Structural Assessment of Existing Facility

Visual Inspection

June 2025

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PART 1 - INTRODUCTION:

DAR was requested to conduct an observation-based inspection and structural condition assessment of the existing buildings and structures within the Jeita Grotto Facility. The objective of this assessment is to evaluate the current structural condition of the facility and to determine an appropriate rehabilitation and reinstatement strategy that would allow for its safe reuse.

In general, regardless of the level of visible damage, the structural detailing of the connections between various structural and façade elements, the cantilevered columns supporting the cable car, and the design and reinforcement of the basement walls must be adequate to resist seismic actions in accordance with the latest Lebanese seismic codes, especially given that the Jeita area is susceptible to severe earthquakes.

However, considering the limited available budget and the extensive scope of work required to upgrade the structural systems of the various blocks to meet current seismic standards, this aspect of retrofitting will not be addressed in the current report. Nonetheless, it is strongly recommended that seismic strengthening measures be studied and implemented at the earliest opportunity.

PART 2 - VISUAL INSPECTION

A visual inspection was conducted on 13 June 2025 and was limited to the exploration of the site perimeter, as well as the examination of exposed and accessible structural elements across all blocks, including both the lower and upper grotto areas.

The in-scope structures are as follows:

1. Lower Cave.
2. Upper Cave.
3. Parking Building.
4. Lower Cable Car Building.
5. Upper Cable Car Building, including the amphitheatre.
6. The administration building and the restaurant.

The construction of the majority of the structures was completed over 50 years ago and, since then, they have only undergone occasional maintenance.

The objective of the current campaign was to conduct a visual inspection of the structural elements and to provide recommendations on the following aspects:

1. Determining the defective areas,
2. Actions and way forward.

The administration building and the restaurant structure appear to be in sound condition based on the visual inspection. As such, the following sub-sections will focus on the first five blocks/areas listed above.

These sub-sections will present the findings of the structural assessment campaign, addressing the structural soundness of each area, identifying potential strengthening needs, and providing recommendations for any required interventions.

2.1 Lower Cave:

The lower cave consists primarily of several slabs on grade at different levels, stairs cast directly on grade, and a steel deck at the boat docking area.

At the entrance to the lower cave, a portion of the rock formation appears to be cracked and at risk of detachment. It is therefore recommended to investigate the stability of this rock block and ensure that appropriate measures are taken to secure it in place.

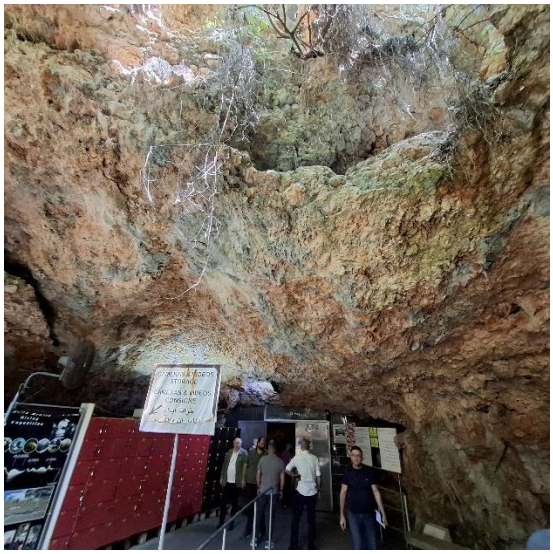


Figure 1: Stone Block at the Entrance to the Lower Cave.

The slabs and stairs on grade do not show any visible deficiencies, noting that these elements are not subject to significant stresses, as they are supported directly on the underlying rock substrate.

The steel decks at the boat docking area, however, should be thoroughly inspected from all accessible sides. If any part of the structural framing or connections is found to be corroded or damaged, appropriate reinstatement works should be carried out. Following any necessary repairs, the steel elements should be protected with a suitable anti-corrosion coating to prevent further deterioration.

