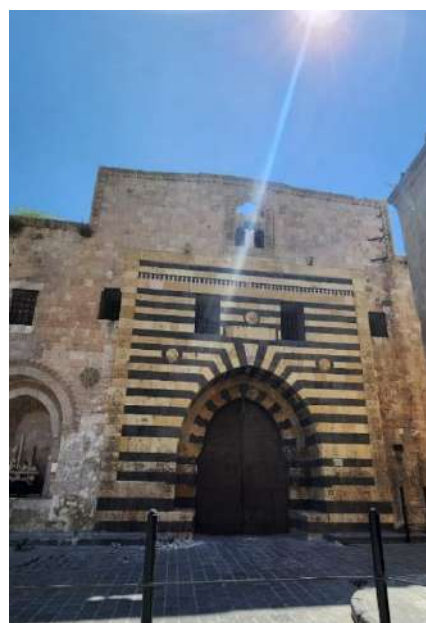




Ottoman Barrack, wind mill, and Hall of Throne – Aleppo Citadel



Khan al Jomrok



Khan al Wazir





Al Halawiya school



Al Aqaba cluster



Antakia Gate

Alaa tower



Lybia - The city of Derna – post floods 2023

(Damage assessment after the 2023 floods)



The archeological site of Appolonia

(Damage assessment after the 2023 floods)



The archeological site of Cyrene (Damage assessment after the 2023 floods) 1/2



The archeological site of Cyrene (Damage assessment after the 2023 floods) 2/2



5.4 Post-Disaster urgent stabilization

Sursok Palace - Beirut - Stabilization of the North Façade (Design & Supervision)



Sursok palace Beirut damaged by the Beirut blast 2020 – North Façade Out of Plane deformation 25cm



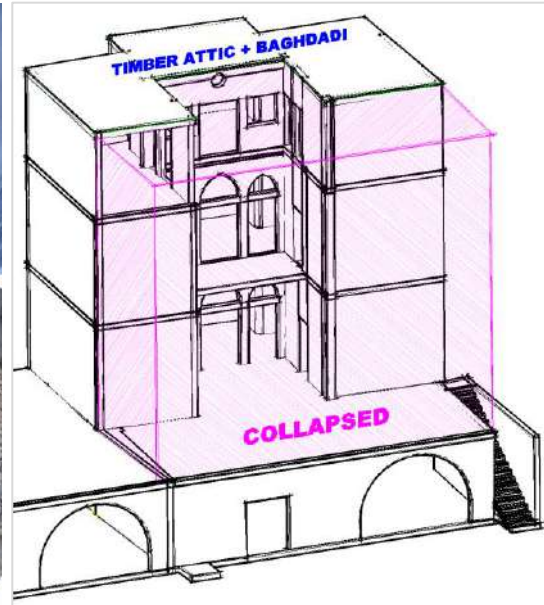
Before stabilization

North elevation

After stabilization



Stabilization of Rmeil 733 - Beirut (Design & supervision)



Scale of destruction of the building following the blast - Collapsed part of Rmeil 733



Urgent propping





Propping and Strangling systems at all rooms



Tie rods strengthening systems



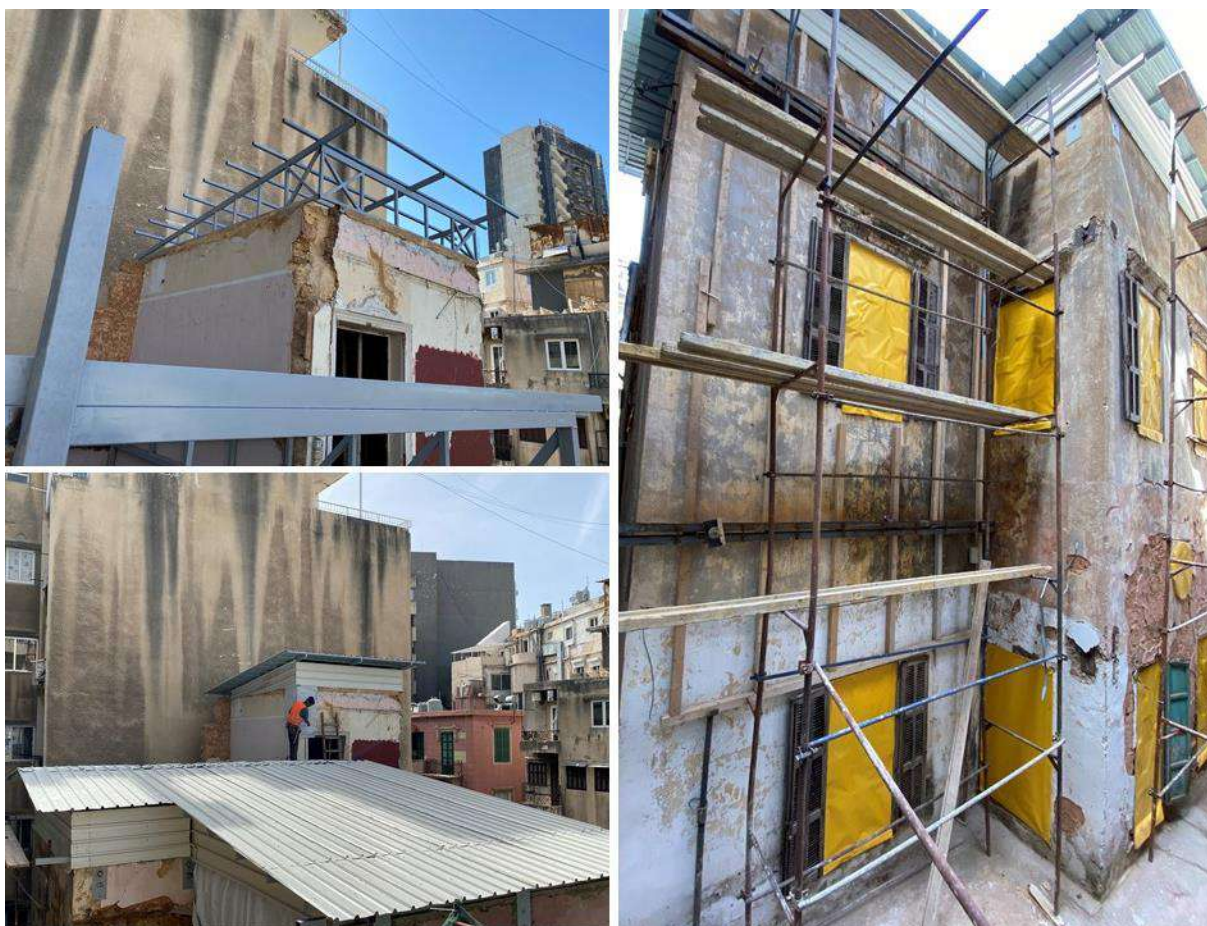


Tie rods strengthening systems



Removal of the collapsed concrete slab





installation of sheltering system



Exterior view of the building, (a)- Upon the blast, (b)- After stabilization works



6. CONTEMPORARY BUILDINGS



Residence Garabesh – North Lebanon

Structural Design & Supervision







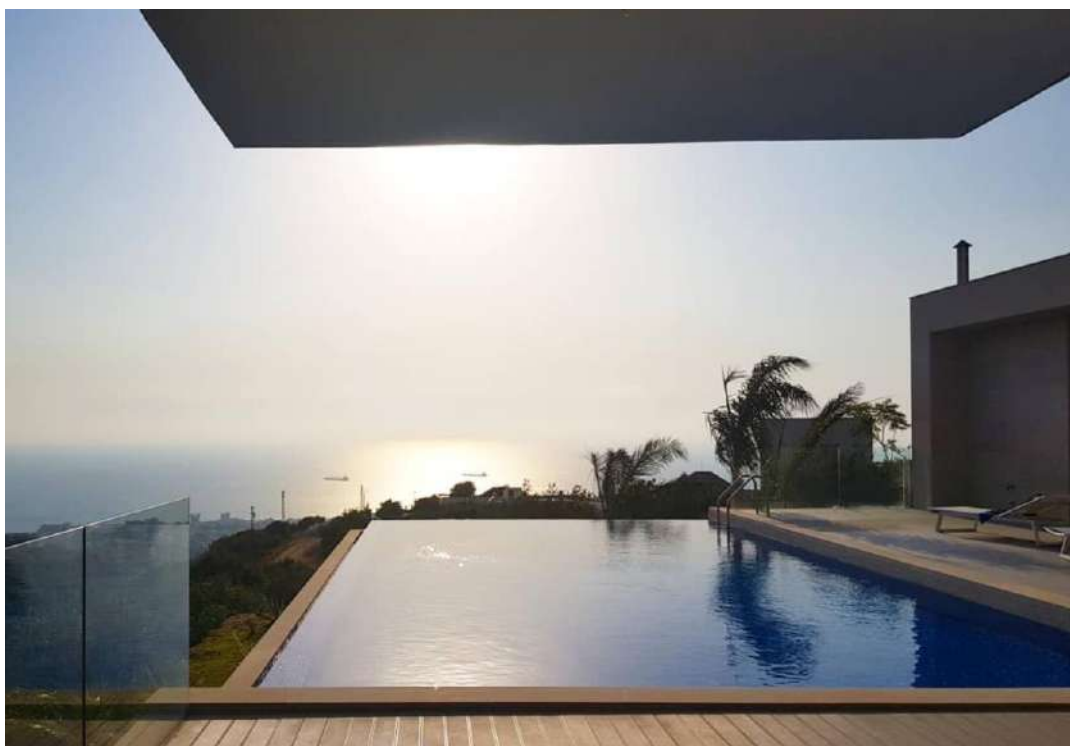
Residence Haddad - Batroun

Structural Design - Execution









3D Model



Execution



Residence Batroun – North Lebanon

Structural Design & Supervision



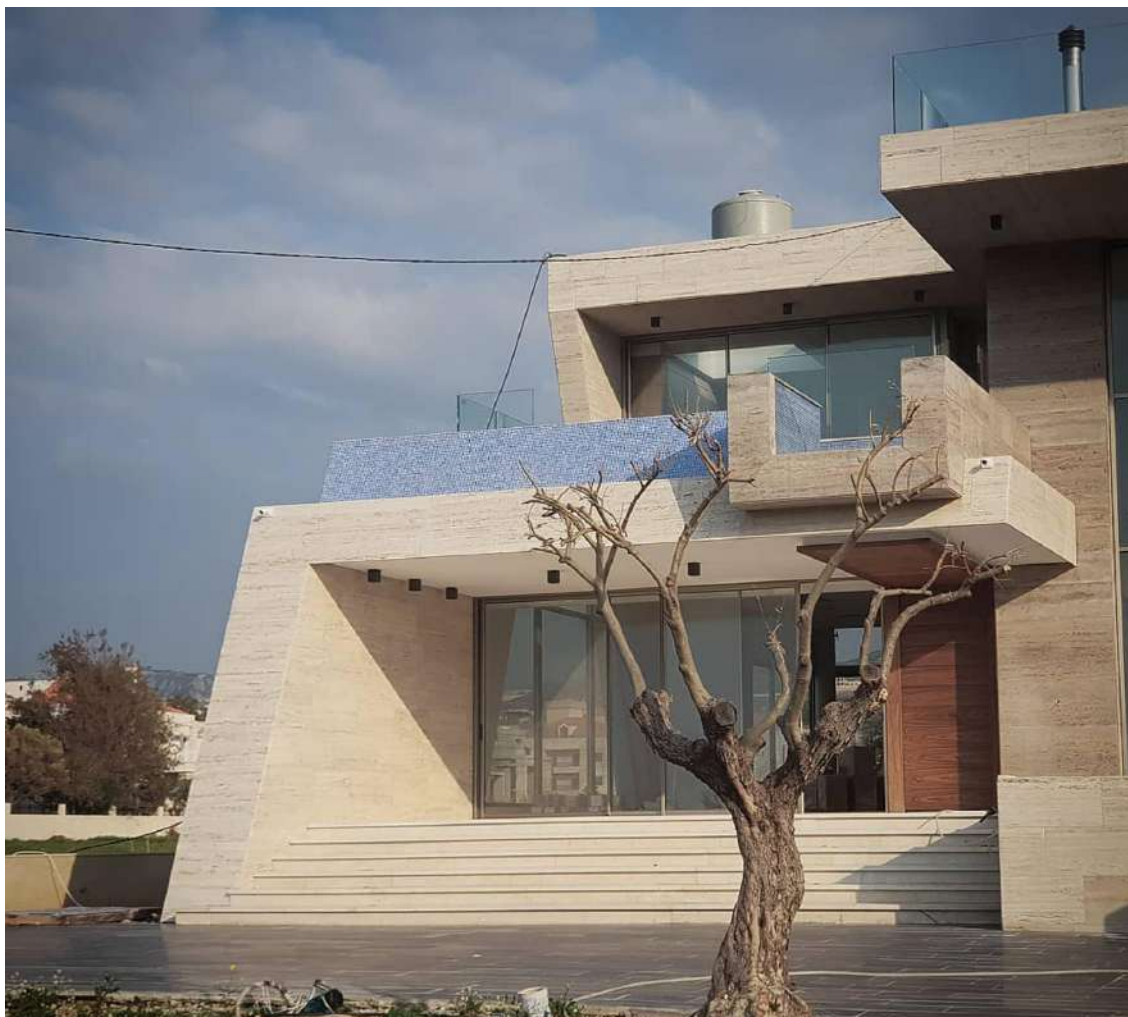
Aged people rest house St Antoine de Padou - Kfarzeina - North Lebanon

Design - Build



Residence Mastoury - Chekka – Lebanon

Structural Analysis / Management & Supervision









Residence Ehden – Lebanon

Structural Design & Supervision



Chalhoub Residence Kfarzeina - North Lebanon Design-Build





Concept Design

Finatrade residential Compound Acra (Ghana)



Nazareth parking and theater - Beirut (Lebanon)



