LYCÉE LOUIS MASSIGNON
ليسيه لوي مسينيون

ÉTABLISSEMENT EN GESTION DIRECTE

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Agence pour l'enseignement français à l'étranger

HELAL&PARTNERS
ARCHITECTS I ENGINEERS I TOWN PLANNERS

RENOVATION OF BLOCK B' FOR FRENCH SCHOOL (LYCEE LOUIS MASSIGNON)

CONCRETE REPAIRS AND STRUCTURAL REINFORCEMENT

PLOT (26_27), SECTOR (E40)
ABU DHABI ISLAND
EMIRATE OF ABU DHABI
UNITED ARAB EMIRATES

VOLUME 5 – Part 4 of 7

M/s eForce Inspection Consultancies
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eFORCE Inspection Consultancies
(CENTER FOR ENGINEERING STUDIES & CONSULTANCY SERVICES)

إيفورس لإستشارات الكشف على الإنشاءات
(مركز الدراسات الهندسية والخدمات الإستشارية)

STRUCTURAL STUDY OF EXISTING STRUCTURE OF THE GYMNASIUM, SWIMMING POOL AND AUDITORIUM LYCÉE LOUIS MASSIGNON SCHOOL, ABU DHABI, UAE
(Phase 1: Assessment, Pre design and Scenarios)

Submitted to	**M/s Lycée Louis Massignon school**
Reference code	eFORCE/195/2019

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28th January 2020 ver 2

Preliminary note

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1 INTRODUCTION

1.1 General

On March 28th 2019, eFORCE Inspection Consultancies (Center for Engineering Studies and Consultancy Services) was requested by M/s Lycée Louis Massignon School to do structural Study of the Gymnasium, Swimming Pool and Auditorium.

A WORKING TEAM from eFORCE has carried out visual inspection of building, assess the quality of concrete, and conduct concrete tests to investigate the current situation.

1.2 Scope of the Consultancy Work

Evaluate the test results done by the consultant "APAVE". Assessment of the documents sent by the client. Visual inspection of the defected locations in the gymnasium, swimming pool, auditorium and Building B. Mapping out of the defects on the structural drawings. Proposal of the remedial/strengthening works required. Provide the specifications, Method statement to be used in the tender documents. Preparation of the tender documents. Submit a technical report covering all the findings along with the tender documents required for the bidding.

2 THE BUILDINGS DESCRIPTION

For the **Building B**

The building consists of G+2+R the structural system is hordi slab based on hidden beams and ribs on columns

For the **Auditorium and Playing Area**

The auditorium consists of wooden roof based on columns and the playing area (Dojo) building consists of hordi slab based on hidden beams and ribs on columns.

For the **Gymnasium**

The Gymnasium consists of wooden roof on concrete columns

For the **Swimming pool**

The swimming pool consists of wooden roof on concrete columns

The buildings under consideration are shown in figures 2-1 to 2-5.