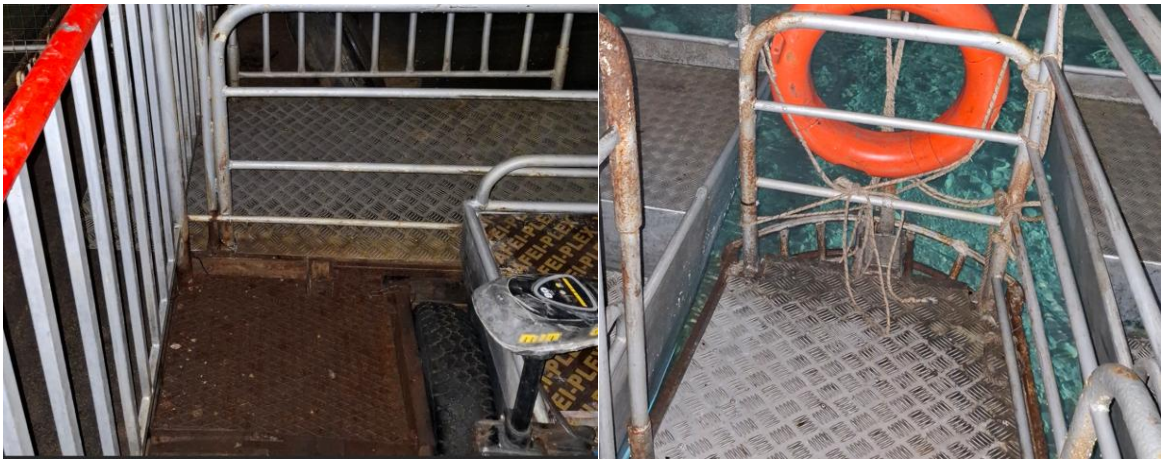


Figure 2: Steel Docks at the Lower Cave.

2.2 Upper Cave:

The structural elements of the upper cave consist primarily of the entrance tunnel, several slabs on grade at different levels, stairs on grade, elevated passages supported by columns or brackets, and suspended stairs and platforms.

The tunnel, which is excavated within a rock formation and not exposed to a corrosive environment, shows no visible signs of distress based on the visual inspection.



Figure 3: Tunnel Entrance to the Upper Cave.

Structures supported directly on the rock substrate are in good condition, with no visible signs of distress. These elements will likely require only the application of anti-slip coatings on their top surfaces and anti-carbonation protective coatings on exposed concrete surfaces.

The suspended stairs, passages, and platforms are also generally in good condition. Minor spalling was observed around the handrail fixation points, along with some localized corrosion of reinforcement bars that were placed too close to the surface and lack adequate concrete cover.



Figure 4: Spalls at Handrail Fixation Locations - Upper Cave.