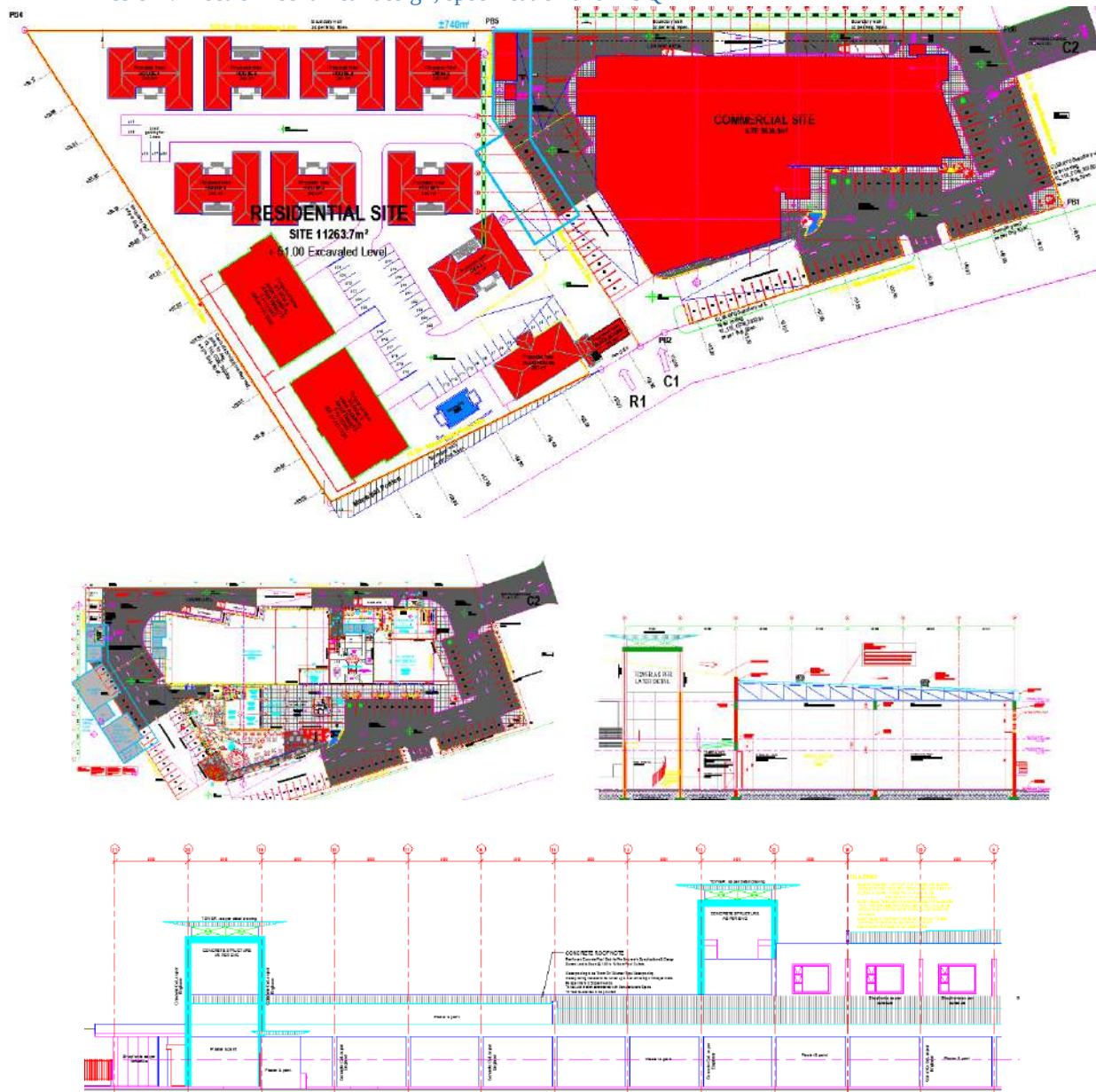
Las Salinas five Spa bike pool



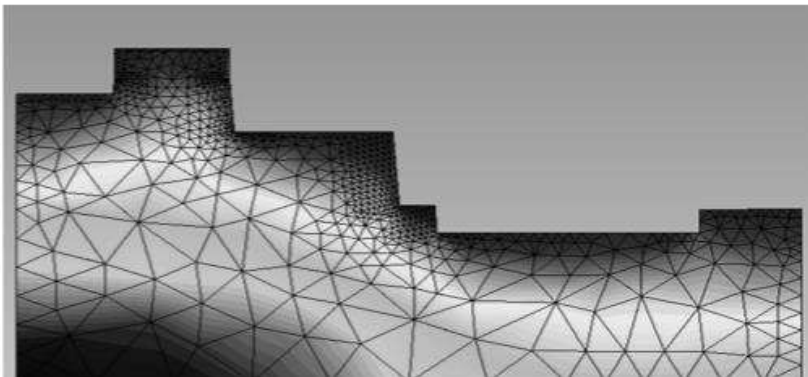
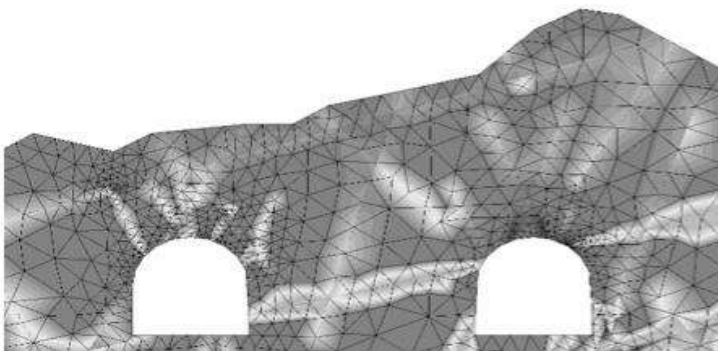
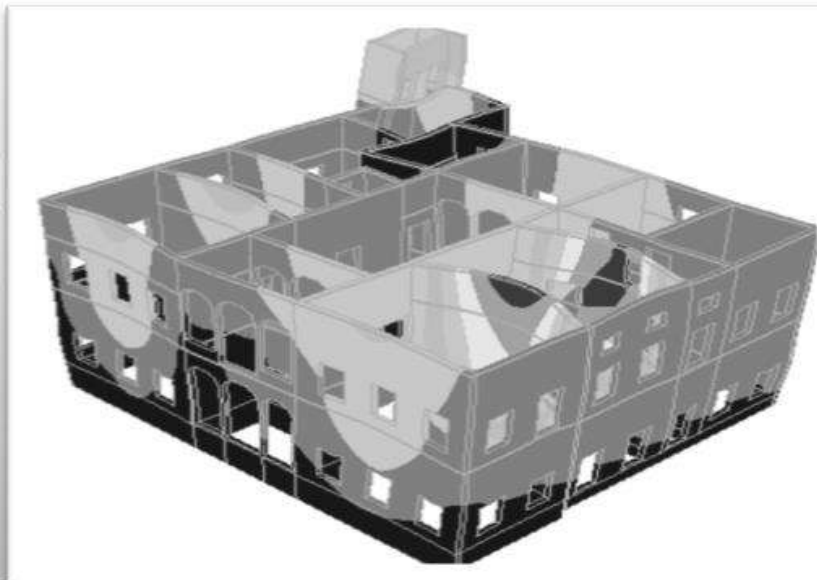
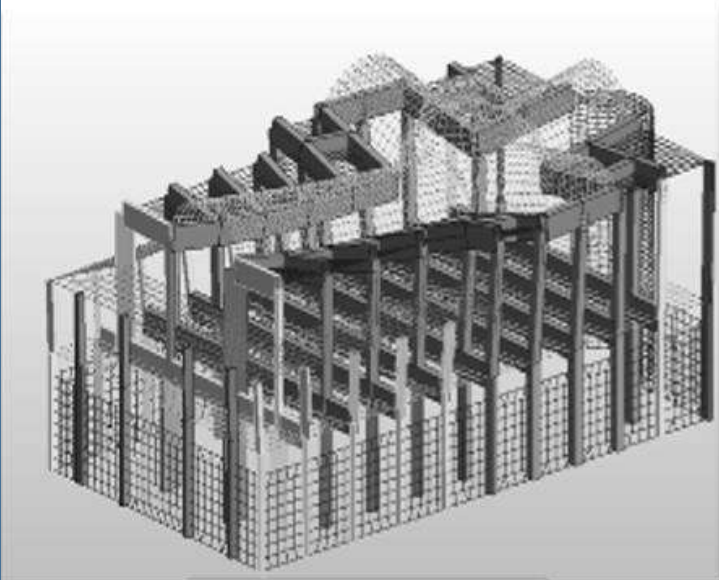
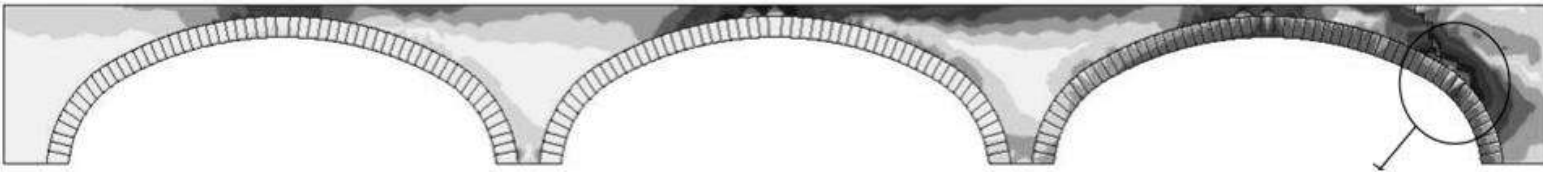
Multi use development project – Takoradi (Mall and residential)

Client : Davenport Developers Ltd – Ghana

Mission : Electro-mechanical design, specification and BOQ

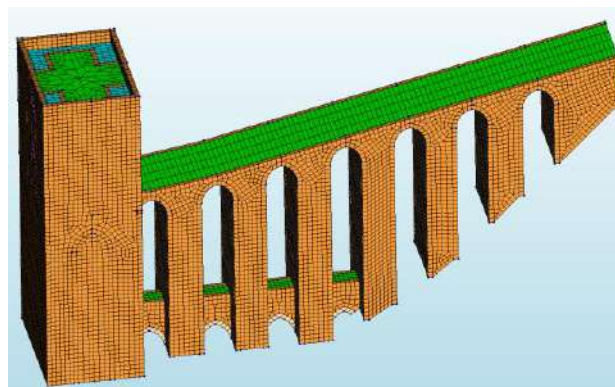


7. ADVANCED FINITE ELEMENT MODELING (FEM)

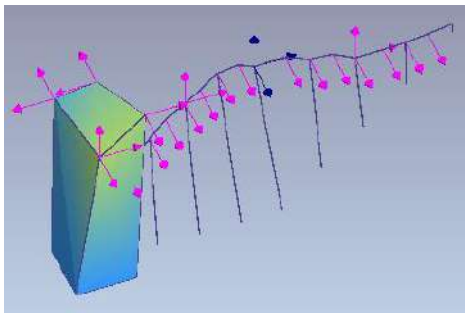
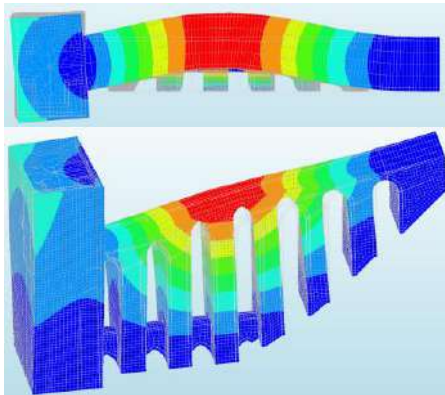
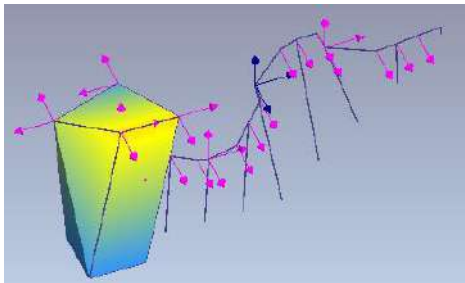
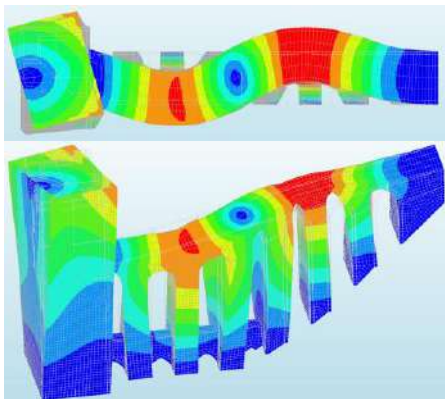


7.1 FEM - Built Heritage

Operational and FEM Modal analysis: the Historic Bridge of Aleppo Citadel



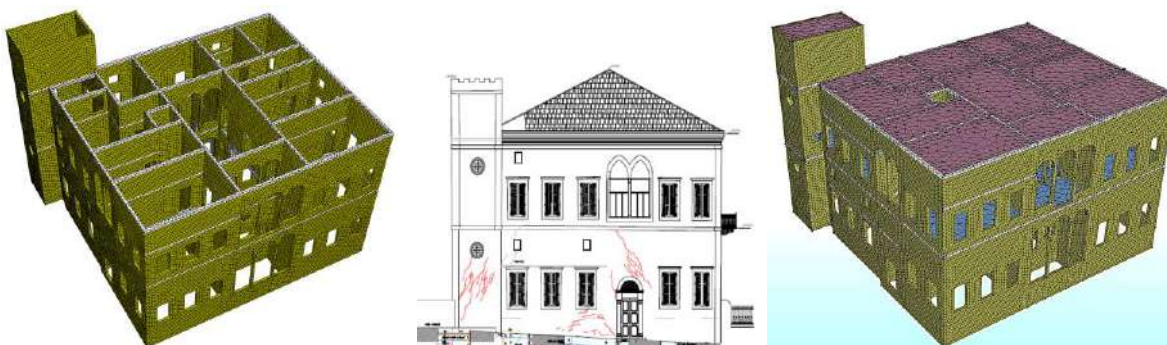
3D mesh of the FE model

	
OMA Mode 3: 3.467Hz	FEM Mode 3: 3.468Hz
	
OMA Mode 5: 5.908Hz	FEM Mode 5: 6.164Hz

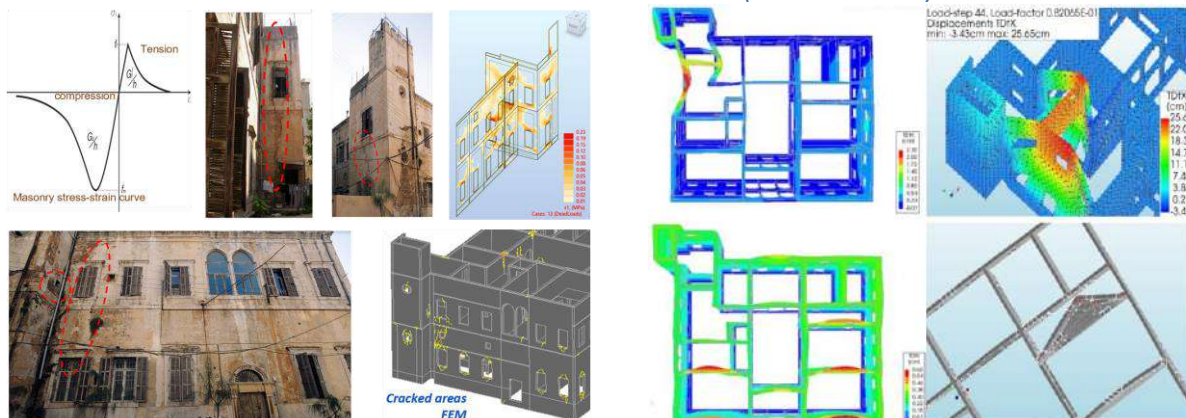


Achrafieh 1098 Palace – Beirut

Non-linear push-over and Seismic assessment

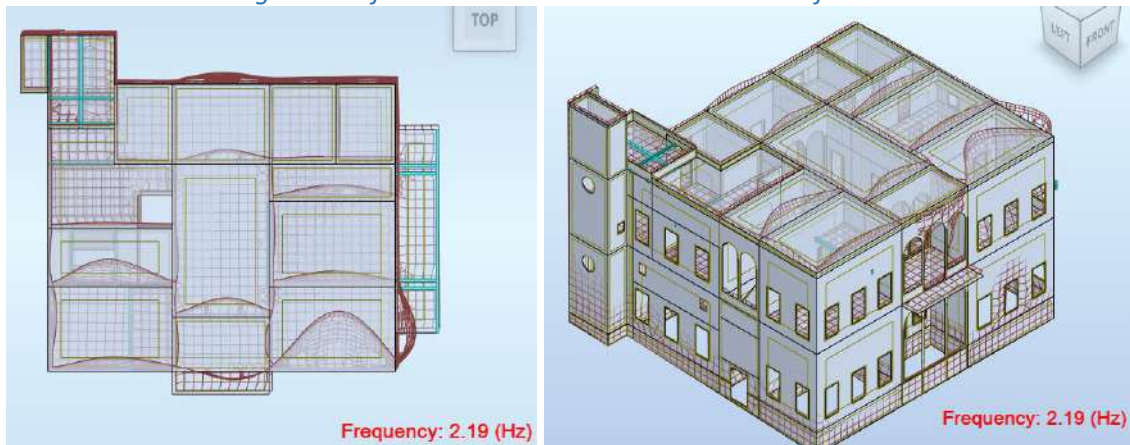
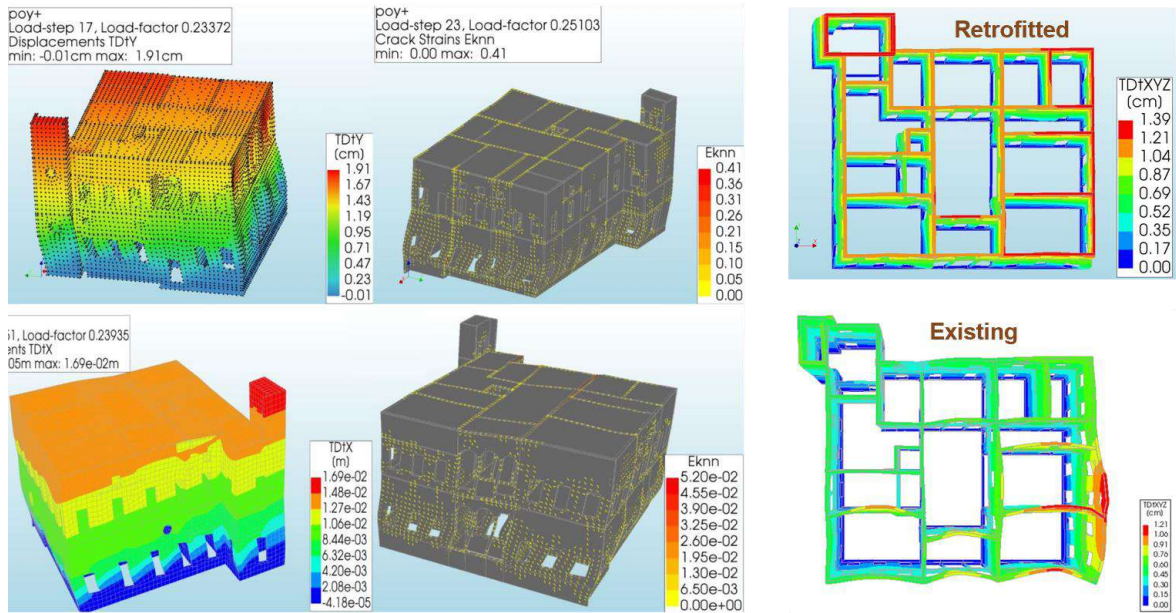


Nonlinear 3D Finite element model (tetra elements)

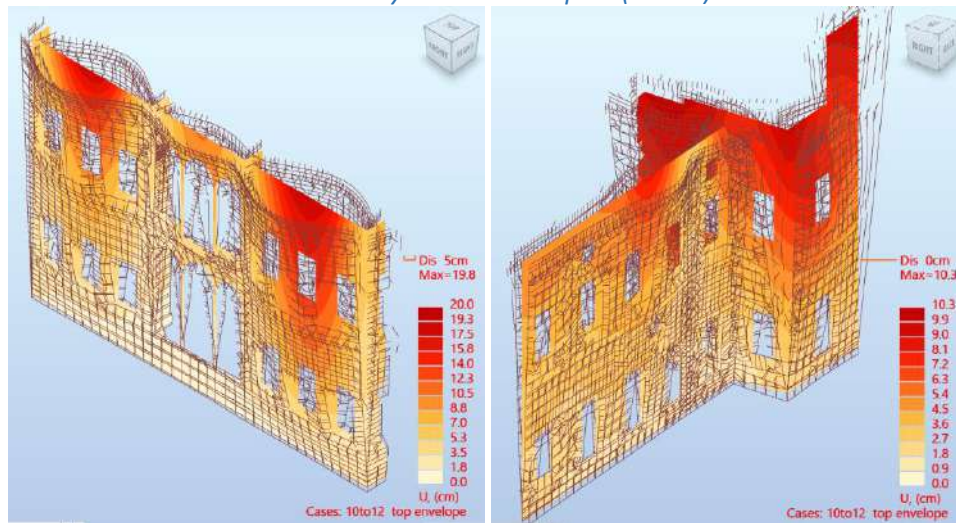


Seismic assessment, non-retrofitted model





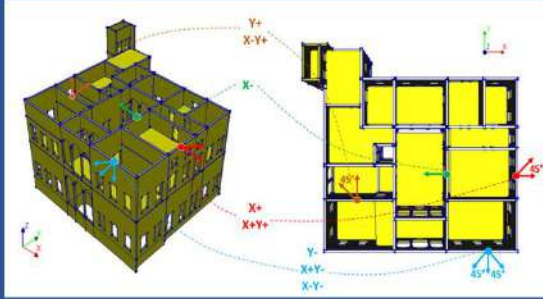
Modal analysis: Mode shape Y (37.8%)



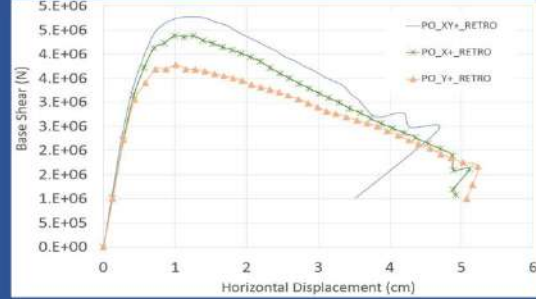
Displacement envelopes



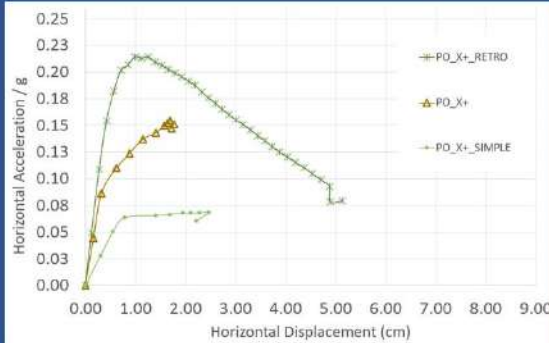
Control node selection



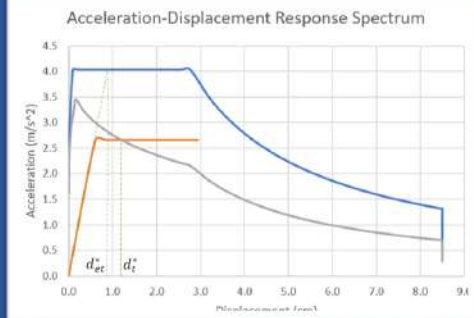
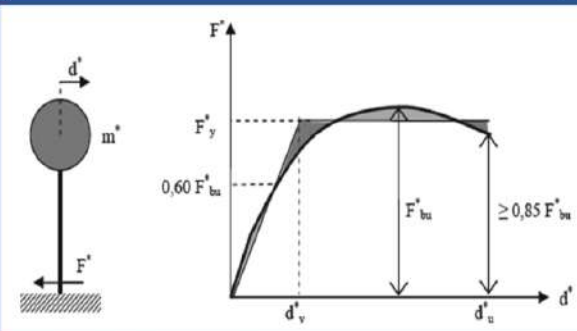
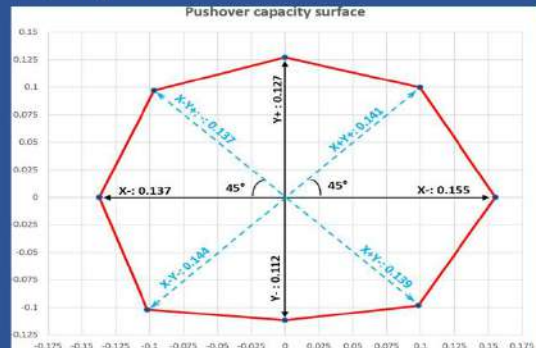
Capacity curves: Retrofitted



Capacity curves: Retrofitted/Non retrofitted



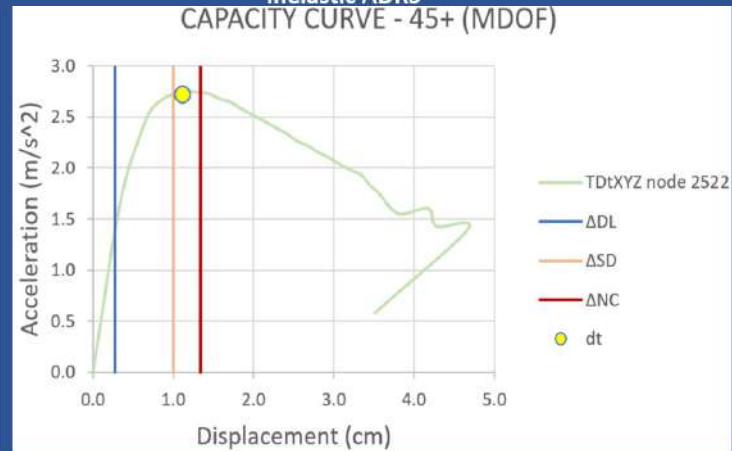
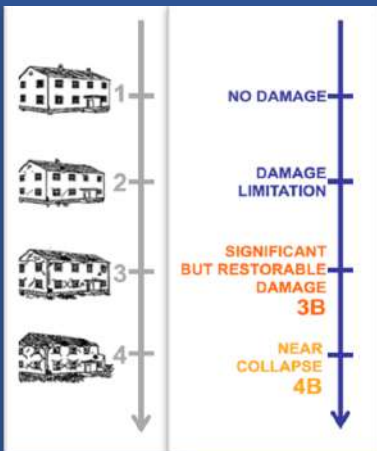
Capacity surface



SDOF equivalent capacity curve

SDOF curve compared to local elastic and inelastic ADRS

CAPACITY CURVE - 45+ (MDOF)



Damage Scale

Limit States (Eurocode 8)

Seismic capacity and damage level assessment

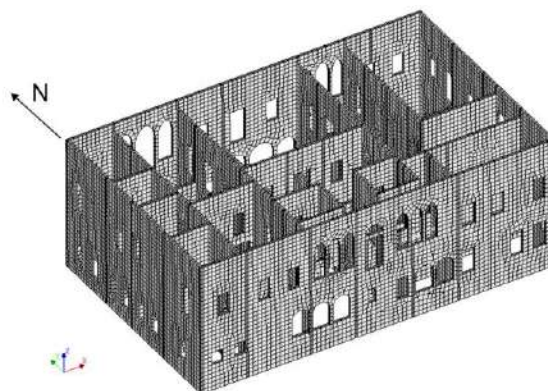


Historic buildings and monuments: Rmeil 356 - Beirut

Non-linear push-over analysis – Seismic assessment

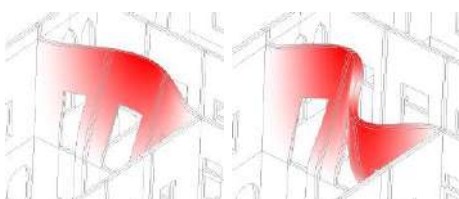
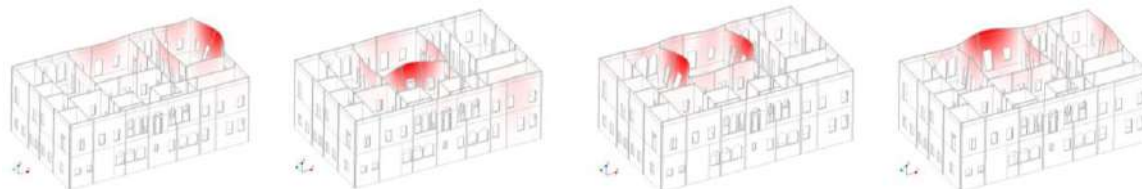


GEOMETRY

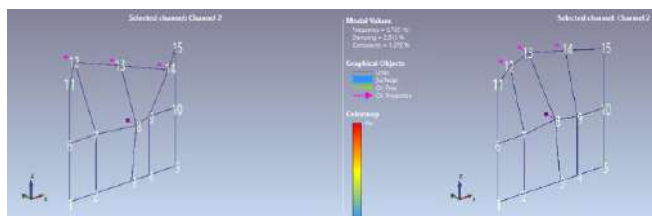


FE MESH

Mode shapes

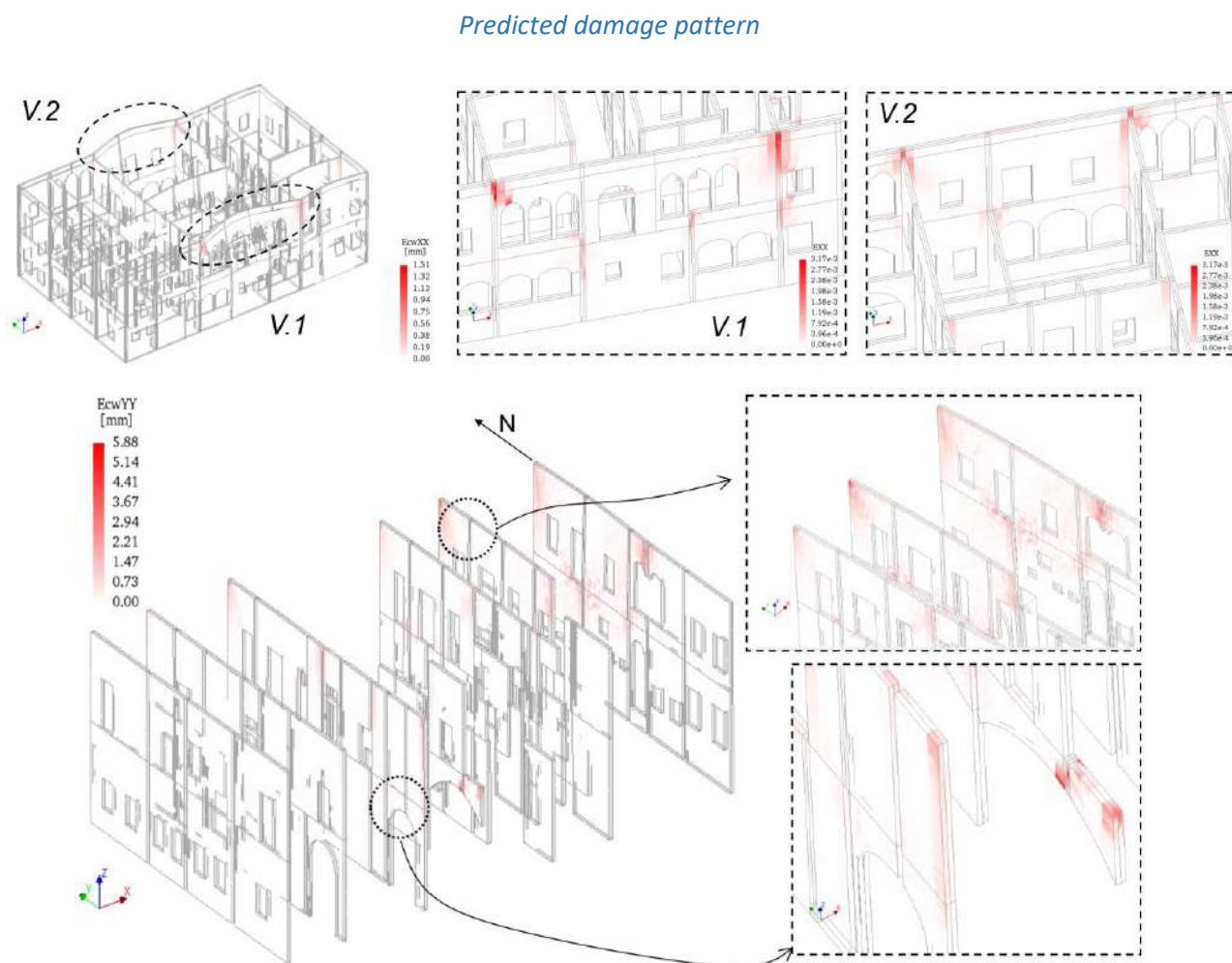
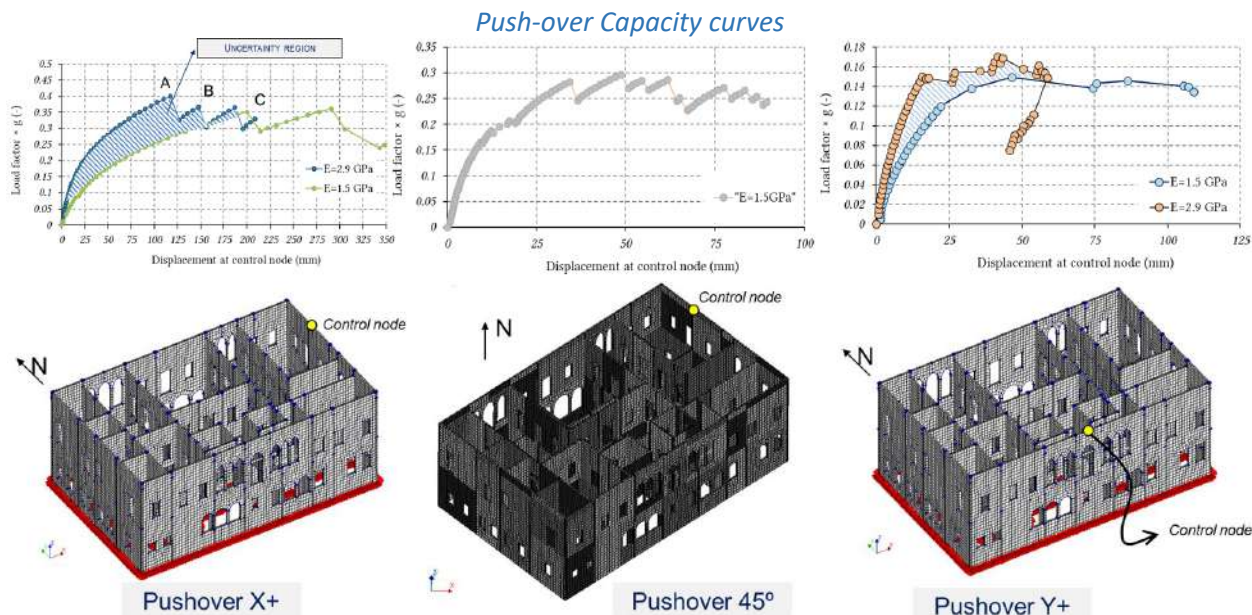


Numerical



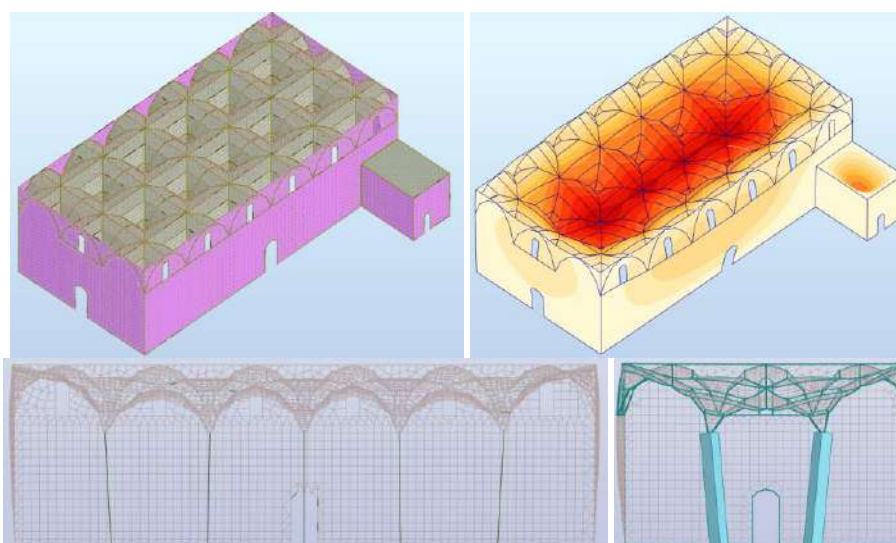
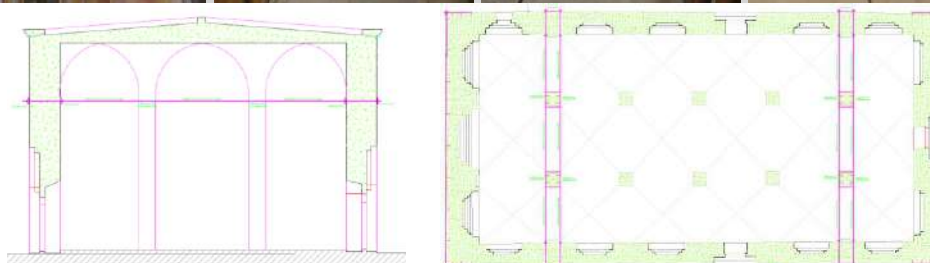
Experimental





National Heritage - Lebanon St Georges Church Ehden

Structural assessment & retrofitting design

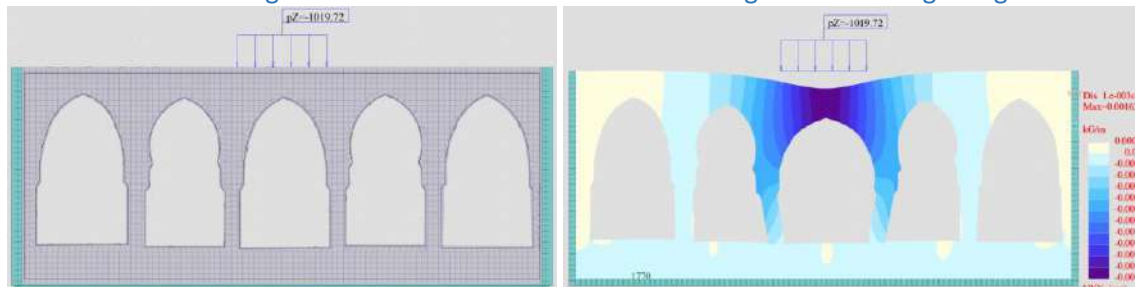


Finite Element 3D model

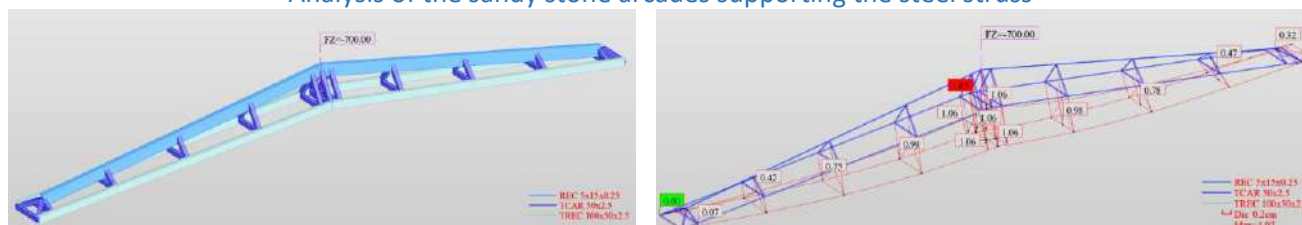


National Heritage – Lebanon
Debbaneh Museum – Saida

Structural retrofitting for additional load : Addition of a 700kg luster crossing a Baghdadi roof



Analysis of the sandy stone arcades supporting the steel struss



Steel truss finite elements modeling and deflection



Load Test process where the white Baghdadi ceiling is seen at the left photo



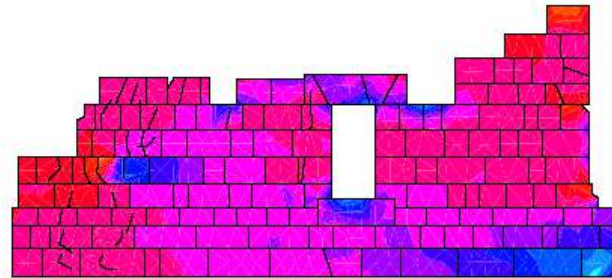
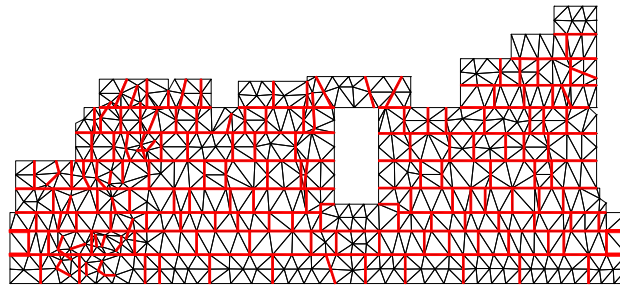
Steel truss supporting the Luster

Luster final Sate



National Heritage – Lebanon: Roman temple in Yanouh - Lebanon

Numerical analysis of the temple for strengthening purpose using Enriched Joint Finite Element Method



National Heritage – Lebanon: Roman Nahr Ibrahim Aqueduct

Structural study for the virtual reconstruction of the aqueduct geometry



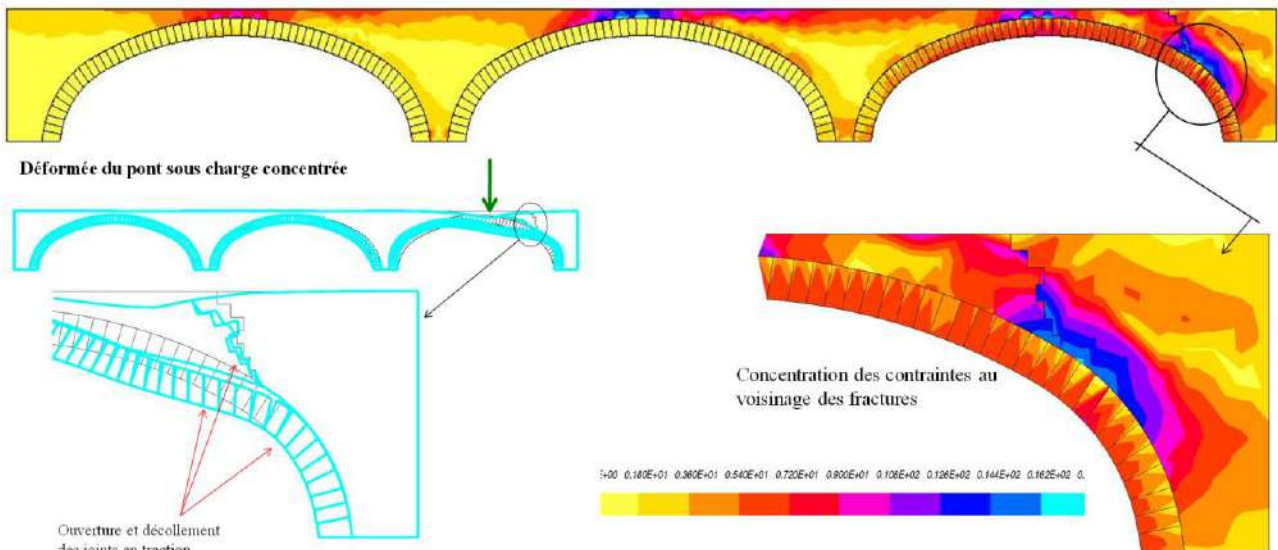
National Heritage – Lebanon: Ottoman bridge of Nahr El Kalb

Structural assessment of the Moving Load Capacity using Enriched Joint Finite Element Method