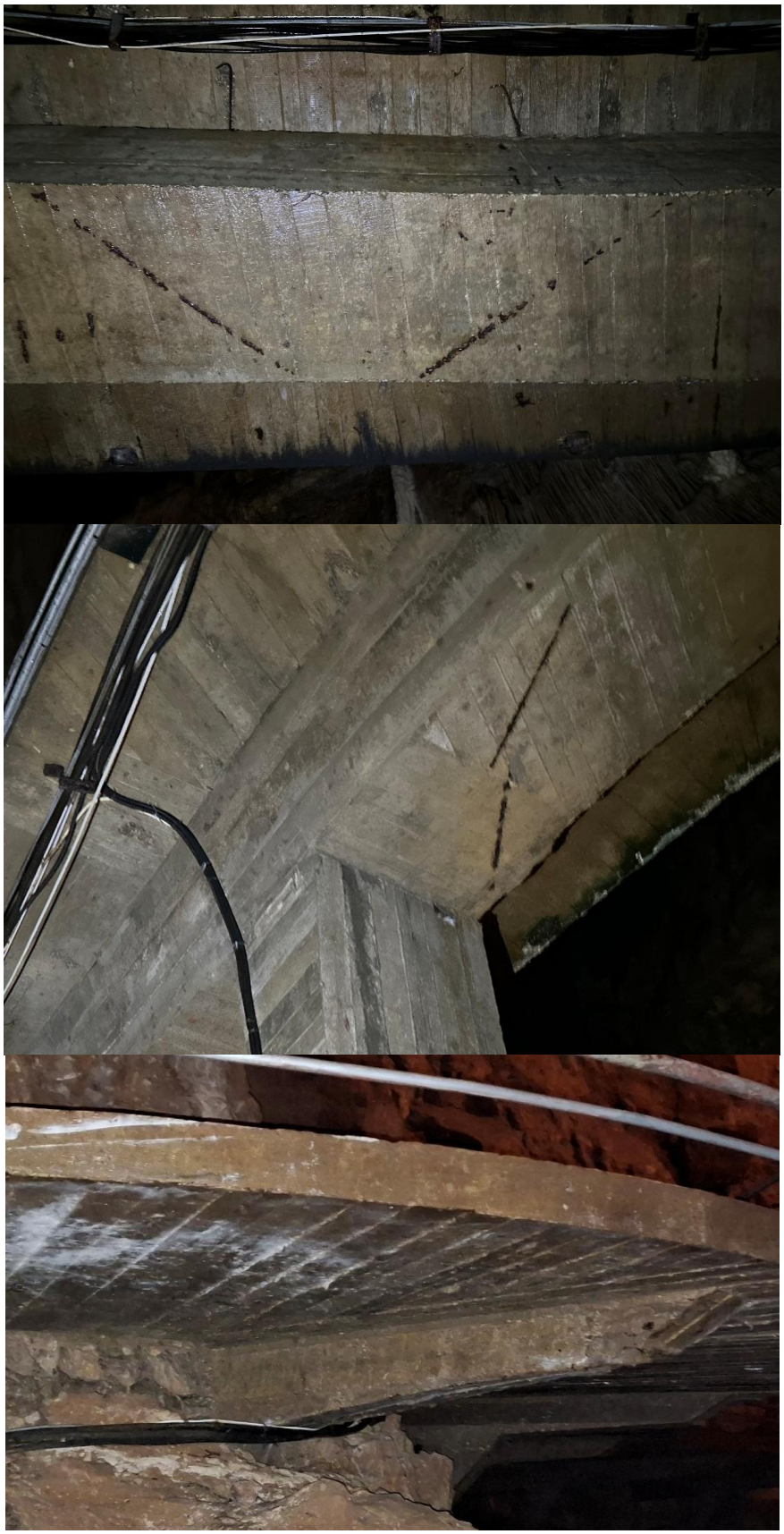


Figure 5: Minor Surface Rebar Corrosion and Efflorescence at Lower Surfaces of Passages - Upper Cave.