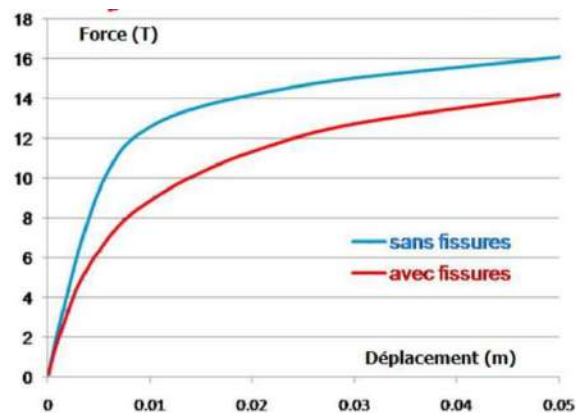


Pont de Nahr el Kalb-Liban

Cartographie de la contrainte verticale



Discontinuous Finite Element Model



Moving load capacity

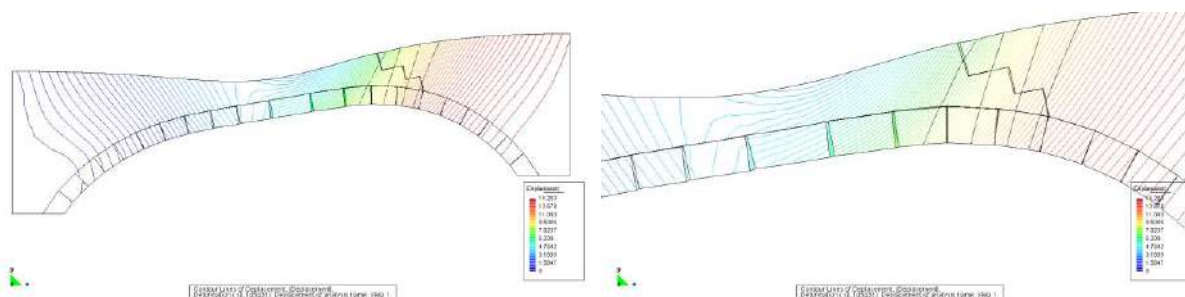


Advanced Numerical Modeling & Structural analysis (Academic) Built heritage

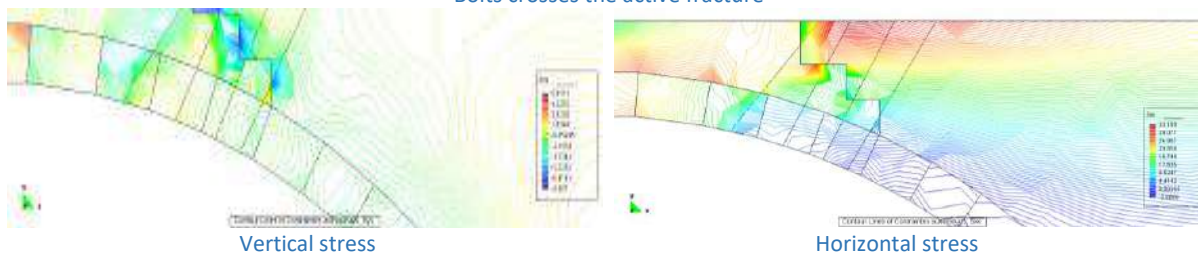
Strengthening of a masonry bridge suffering from the development of an active fracture due to a foundation settlement



Geometry of the masonry bridge including fractures - Finite elements mesh

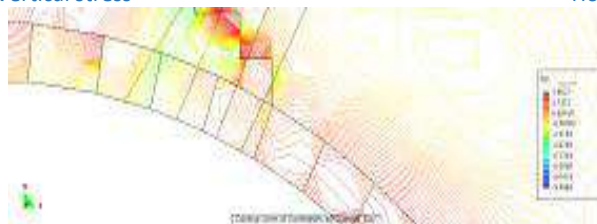


Deformed shape: Total displacement
Bolts crosses the active fracture

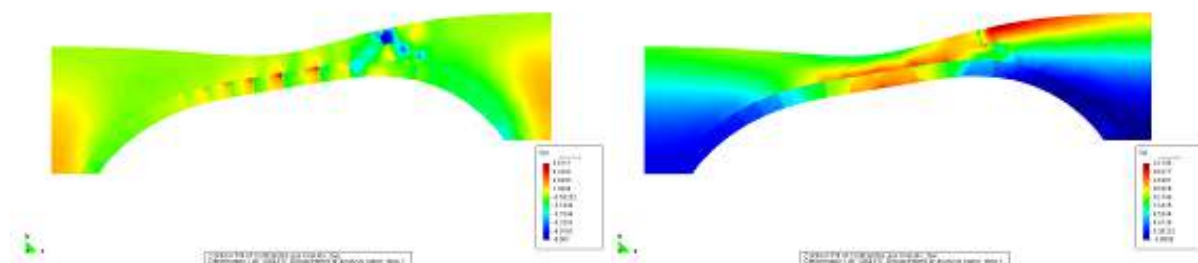


Vertical stress

Horizontal stress



Shear stress



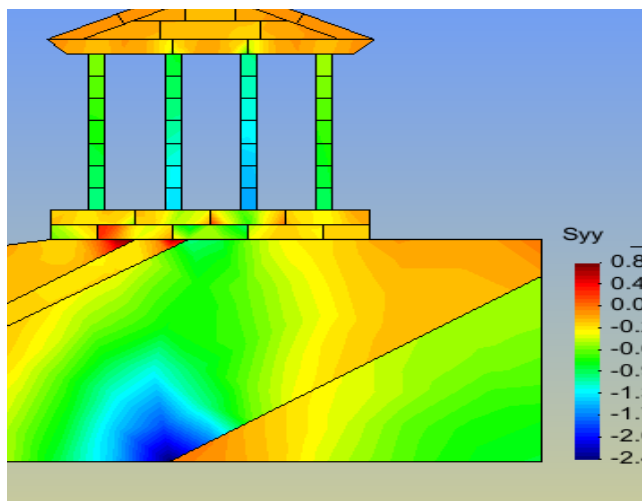
Vertical stress

Horizontal stress

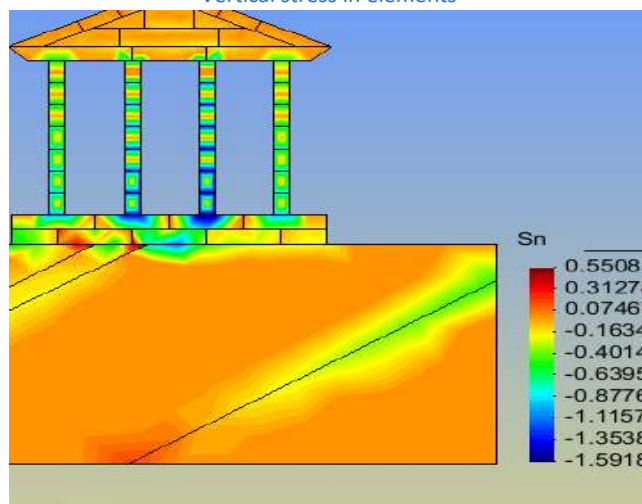
Deformed shape: Settlement of the left foundation



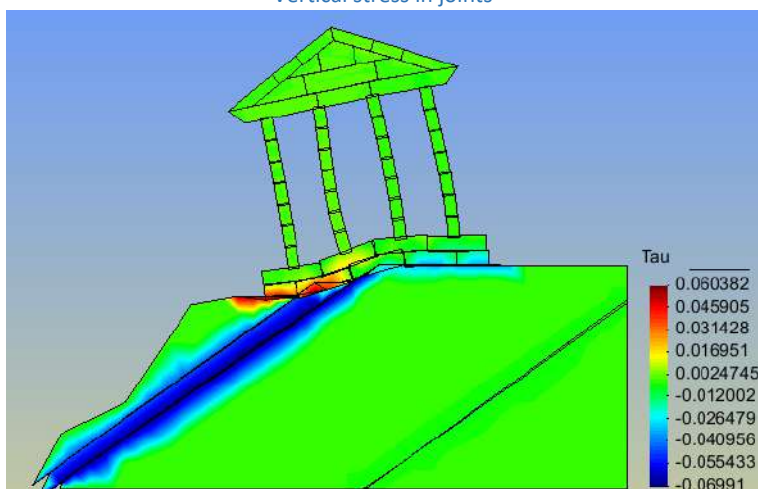
Effect of a rock mass sliding on a temple stability



Vertical stress in elements



Vertical stress in joints



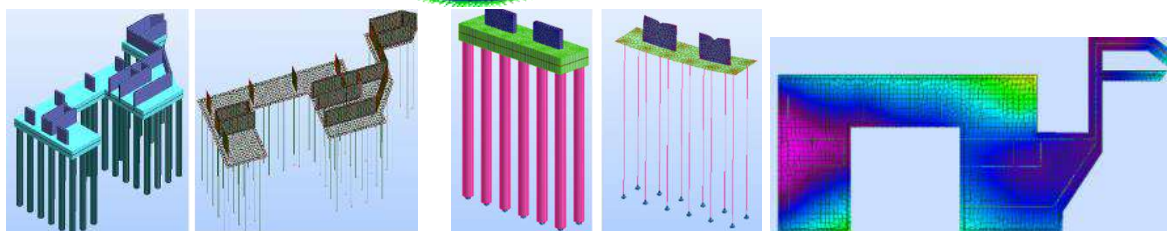
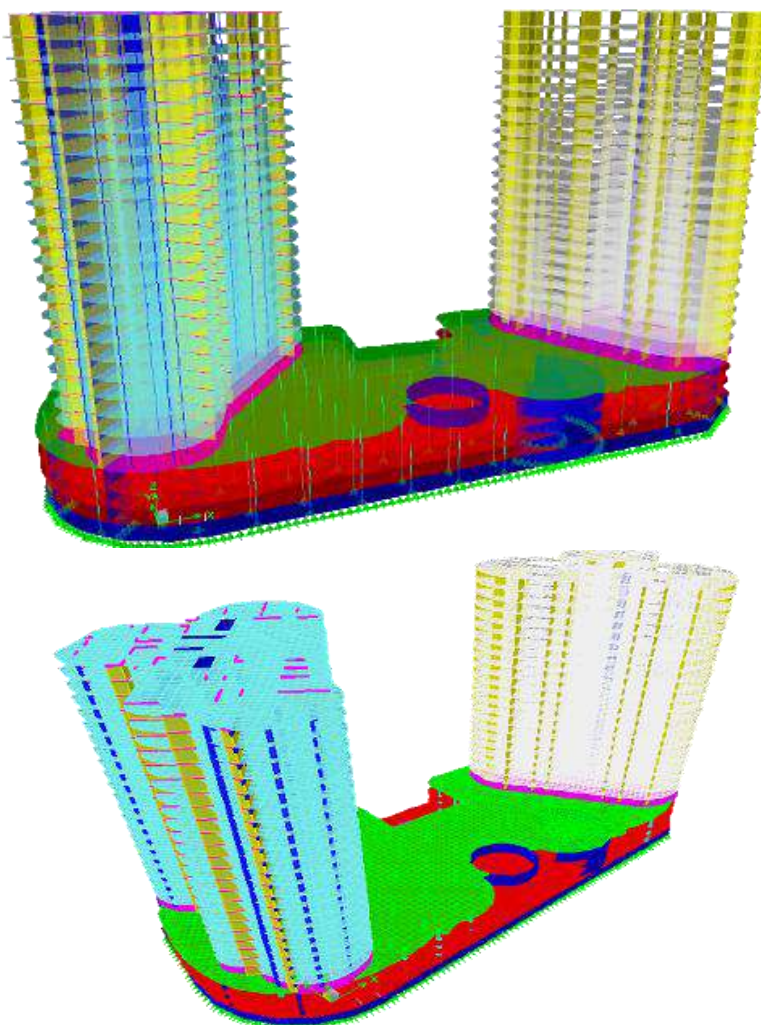
Deformation and Shear stress in joints



7.2 FEM - Contemporary structures

reinforced concrete & steel

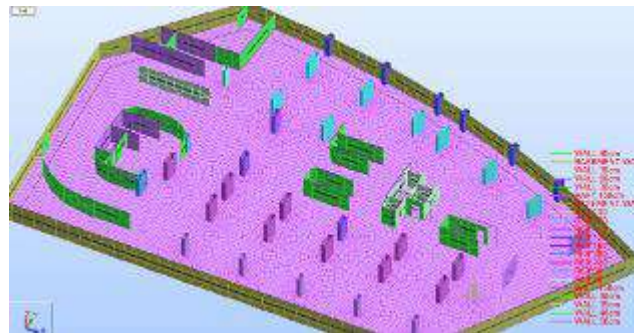
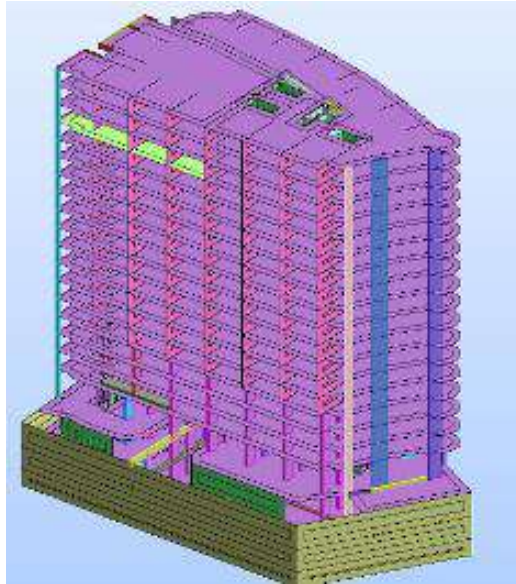
Project	: Beach tower (Abu Dhabi)
Client	: For the interest of PACE.
Mission	: Modeling, design and tender drawings.
Notes	: Residential building 25 stories; seismic and wind loads design, twin towers on piles, 115m width without joints integration.



Raft settelment



Project : Liya tower (Abu Dhabi)
 Client : For the interest of PACE.
 Mission : Modeling, design and tender drawings.
 Notes : 5 stars hotel; seismic and wind loads design, transfer slab, post tensioned slab, tower on raft: uplift analysis.

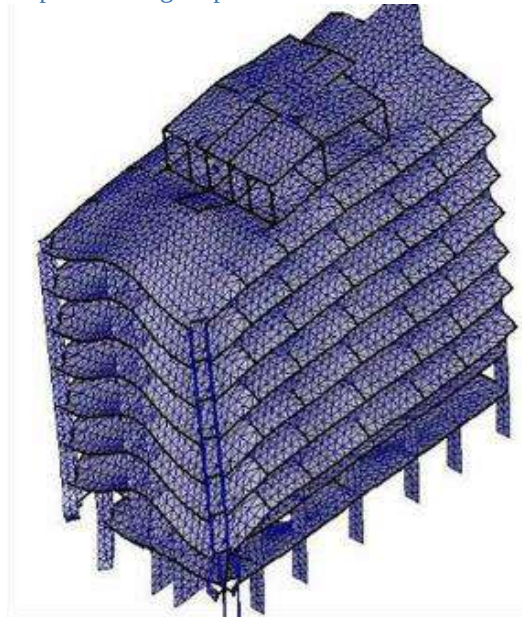
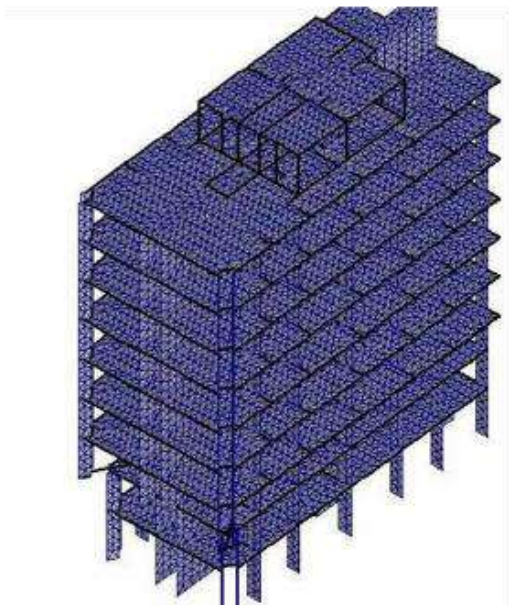


Raft

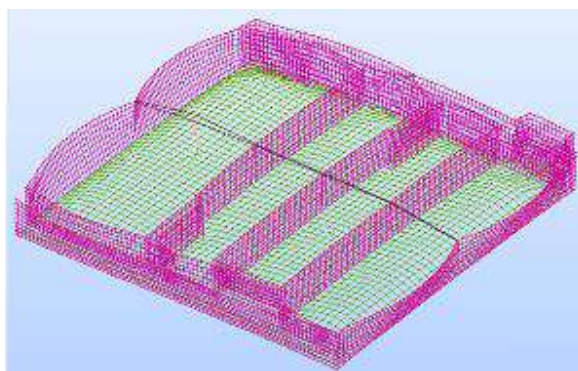
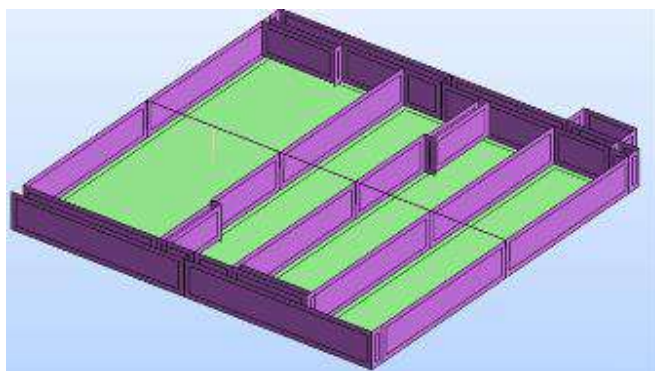
Project : P37 twin towers (Dubai)
 Client : For the interest of PACE.
 Mission : Modeling, design and tender drawings.
 Notes : Residential building; 28 stories, transfer slab, seismic and wind loads design, twin towers on piles without joints.



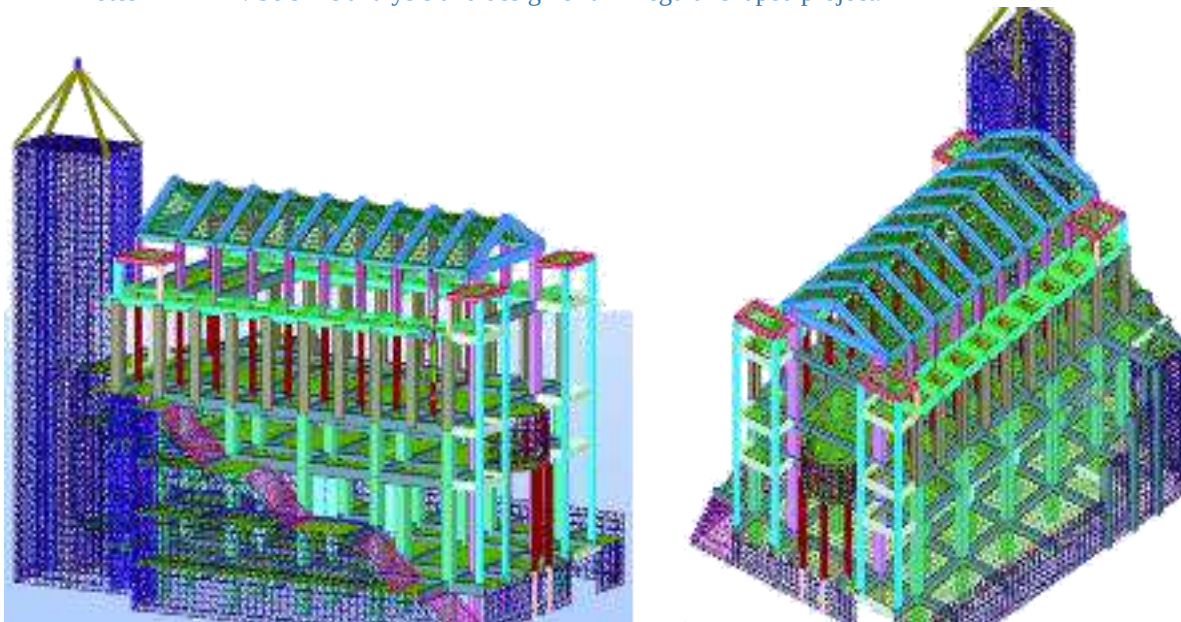
Project : Residential building. (Kuwait)
 Client : GREYS.
 Mission : Modeling and design.
 Notes : Analysis and design of an irregular shaped building on piles.



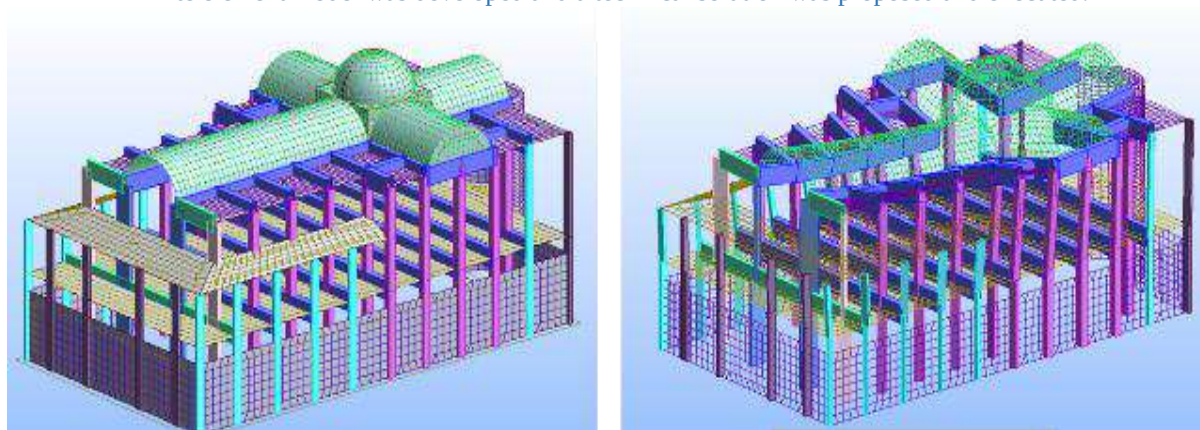
Project : Waste water reservoir. (Qatar)
 Client : For the interest of LibanConsult.
 Mission : Modeling, design and shop drawings.
 Notes : Analysis and seismic design of large reservoir for a water treatment station.



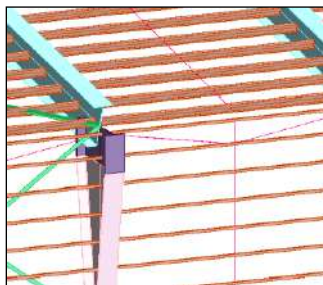
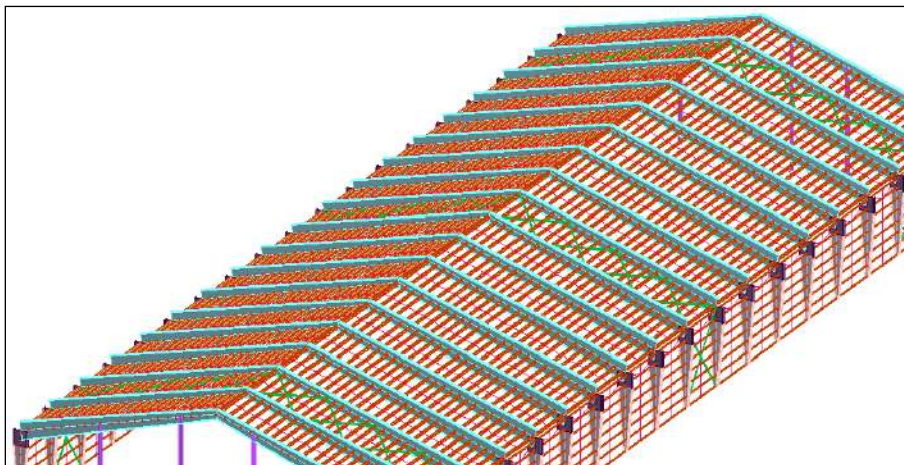
Project : Saint Marry Church (Lebanon).
 Client : For the interest of Younan Architects.
 Mission : Modeling, design and shop drawings.
 Notes : Seismic analysis and design of an irregular shaped project.



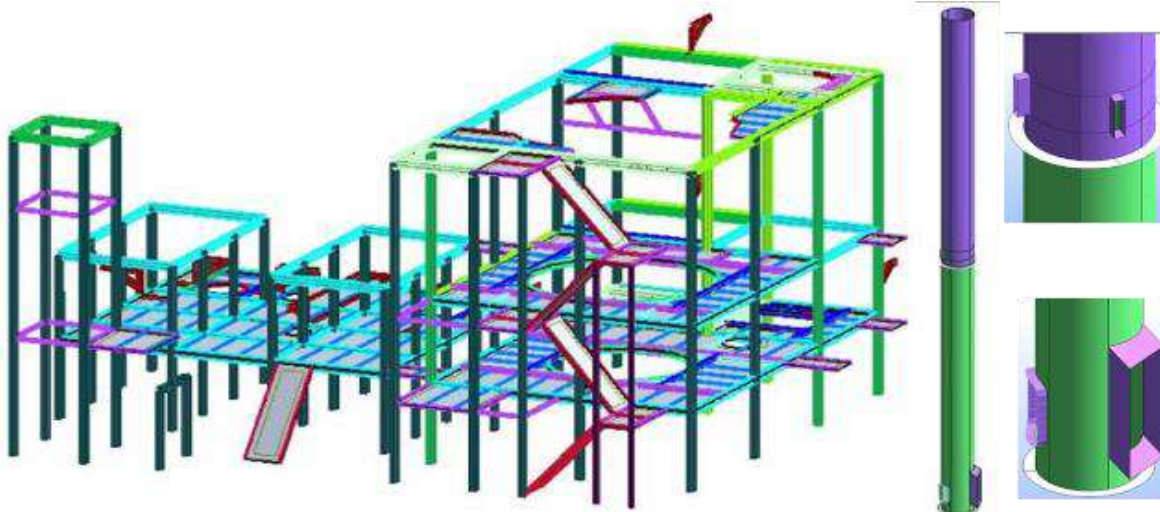
Project : Saint Elie Church (Rachine- the North - Lebanon).
 Client : Rachine village.
 Mission : Rehabilitation, modeling, design drawings and supervision.
 Notes : Excessive deflection was detected for the beams supporting the intersecting domes. A finite element model was developed and a technical solution was proposed and executed.



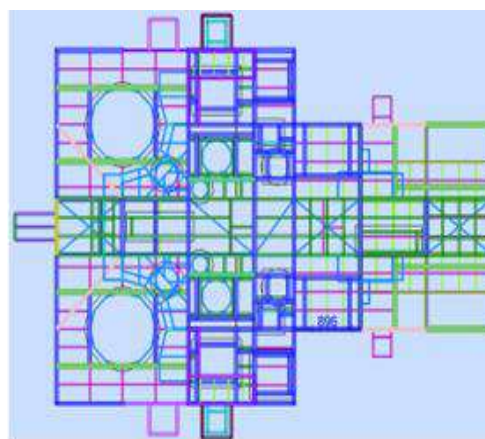
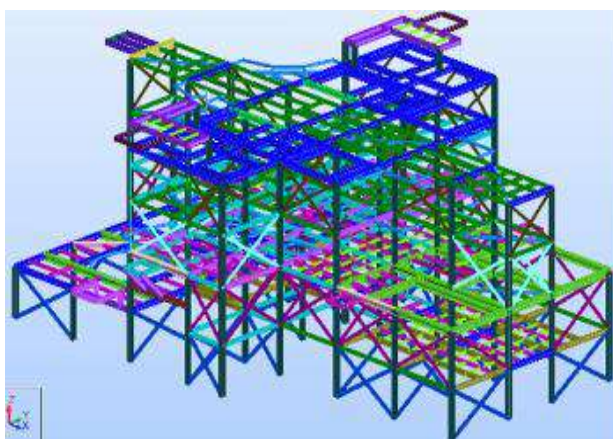
Project : Bar Elias Hangars - Lebanon.
Client : Liban consult SAL
Mission : Design
Notes : 400Tones of tapered steel section hangars.



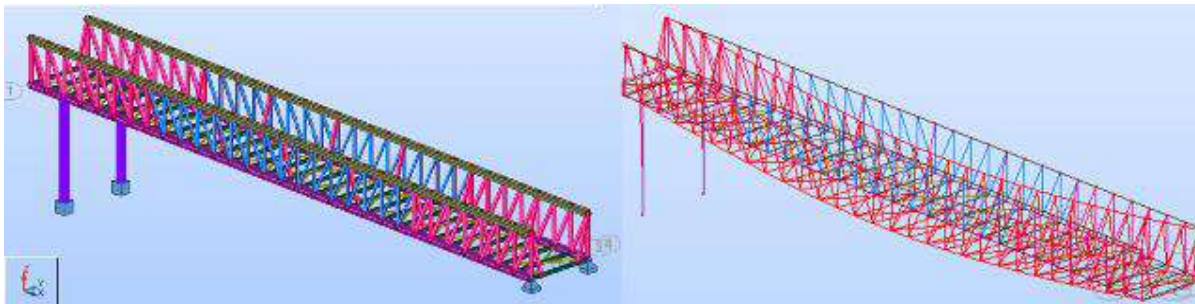
Project : Gdansk Incinerator (Poland)
Client : Degremont - Poland.
Mission : Modeling design and Bill of Quantities.
Notes : Wind design. Thermal non linear analysis for chimney.



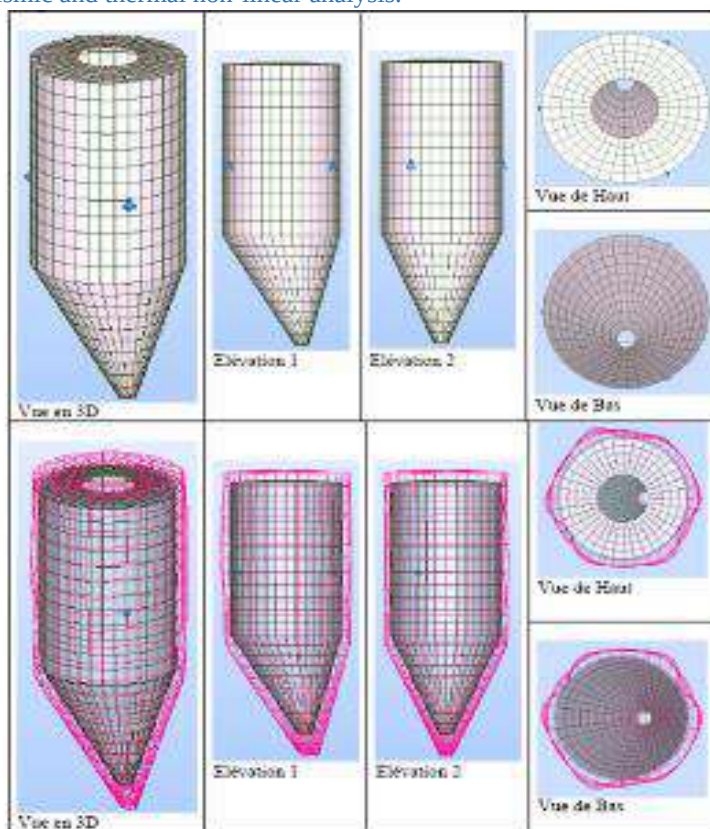
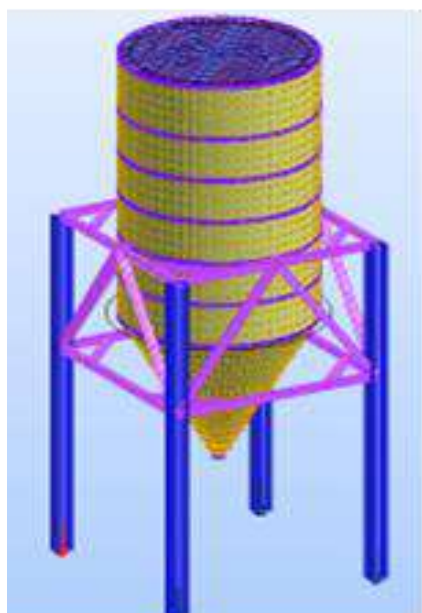
Project : Steel works Tripoli Incinerator (Lebanon).
Client : Narcis-Degrémont.
Mission : Shop drawings.
Notes : 130 Tons of standard and built-up sections and connections.



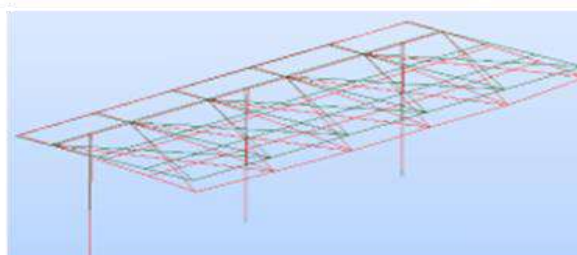
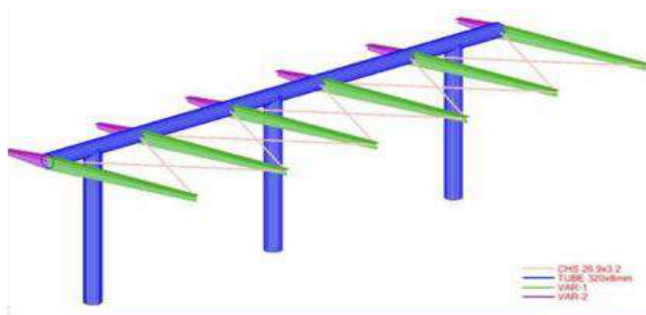
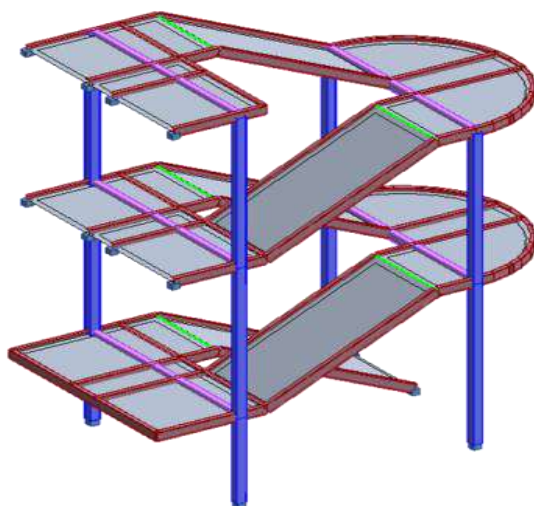
Project : School Bridge (Paris - France)
Client : TMC.
Mission : Modeling and design.
Notes : Steel structure design with wind and seismic calculation



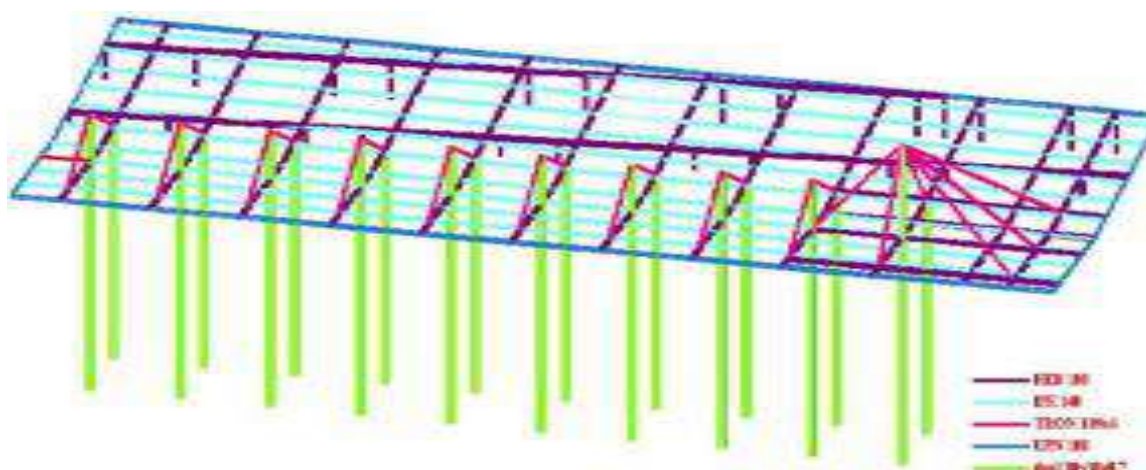
Project : Ashes silo (Jumayrah)
Client : Narciss-Degrémont.
Mission : Modeling design and shop drawings.
Notes : Silo design with seismic and thermal non-linear analysis.



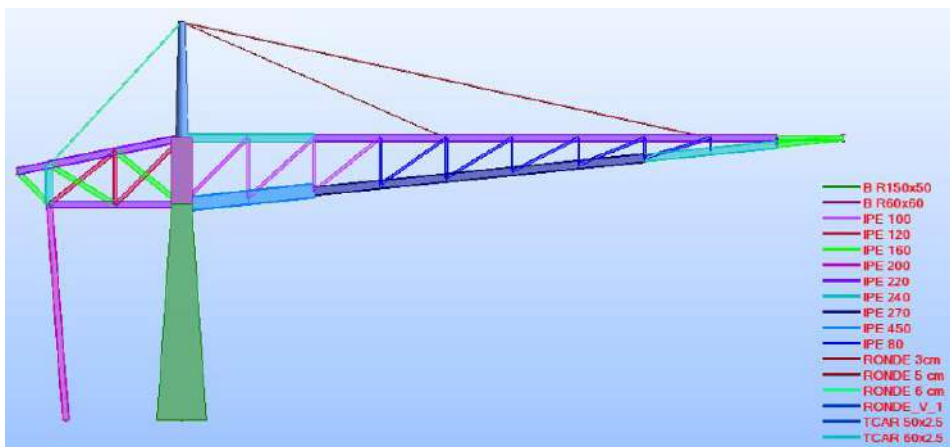
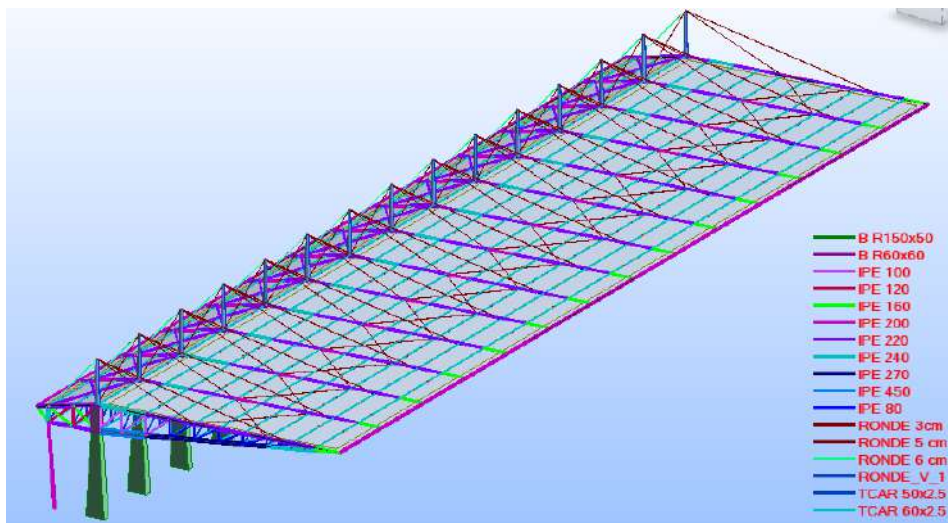
Project : Steel works Larnaka Airport (Cyprus)
 Client : For the interest of Glassline- Bouygues.
 Mission : Design and modeling.
 Notes : 3D modeling and design stairs and canopies with cables, Seismic and wind design.