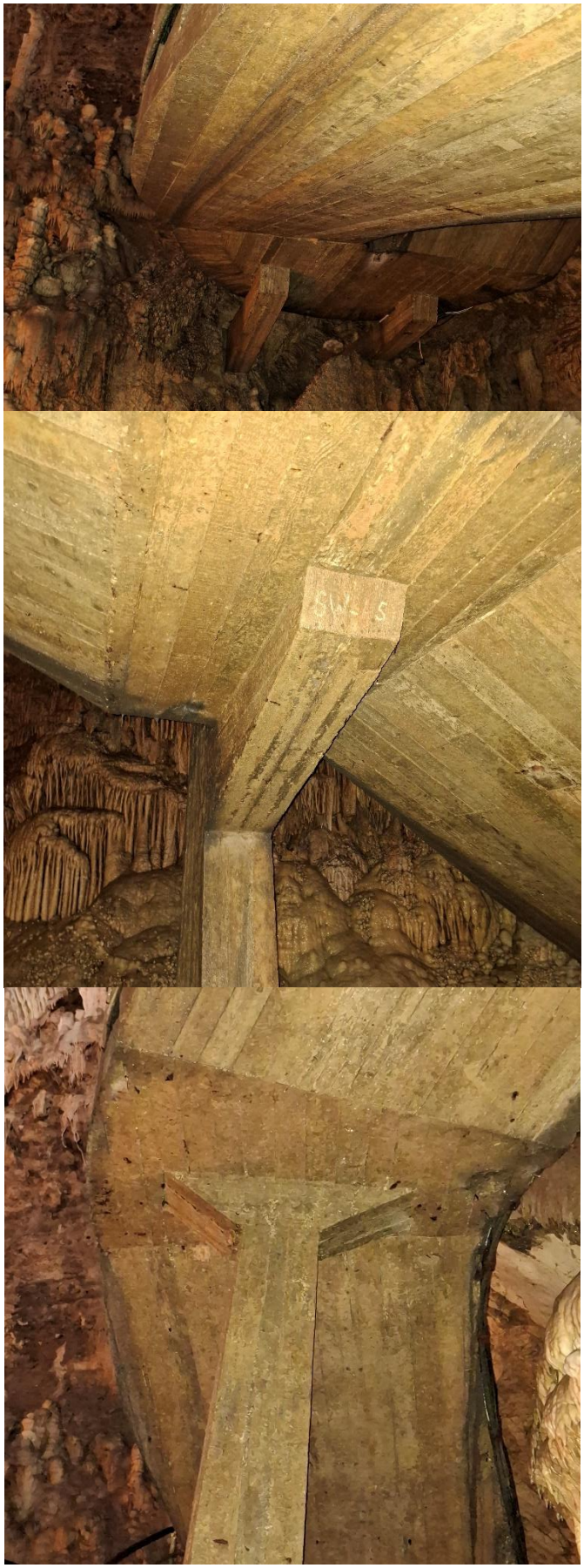


Figure 6: Good Condition at Lower Surfaces of Passages and suspended stairs - Upper Cave.

2.3 Parking Building:

The Parking Building comprises three semi-basement levels. The uppermost level (B1) has the largest built-up area—approximately twice the size of the B2 and B3 levels. The suspended slabs are primarily solid slabs. At the B1 level, these are supported by one-way thickenings at column strips, while at the lower levels (B2 and B3), the slabs are supported by drop beams of variable thickness.



Figure 7: Column Strips Thickenings at Ceiling of Parking First Basement.



Figure 8: Solid Slabs on Top of Drop Beams at Ceiling of Parking Second and Third Basement.

The ceiling of the first basement is supported on a stone masonry wall at the Northern side.



Figure 9: Ceiling of First Basement Supported on Masonry Wall to The Northern Side.

The ceiling of the first basement level, along with the supporting columns—particularly at their tops—exhibits several spalls and signs of damage caused by corrosion of slab reinforcement. This is most prominent near the ramp and expansion joints, and is primarily due to water infiltration. Once concrete repairs are completed, the system will require the application of a suitable roofing membrane at ground floor level, along with watertight treatment and sealing of the expansion joints.

At the lower basement levels, damage is mostly concentrated along the main façade and at expansion joints—specifically in areas exposed to rainwater and infiltration. At the third basement level, water ponding is observed on the slab near columns, posing a risk of further deterioration to the reinforced concrete elements. This should be addressed by introducing drainage trenches and measures to prevent water ingress into the structure.

In addition, the foundation of the circular retaining wall at the west side of the parking structure—supporting the first basement floor—is subject to scour caused by river flow. To ensure stability and prevent further erosion, a protective ground beam should be cast in front of the foundation, and concrete injection carried out beneath the exposed footing.



Figure 10: Ceiling of First Basement Showing Deterioration and Spalls Near Expansion Joint.



Figure 11: Cracks and Spalls at the Top of Columns Supporting Ground Level.



Figures 12: Ceiling of First Basement Showing Deterioration, Cracks, and Spalls.



Figure 13: Alarming Vertical Crack in a Column at the Corner of the Workshop at First Basement.



Figure 14: Ceiling and Supporting Beams of Second and Third Basement Showing Deterioration and Spalls Near Expansion Joint.



Figure 15: Spalls and Deterioration of a Column Supporting Second Basement Slab.



Figure 16: Spalls and Deterioration at Exposed Slabs Edges.



Figure 17: Spalls and Deterioration at Edge Parapet.



Figure 18: Water Infiltration at Third Basement.



Figure 19: Scouring Below the Foundation of the Circular Retaining Wall.

2.4 Lower Cable Car Building:

The Lower Cable Car Building consists of multiple levels, featuring main T-shaped columns that support the cable car system, with a sewage treatment plant located at the lower basement level. Only minor structural damages are observed, including a few hairline cracks, limited water infiltration, and exposed concrete surfaces subject to weathering.

To preserve the structural integrity, sources of water infiltration should be identified and treated. In addition, appropriate waterproofing systems and anti-carbonation coatings should be applied to protect the existing concrete elements from further deterioration.



Figure 20: Concrete Surfaces Exposed To Weathering As Anti-carbonation Coating Is Damaged.



Figure 21: Cracks in Slab Edge and Base Of Parapets.



Figure 22: Sewage Treatment Plant at Second Basement, Where Corrosive Water Is Ponding On Top Of the Foundations.