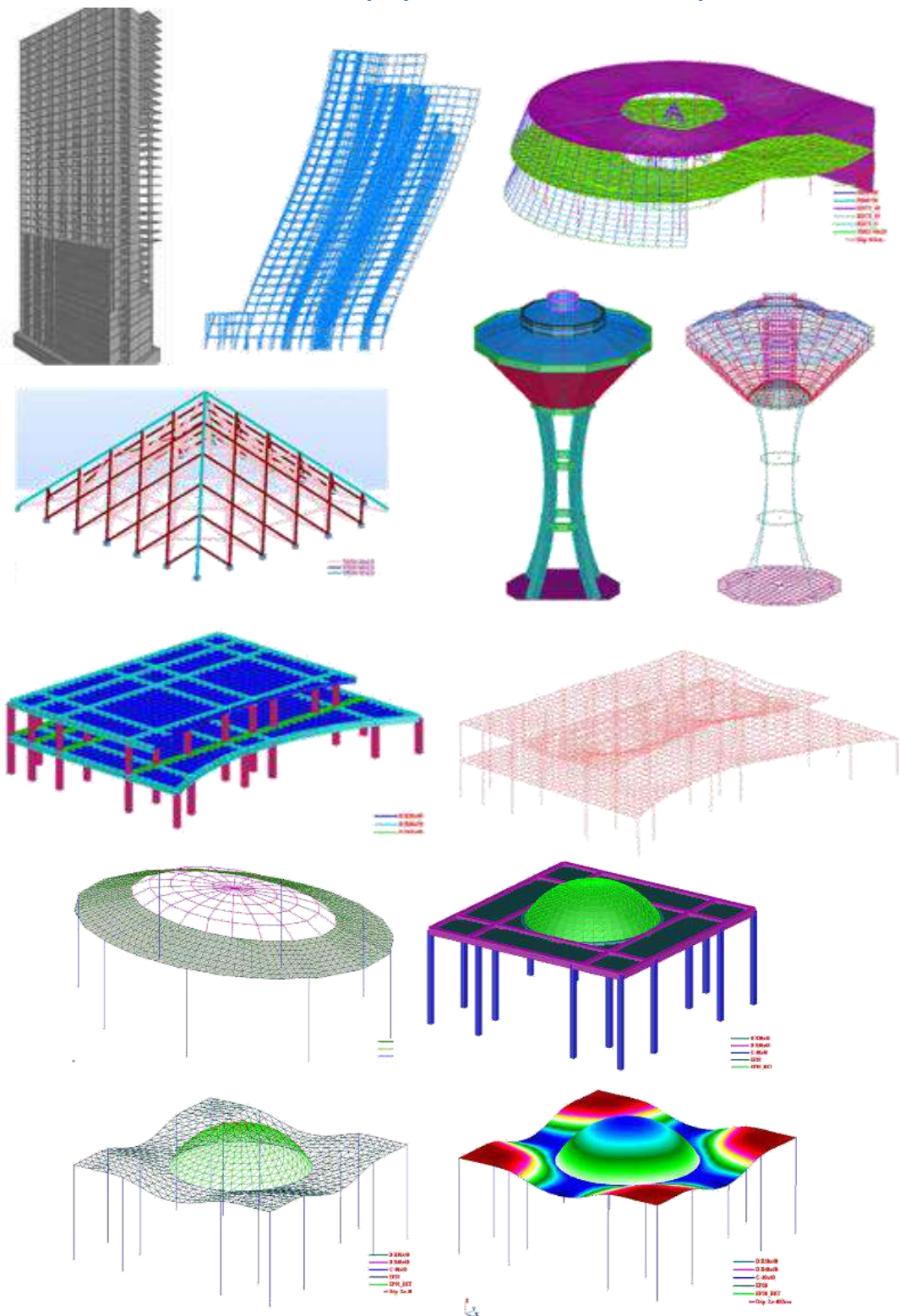
Project : Chams Dubai (Dubai)
 Client : Marwan Gharios.
 Mission : Modeling, design and shop drawings.
 Notes : Steel structure with cables.

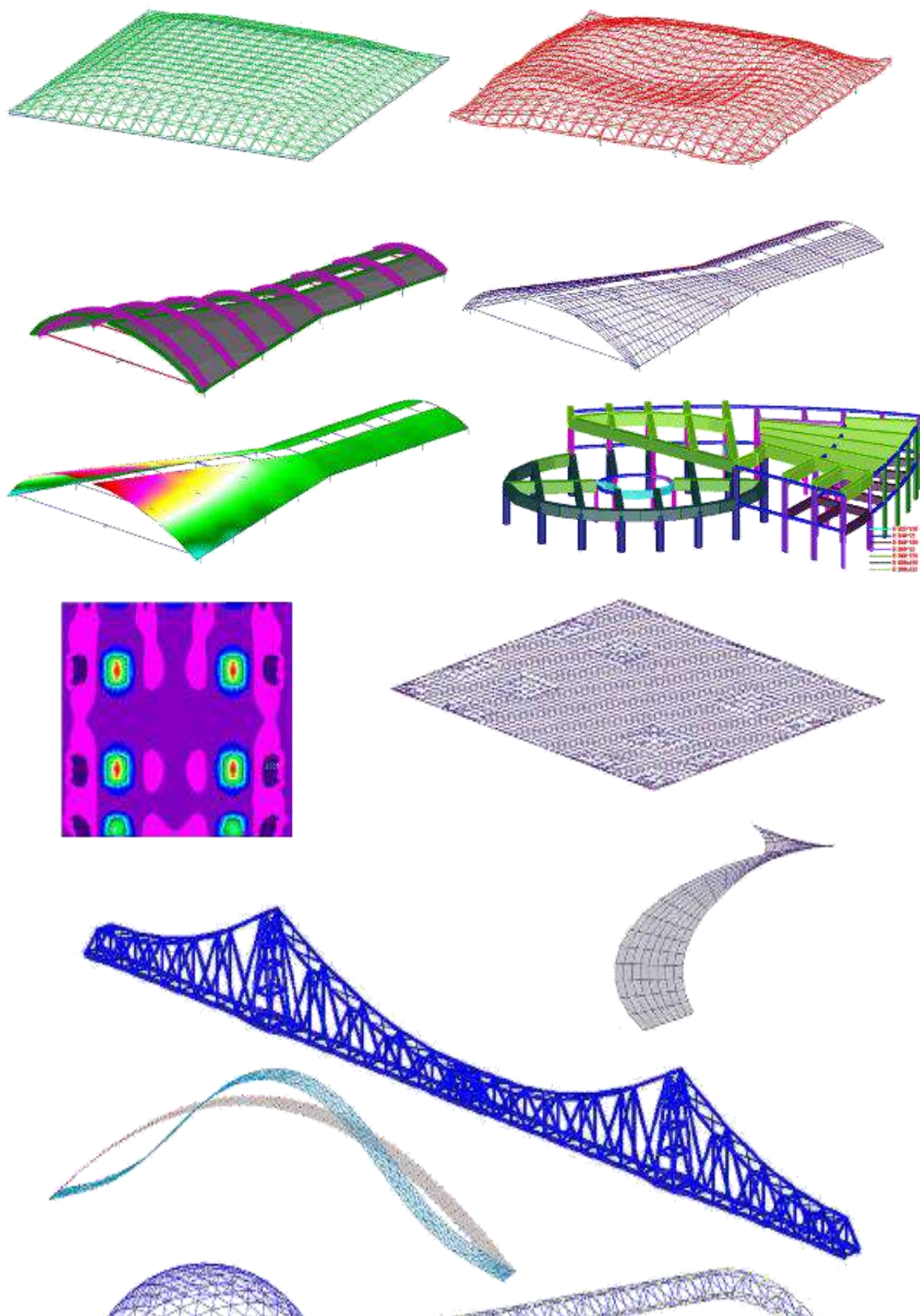


Project : New Sudan Parad (Sudan)
 Client : Vendome international.
 Mission : Modeling, wind design and shop drawings.
 Notes : Steel structure with cables: A 19 m cantilever structure made of 83T of steel.



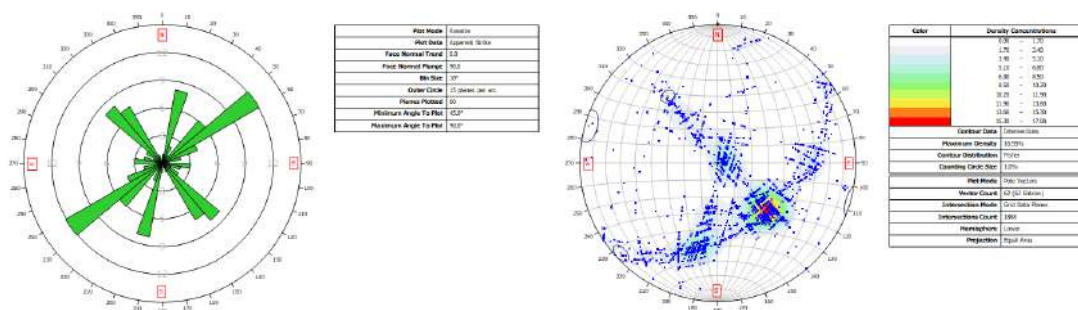
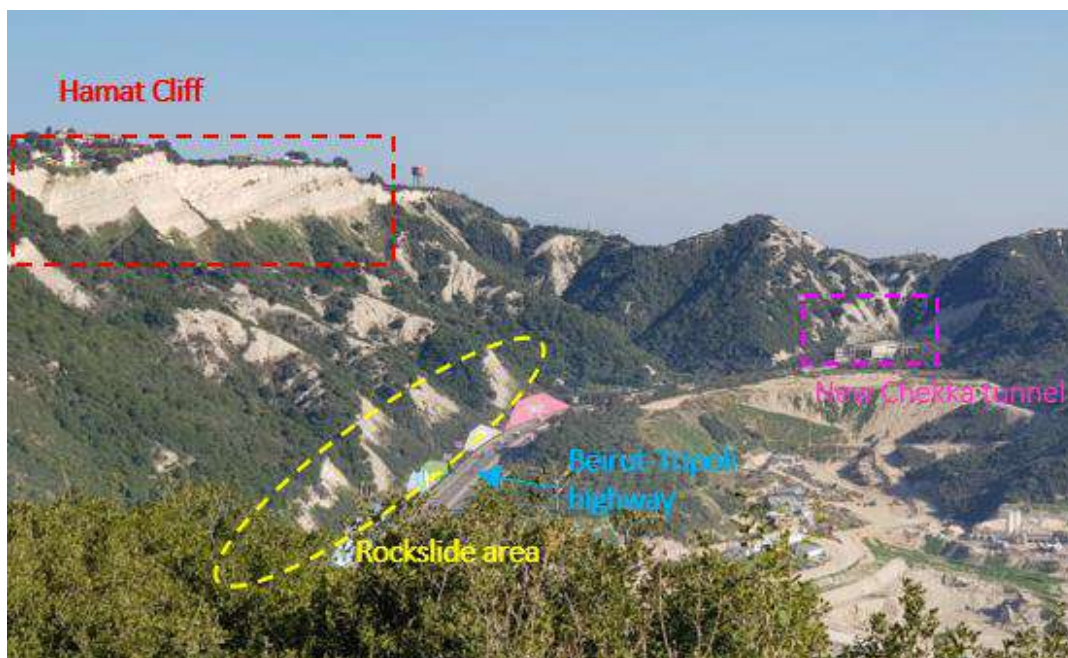
Academic: Master projects – Lebanese University





7.3 FEM - Rock mechanics

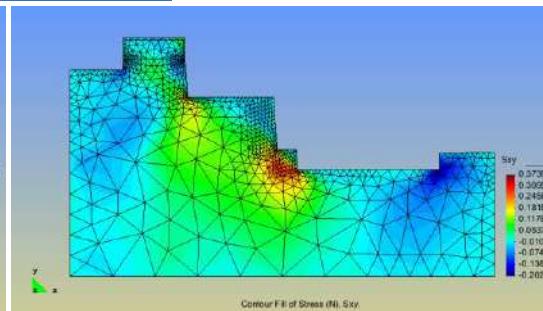
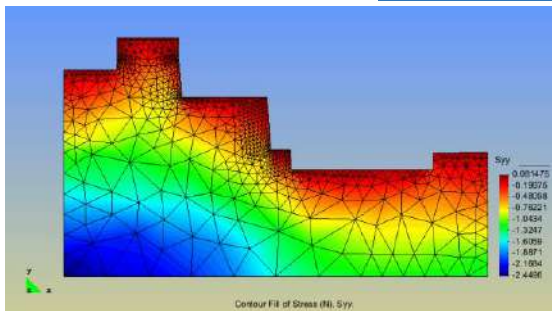
Chekka Landslide - Fractures survey & FEM slope stability analysis



Excavation, Rock slope stability & anchors design: Thakher - KSA (height of rock slope 43m, 1H:18V)



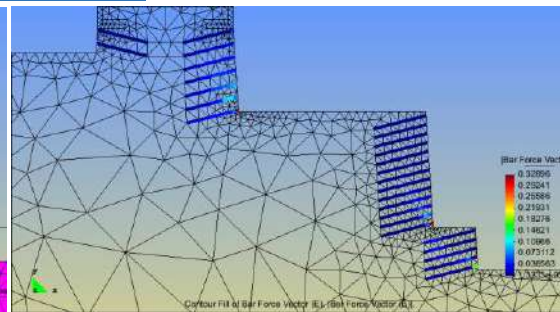
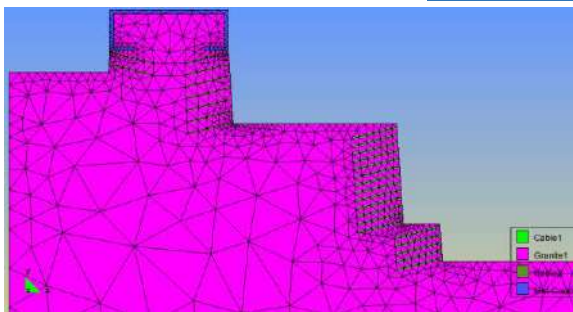
Phase one: initial stress state



Vertical stress

Shear stress

Phase 2: bolts activation

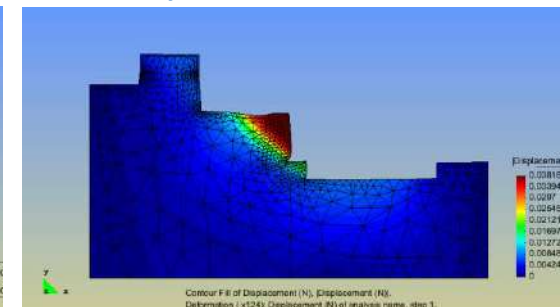
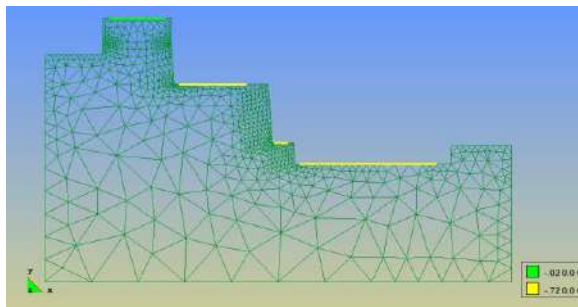


Mesh and materials

Forces in bolts

Phase 3: application of the building pressure on the excavated rock mass

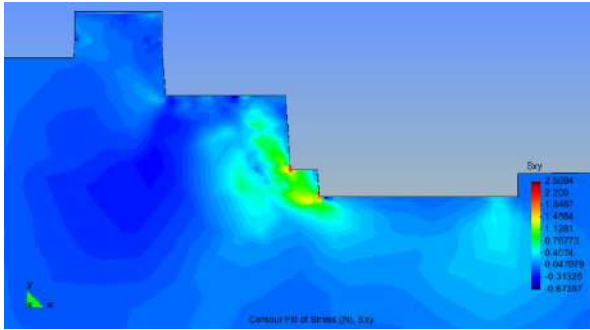
Stress Reduction Factor Method: Safety factor 1.2



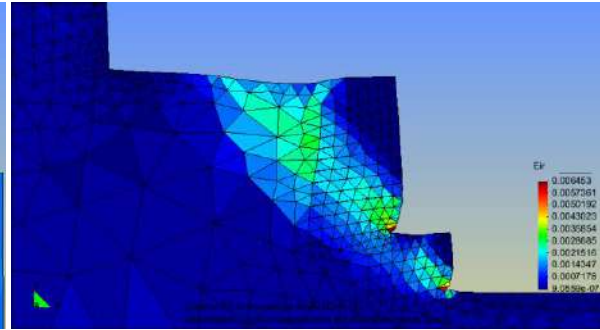
Building pressure on the excavated rock mass (0.72MPa)

Displacement (m)