Figure 23: Corroded Reinforcement Is Drop Beams at Sewage Treatment Plant at Second Basement.

2.5 Upper Cable Car Building, Including the Amphitheater:

The Upper Cable Car Building comprises several levels, with main T-shaped columns supporting the cable car system. The building includes an amphitheater at ground floor level, as well as a sewage treatment plant and a generator room located at the fourth basement. The structural system consists primarily of solid and ribbed slabs supported by drop beams and reinforced concrete columns.

The condition of the reinforced concrete elements is similar to that of the Lower Cable Car Building. In areas exposed to water leakage and infiltration, deterioration of concrete is evident. Additionally, many surfaces are affected by carbonation and weathering, indicating the need for protective measures.



Figure 24: Water Infiltrations Damaging RC Slabs at First Basement.



Figure 25: Exposed to Weathering Surfaces, Inducing Damages to RC Slabs.



Figure 26: Damaged/Carbonated Concrete Surfaces Under the Amphitheater.



Figure 27: Damaged Concrete Column at The Fourth Basement Under the Amphitheater And The Cable Cars Structure.

2.6 Conclusion:

Although the reinforced concrete structures are not severely damaged, they exhibit signs of concrete carbonation, reinforcement corrosion, and surface deterioration. These issues are primarily due to insufficient protective measures, prolonged water leakage, exposure to aggressive environmental conditions, and a lack of maintenance over the past decades.

As a way forward, and to reduce the extent of testing required during a future detailed structural survey, the following recommendations are proposed:

1. The reinforced concrete elements in both the Upper and Lower Caves may be affected by concrete carbonation and reinforcement corrosion due to prolonged exposure to high humidity levels. A limited testing campaign is recommended to assess the current condition of the concrete. The specific tests to be conducted will be outlined in detail later in this report.

2. The steel structures at the boat docks within the Lower Cave should undergo a thorough visual inspection and material testing to evaluate their condition and determine whether repair or replacement is required.
3. The Parking Block exhibits signs of concrete deterioration, reinforcement corrosion, and carbonation, primarily due to long-term exposure to aggressive environmental conditions and the absence of adequate maintenance. This block will require a comprehensive repair program to address existing damages.

To adequately assess the condition of the structural elements and define the extent of the required rehabilitation measures, it is recommended that the following be carried out by a specialized and reputable testing agency:

1. Finishes should be removed from the concrete surfaces of the parking block, including finishes at ground floor level and concrete screed at the ramps, algae cleaned from all concrete surfaces, and spalled concrete to be removed exposing sound reinforced concrete, in order to be able to make relevant tests on reinforced concrete skeleton.
2. Geometrical survey should be conducted for all blocks to complement the current data and plans, determining the thicknesses and location of the structural elements, such as slabs, beams, columns, walls…
3. Cracks and damages mapping for all structures at different blocks in order to determine the degree of deterioration and to assess the efficiency of rehabilitation.
4. Core samples should be extracted from the walls, columns, slabs, and beams to evaluate the structural integrity and safety of the existing reinforced concrete, and to define the extent of the required rehabilitation measures. A minimum of four (4) sets of cores should be taken from each block, with each set consisting of three (3) cores, as follows:

    a. One set from external columns and walls

    b. One set from deteriorated slabs and beams

    c. One set from main internal columns and walls

    d. One set from basement walls, foundations, and ground beams (where accessible)

    Additional core samples may be taken based on the recommendations of the testing agency, depending on site conditions and findings during the investigation.

5. The following tests should be conducted on the extracted cores, with rates as recommended by the testing agency:

    a. Compressive Strength as per ASTM C39 or BS EN 12390 on all cores

    b. Depth of Carbonation as per BS EN 14630

    c. Chloride Content Test as per BS 1881-124

    d. Sulfate Content Test as per BS 1881-124
6. The Ultrasonic Pulse Velocity (UPV) method—or any other suitable non-destructive testing method approved by the Consultant and available to the testing agency—should be employed to assess the extent of concrete deterioration. The results will help determine the feasibility of applying reinforced concrete jacketing or Carbon Fiber Reinforced Polymer (CFRP) wrapping as part of the rehabilitation strategy.
7. Additional tests may be required depending on the outcomes of the geometrical survey and the mapping of cracks and concrete damages.