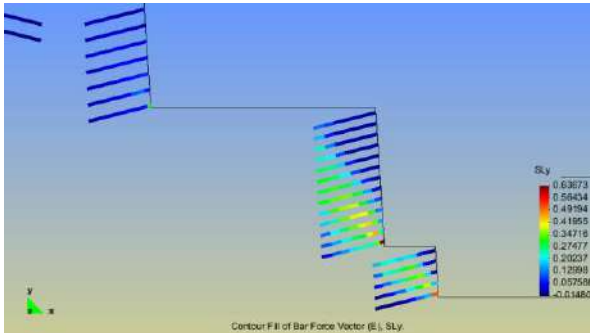




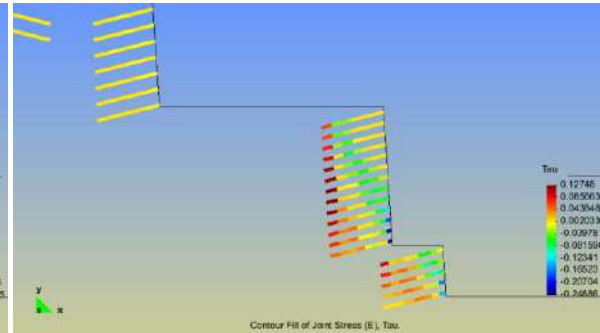
Shear stress



Irreversible strain

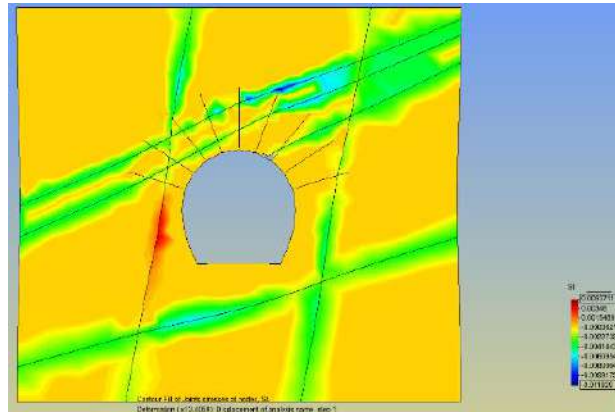
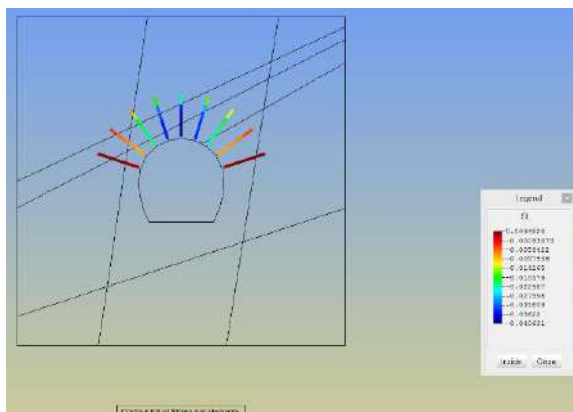
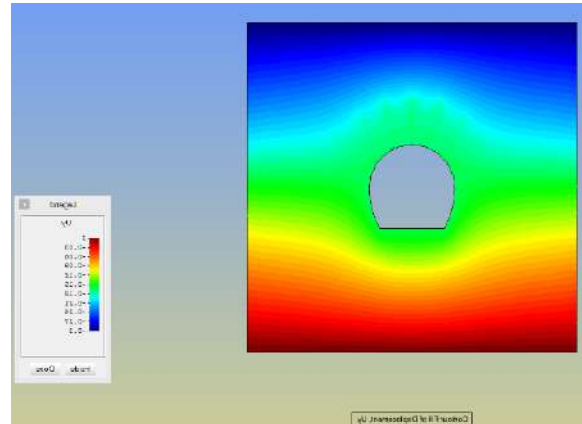
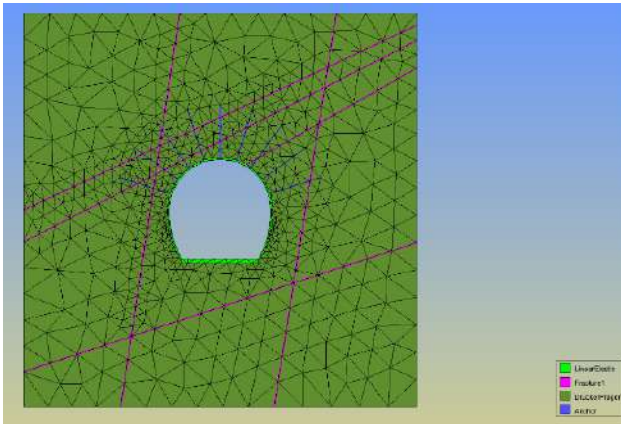


Rock bolt forces (MN)



Stress in grout around bolts

Jannah Dam and Lake Project – Diversion Tunnel



Numerical modeling of Janna diversion tunnel in a fractured rock mass by FEM

Stress in bolts and rock joints



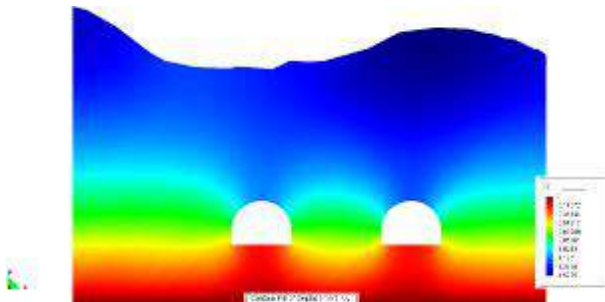
Advanced Numerical Modeling & Structural analysis (Academic)

Rock mechanics

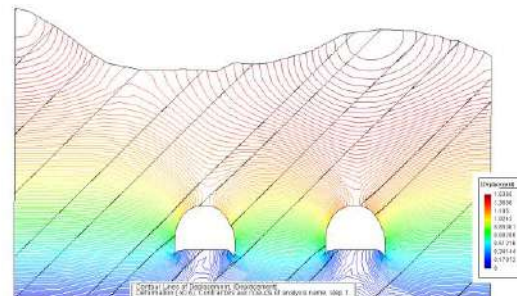
Tunnels

Two adjacent tunnels in a limestone rock mass, FE Modeling including rock joint elements

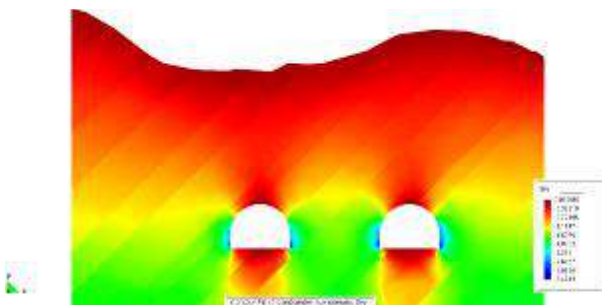
Chekka Tunnel, Lebanon



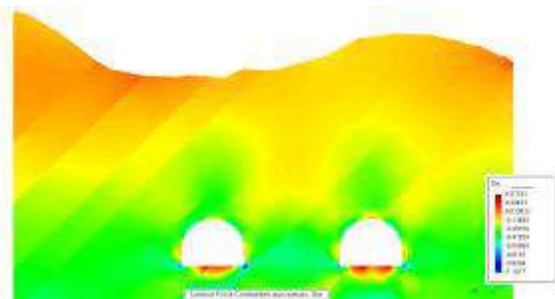
Vertical displacement



Deformed shape total displacement



Vertical stress



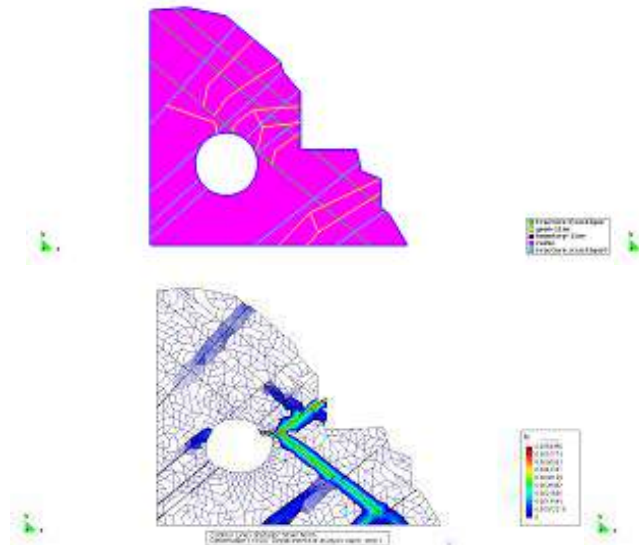
Horizontal stress



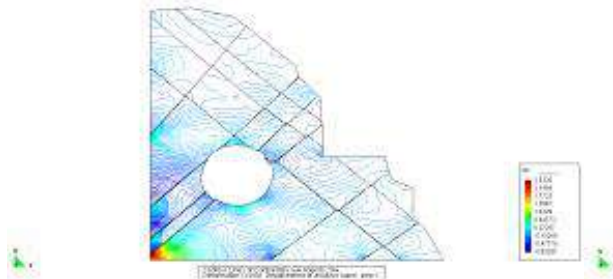
Shear Reduction Factor method: Comparison between the actual state and the stabilized state with anchor bolts of a tunnel and an adjacent road (FE modeling)

WITHOUT anchor bolts

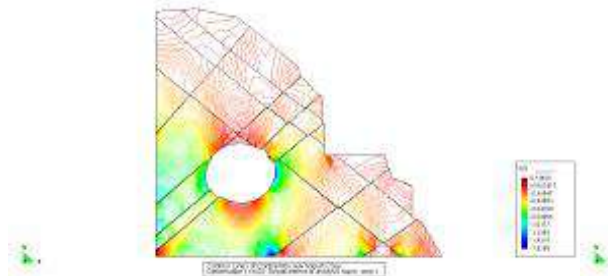
Shear Strength Reduction Factor : **F=2.35**



Plastic strain (without anchor bolts)



Horizontal stress (without anchor bolts)



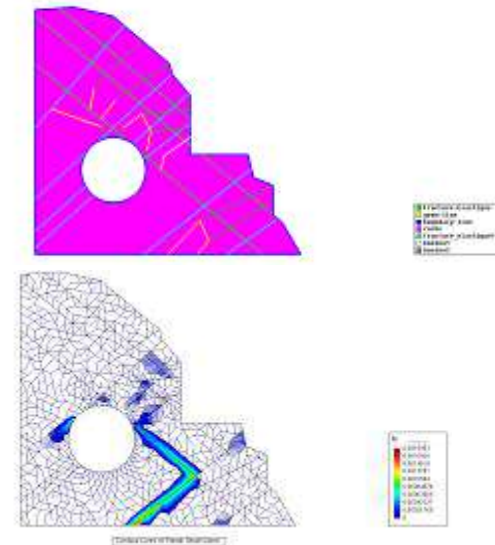
Vertical stress (without anchor bolts)



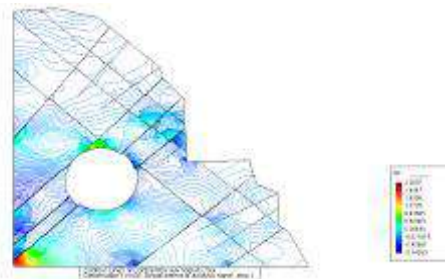
Deformed total displacement (without anchor bolts)

WITH anchor bolts

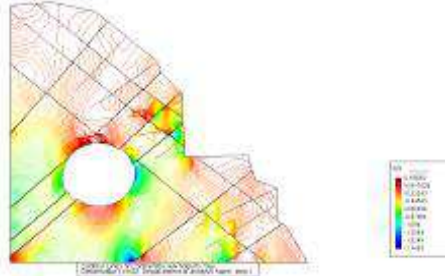
Shear Strength Reduction Factor : **F>30**



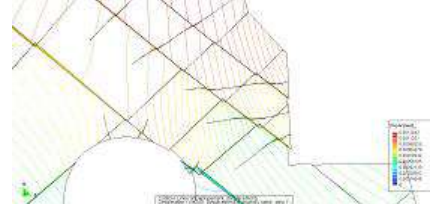
Plastic strain (with anchor bolts)



Horizontal stress (with anchor bolts)



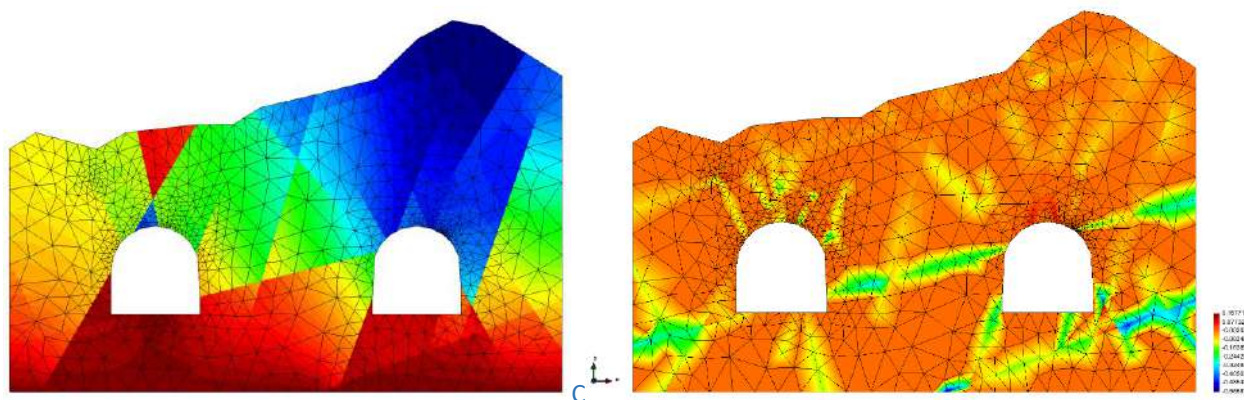
Vertical stress (with anchor bolts)



Deformed total displacement (with anchor bolts)

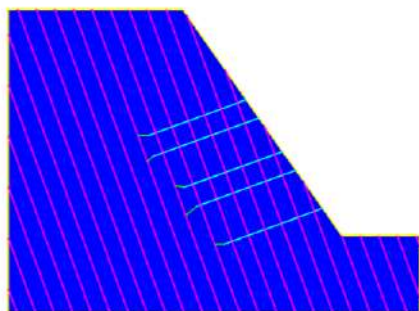


Double-way tunnel design in a rock mass (FE modelling)

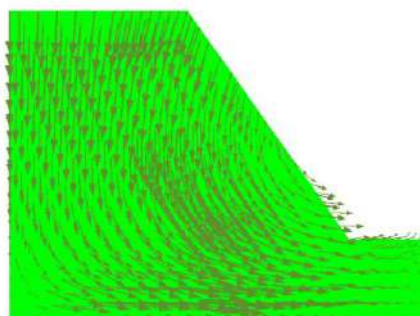


Slopes

Slope stability analysis FE modeling including fractures and cables

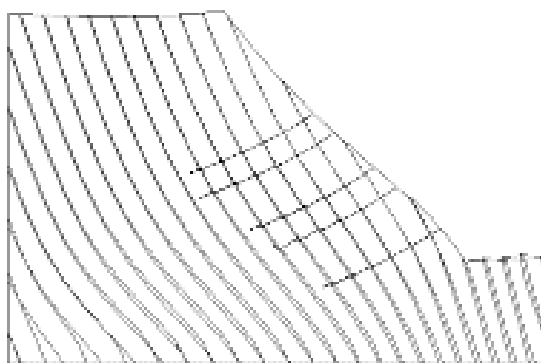


Geometry of fractures intersected by anchoring bolts

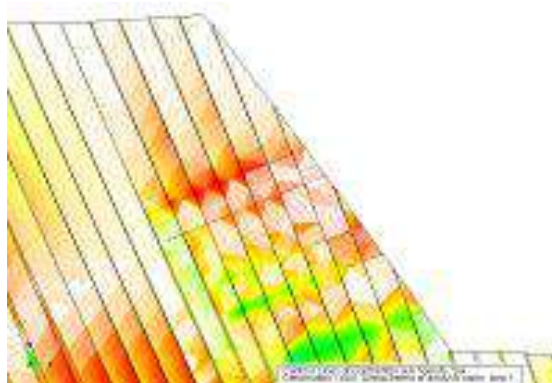


Total displacement vectors

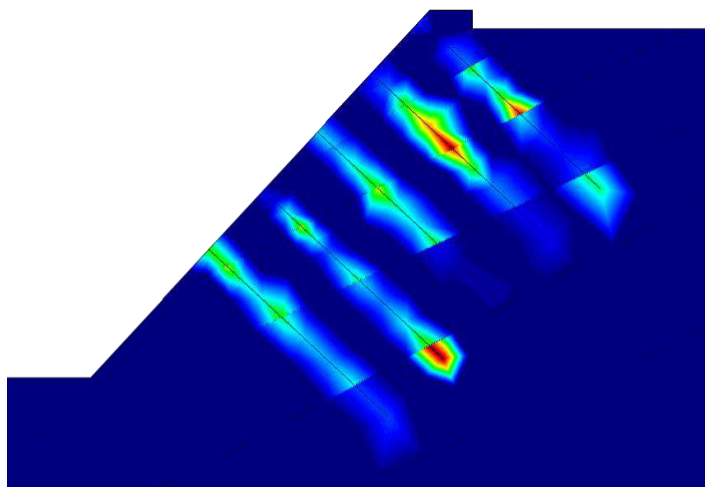
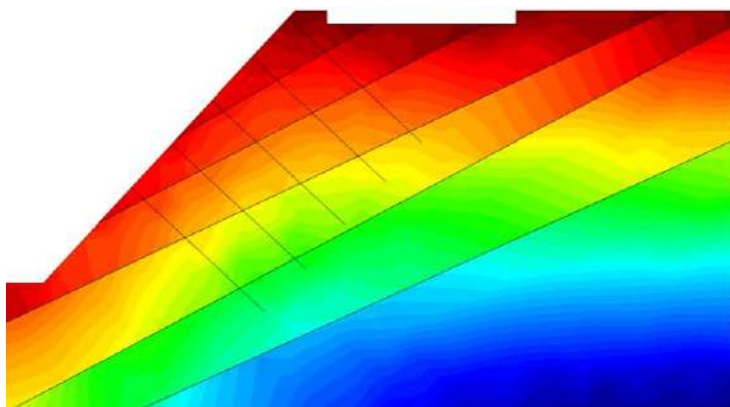




Deformed shape



Concentration of horizontal stress along anchor bolts

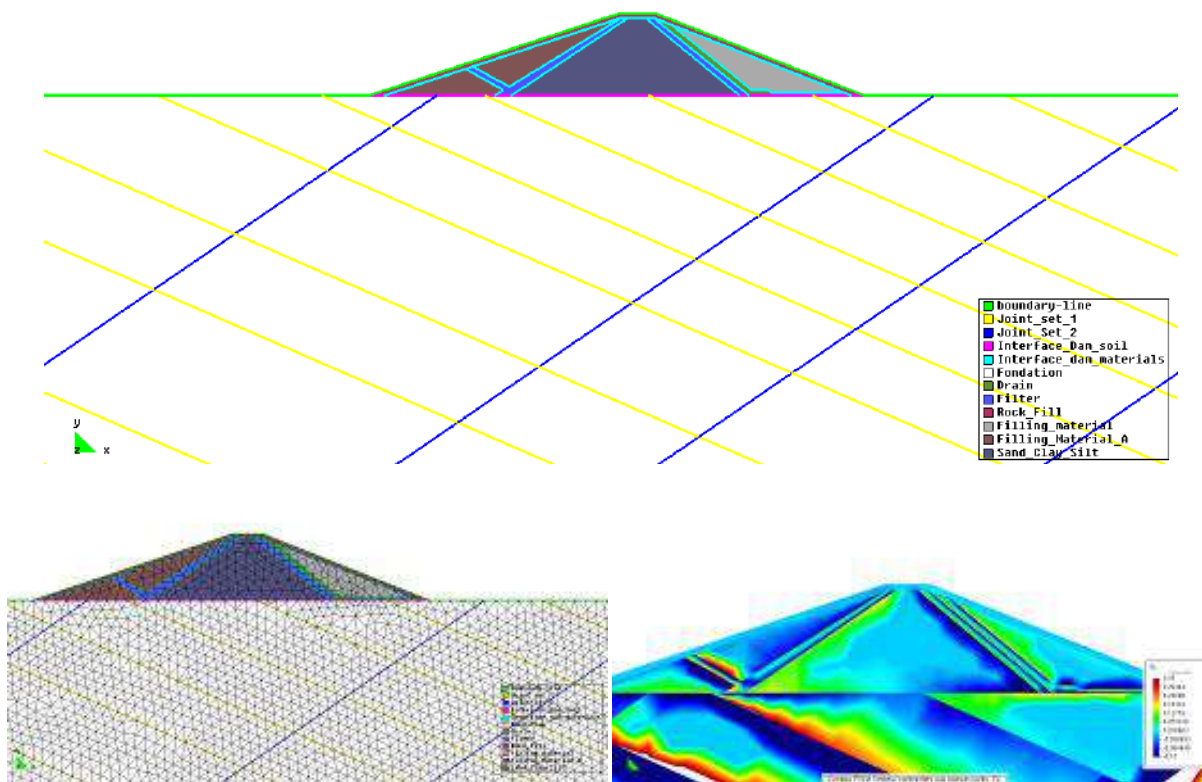


Stress in cables



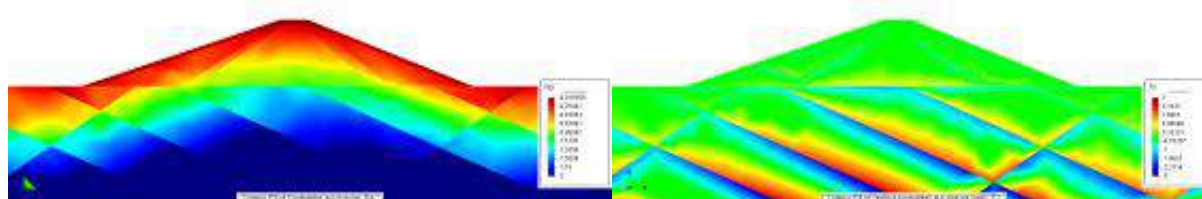
Dams

Cross section of an Earth Dam lying on a rock mass foundation with two sets of discontinuities



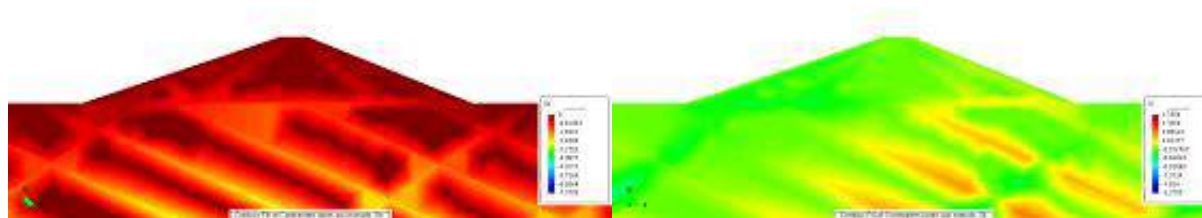
Finite elements mesh

Vertical stress of the rock material



Vertical stress in the dam and underlying rock mass

Vertical stress on fracture planes



Normal stress on fracture planes

Shear stress on fracture planes



8. RENOVATION



Nazareth School Achrafieh – Historic vaulted Kitchen (Design build)



Notre Dame de Barieh - Bsarma - North Lebanon (Design-Build)

Existing



As per design



Execution





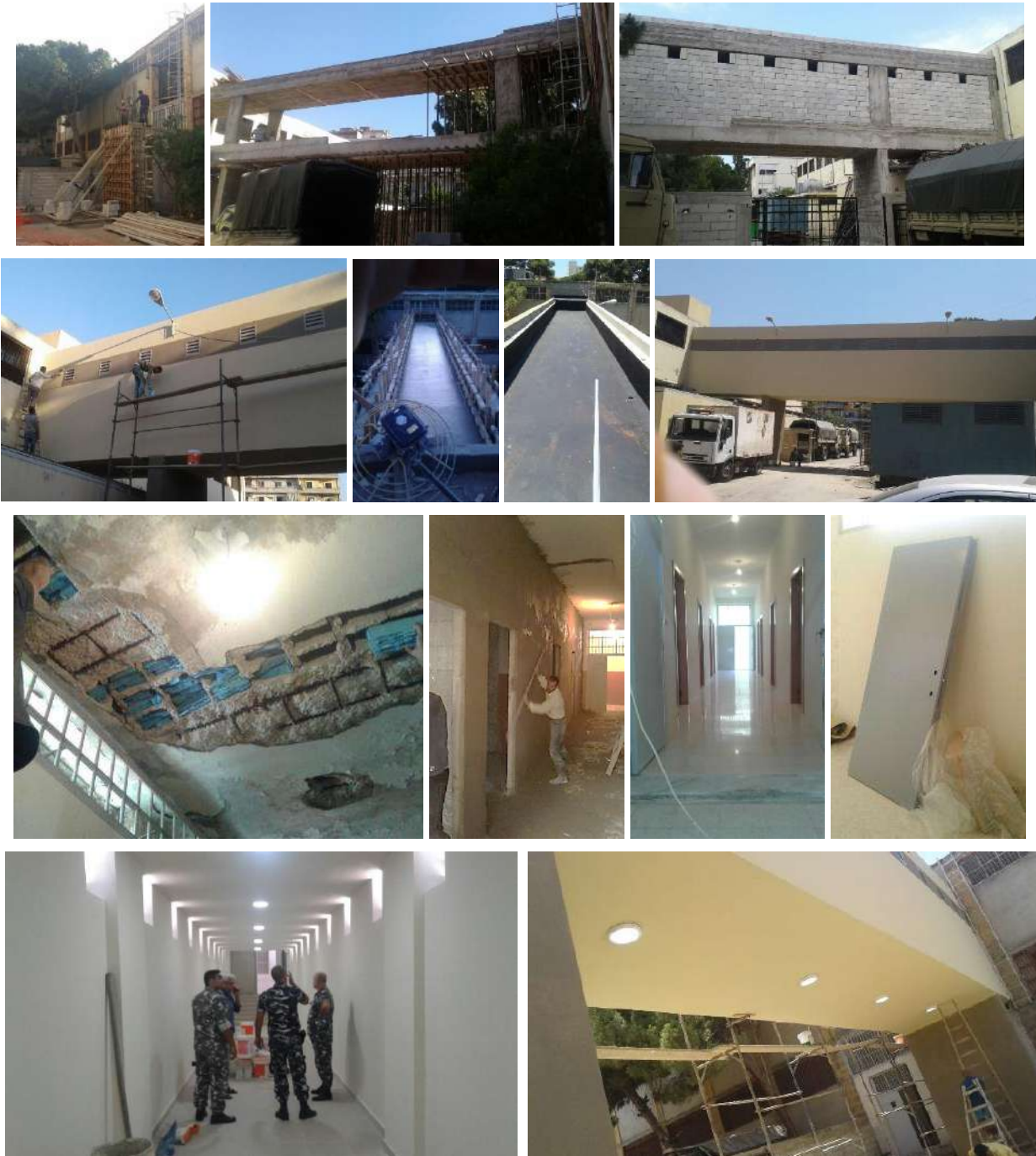
During execution



After renovation



Tripoli Prison - North Lebanon (Contracting)



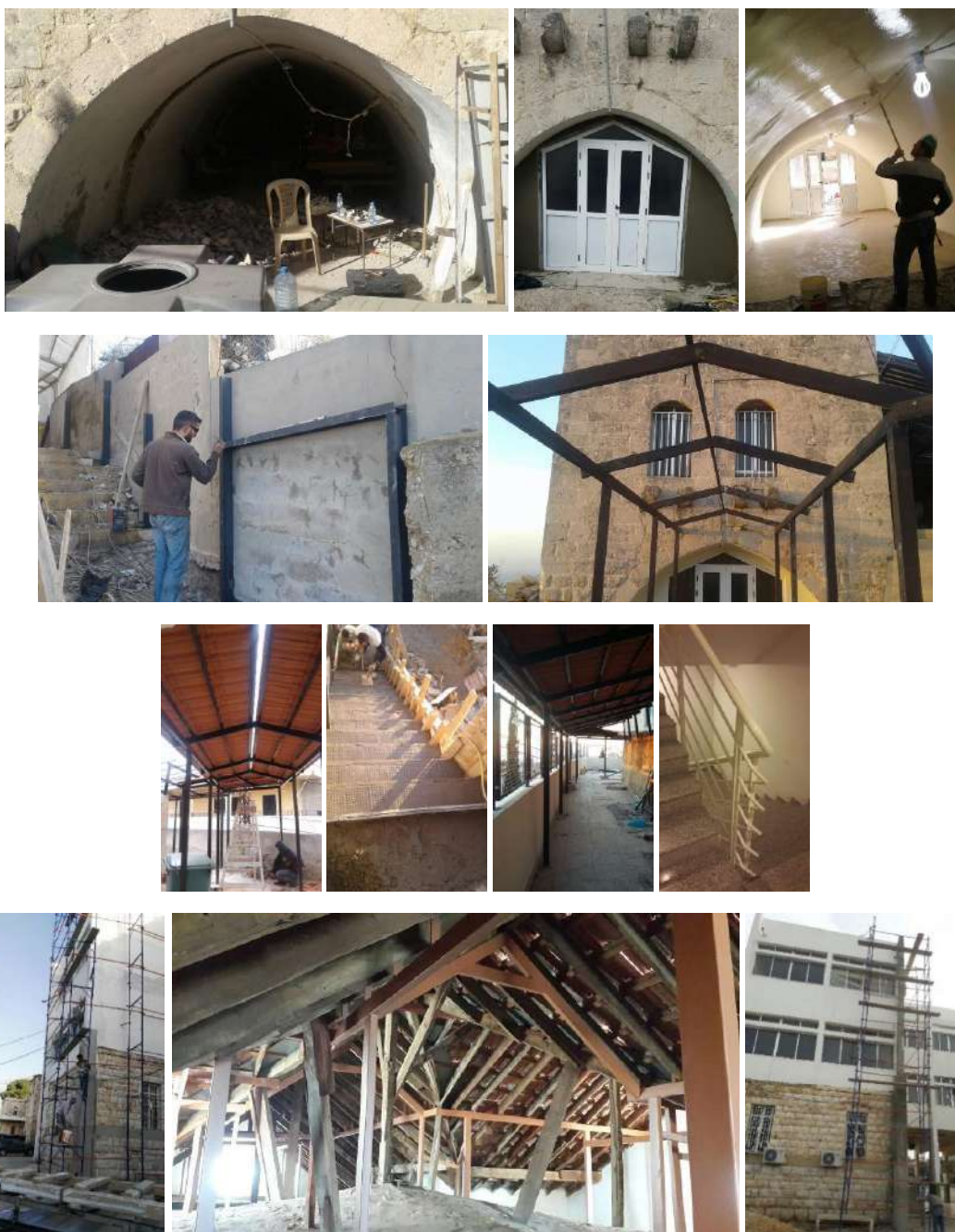
Nazareth Congregation Old School - Ain Alaa (Design build)



Renovation of public Schools Rehabilitation (client: Swiss Embassy in Beirut)

Public schools: Rihaniyeh - Akkar, Old Chekka - Chekka, Barsa - Koura, Dar Beehtar - Koura, Kobayat - Akkar, Souaisi - Akkar, Al Fadel - Akkar, Haytla - Akkar, Remmeh - Akkar, Rihaniyeh - Akkar, Burj Abi Haidar -Beirut, Ras Al Nabaah Beirut, Msaytbeh - Beirut, Mazraa – Beirut.

Private schools: Notre Dame de Nazareth - Beirut, North Lebanon College - Jdeidet Zgharta, Ecole des Religieuses de Nazareth - Kfarzeina, Ecole des Moines Libanais - Chekka



9. KNOWLEDGE DISSEMINATION



Site school workshop

Heritage Consolidation workshop - Rmeil 360 – Beirut



POST-DISASTER DAMAGE
ASSESSMENT & STABILIZATION

HERITAGE CONSOLIDATION WORKSHOP

SEPTEMBER 2023 - FEBRUARY 2024
BEIRUT, LEBANON

WHO CAN APPLY:
ARCHITECTURE & ENGINEERING
STUDENTS AND GRADUATE

HOW TO APPLY:
FILL OUT THE APPLICATION AND
UPLOAD THE REQUIRED DOCUMENTS
(CV & COVER LETTER)

APPLICATION DEADLINE: 10.08.2023

THE "CHANTIER-ECOLE" IS FREE OF
CHARGE, AND ON A PART-TIME BASIS.

BEIRUT HERITAGE INITIATIVE DiSTRUCT solutions BRITISH COUNCIL FONDATION DE FRANCE



SAFEGUARDING BEIRUT'S DISTINCTIVE HERITAGE

RMEIL 360
HERITAGE
CONSOLIDATION
WORKSHOP

IN PARTNERSHIP WITH: DiSTRUCT solutions

WITH THE SUPPORT OF: FONDATION DE FRANCE BRITISH COUNCIL

BEIRUT HERITAGE INITIATIVE

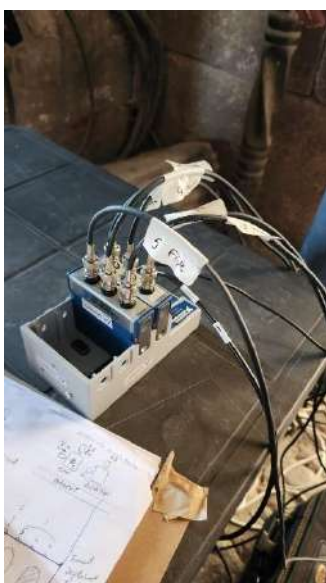




Site school sessions



Site school workshop
Post disaster Damage Assessment & Non-Destructive testing
Aleppo Castle - Syria



Building capacity workshop
Restoration and reconstruction of built-heritage
House of Wonders – Zanzibar



Webinars and documentaries in collaboration with Beirut Heritage Initiative

Structural restoration of the heritage buildings following the Beirut blast 2020



https://www.youtube.com/watch?v=8raP0Enzp_0&list=PLSgveqKud4EyW4fUrPfxuO4IIZ-Shcx1p&index=2

<https://www.youtube.com/watch?v=-HlqCCDwnlw&list=PLSgveqKud4EyW4fUrPfxuO4IIZ-Shcx1p&index=3>

The Blue House structural restoration



Structural Intervention with Michel Chalhoub

<https://www.youtube.com/watch?v=gF9L9nUinBU>



Webinar on Monuments protection – Beirut / Ukraine

In collaboration with ALIPH



Monument protection: Beirut experience/Охорона пам'яток: досвід Бейрута

<https://www.youtube.com/watch?v=BTQJnA1qN-g>

Seminar/Webinar on the Structural Reinforcement of Masonry buildings and Monuments



Seminar – Restoration of Built Heritage – ALBA - Speaker 1: Dr Michel Chalhouh

<https://www.youtube.com/watch?v=zY4Dzq9jmd8>



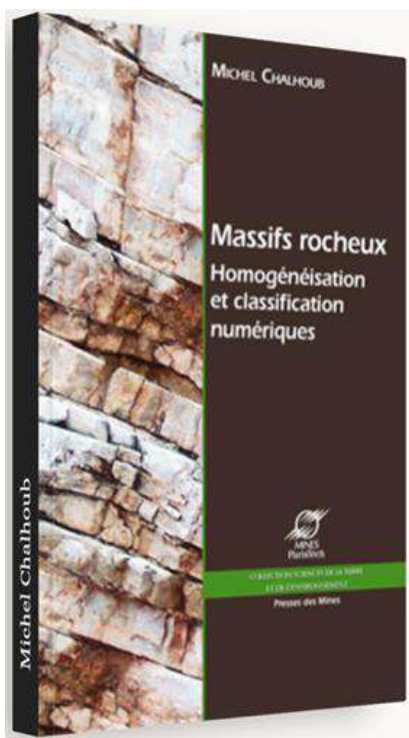
10. PUBLICATIONS



Books

- **Massif rocheux : Homogénéisation et classification numériques.** *Presses des MinesParisTech*, 228 pages, ISBN: 978-2-911256-26-4, 2010.

<https://www.pressesdesmines.com/produit/massifs-rocheux/>



- **HOUSES OF BEIRUT 1860-1925 - Restoration manual,** (main author of the structural chapter) ISBN: 978-9953-0-5560-2.

<https://beirutheritageinitiative.com/restoration-manual/>



Journals and conferences

- Chalhoub, M., Pouya, A. Effective Elastic Properties of Some Varieties of Rockmasses with a High Density of Finite Size Fractures. *Rock Mech Rock Eng* **56**, 3179–3195 (2023). <https://doi.org/10.1007/s00603-022-02895-8>.
- Nini R., Chalhoub M. 2016: Effect of soil drainage on California Bearing Ratio of soaking clay. *International Review of Civil Engineering (I.R.E.C.E)*, Vol.7 N.4, ISSN 2036 – 9913, July 2016.
- Chalhoub M., Pouya A. 2008: Numerical homogenization of a fractured rock mass: A geometrical approach to determine the mechanical Representative Elementary Volume. *Electronic Journal of Geotechnical Engineering*, Volume 13, Bund. K, pp.1 to 12, December 2008.
- Chalhoub M., Casarin F., Pires F. 2024, Dynamic identification of the main entrance tower and the historic bridge of the Citadel of Aleppo after the Syria 2023 earthquake, IOMAC2024, Naples, Italy, 21-24 May 2024.
- Chalhoub M., Souissi S., Essaieb H., Pouya A. 2022: Numerical elastoplastic homogenization of an anisotropic rockmass with non-persistence fractures. *Tunirok 2022, Hammamet*, 26-27 March 2022.
- Souissi S., Chalhoub M., Pouya A., Essaieb H. 2020 : A methodology to determine the deformation modulus of a highly jointed rock mass using field data and Finite Element method. *Fourth international conference on geotechnical engineering, New Developments in Geomechanics and Georisk, Hammamet (Tunisia)*, 9-11 March 2020
- Chalhoub M., Pouya A. 2016 : Modélisation du renforcement des ouvrages en maçonnerie par la méthode des Eléments finis : Etude de deux cas du patrimoine libanais bâti, *IFSTTAR Ecole des Ponts, ParisTech*, 17-18 Mars 2016.
- Pouya A., Chalhoub M. 2008 : Numerical homogenization of elastic behavior of fractured rock masses and micro-cracked materials by FEM. *The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG)*, 1-6 October 2008, Goa, India, pp. 403, 410.
- Chalhoub M. 2007 : Exploitation de la lumière directe dans les bâtiments : Un outil numérique d'aide à la décision. *Construction durable, Université Saint Esprit de Kaslik, Liban* 17-18 Mai 2007, pp. 213-227.
- Pouya A., Chalhoub M. 2007 : Ellipsoidal anisotropy in elasticity for rocks and rock mass. *The 11TH ISRM CONGRESS: The Second Half-Century of Rock Mechanics, Lisbon, Portugal*, July 9 – 13, 2007, pp. 251,254.
- Chalhoub M., Bouillard P., Verbruggue J.C., Tamsah Y. 2003 : Étude du comportement statique et dynamique d'un pieu isolé implanté dans le Sable par Eléments Finis. *Premier Congrès International sur la Modélisation Numérique Appliquée. Beirut, Liban*, 14-15 novembre 2003.



Seminars

- Chalhoub M.: Post disasters built heritage rescue the case of the Beirut Blast 2020 & the Syria earthquake 2023. APT 2023, Seattle, 10 October 2023.
- Chalhoub M.: Urgent stabilization of the Beirut built heritage damaged by the 2020 blast: Technical aspect and illustrations. A seminar organized by ALIPH to share urgent stabilization experience with Ukrainian professionals - December 16, 2022.
https://www.linkedin.com/posts/aliphfoundation_monument-protection-beirut-experience%D0%BE%D1%85%D0%BE%D1%80%D0%BE%D0%BD%D0%B0-activity-7009553845433286656-q7jG/?originalSubdomain=hu
- Chalhoub M.: Structural reinforcement of masonry-built heritage. *December 02, 2022. Académie Libanaise des Beaux arts, University of Balamand.*
- Chalhoub M.: Retrofitting of masonry Historical Monuments: concept, modeling, and execution process, May 20, 2017, *Order of engineer and Architects, North Lebanon.*
- Chalhoub M. : Modélisation numérique des monuments historiques en pierre : Etude de cas Eglise St Georges Ehden-Liban. *April 28, 2015, University of Saint Esprit de Kaslik, Lebanon.*
- Chalhoub M., Pouya A. : Modélisation des ouvrages en maçonnerie : cas du pont ottoman de Nahr EL Kalb-Liban. *October 13, 2009, University of Saint Esprit de Kaslik, Lebanon.*
- Chalhoub M. : Restitution mécanique de l'Aqueduc de Nahr Ibrahim. *December 2009, Municipality of Nahr Ibrahim, Lebanon.*





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