Figure 2-1 Building B under consideration

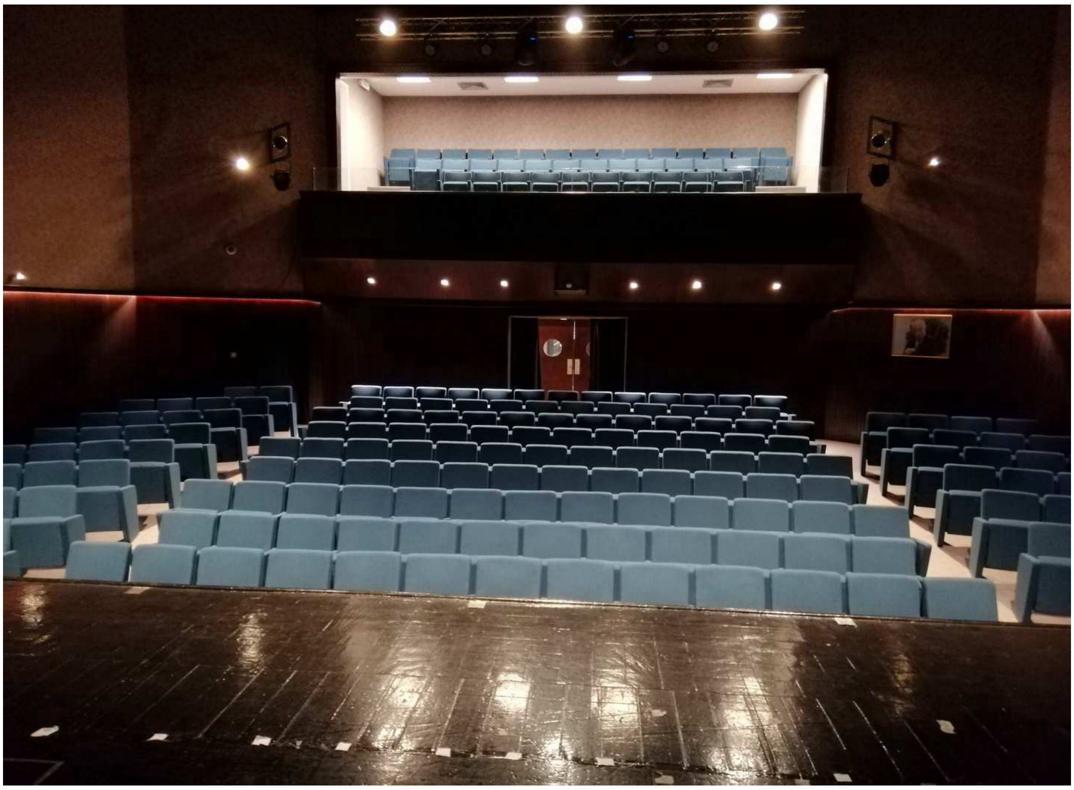


Figure 2-2 The Auditorium under consideration

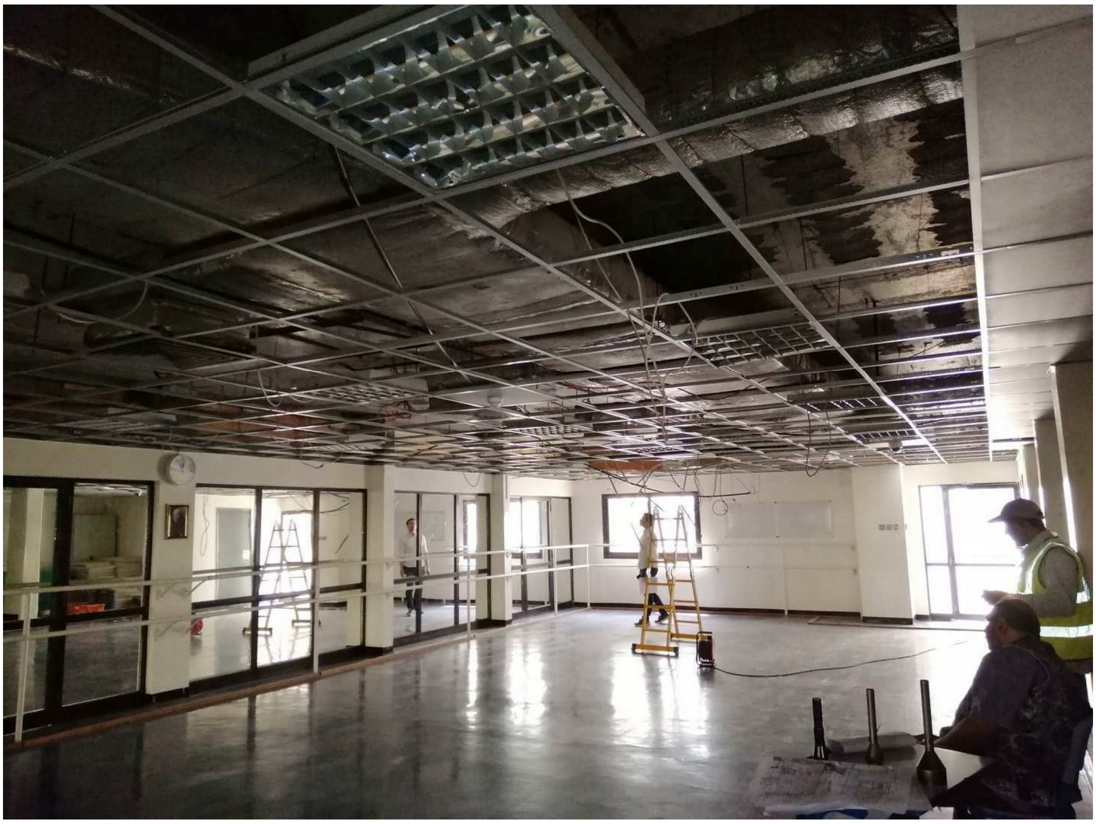


Figure 2-3 playing area (Dojo) under consideration

Figure 2-4 The Gymnasium under consideration

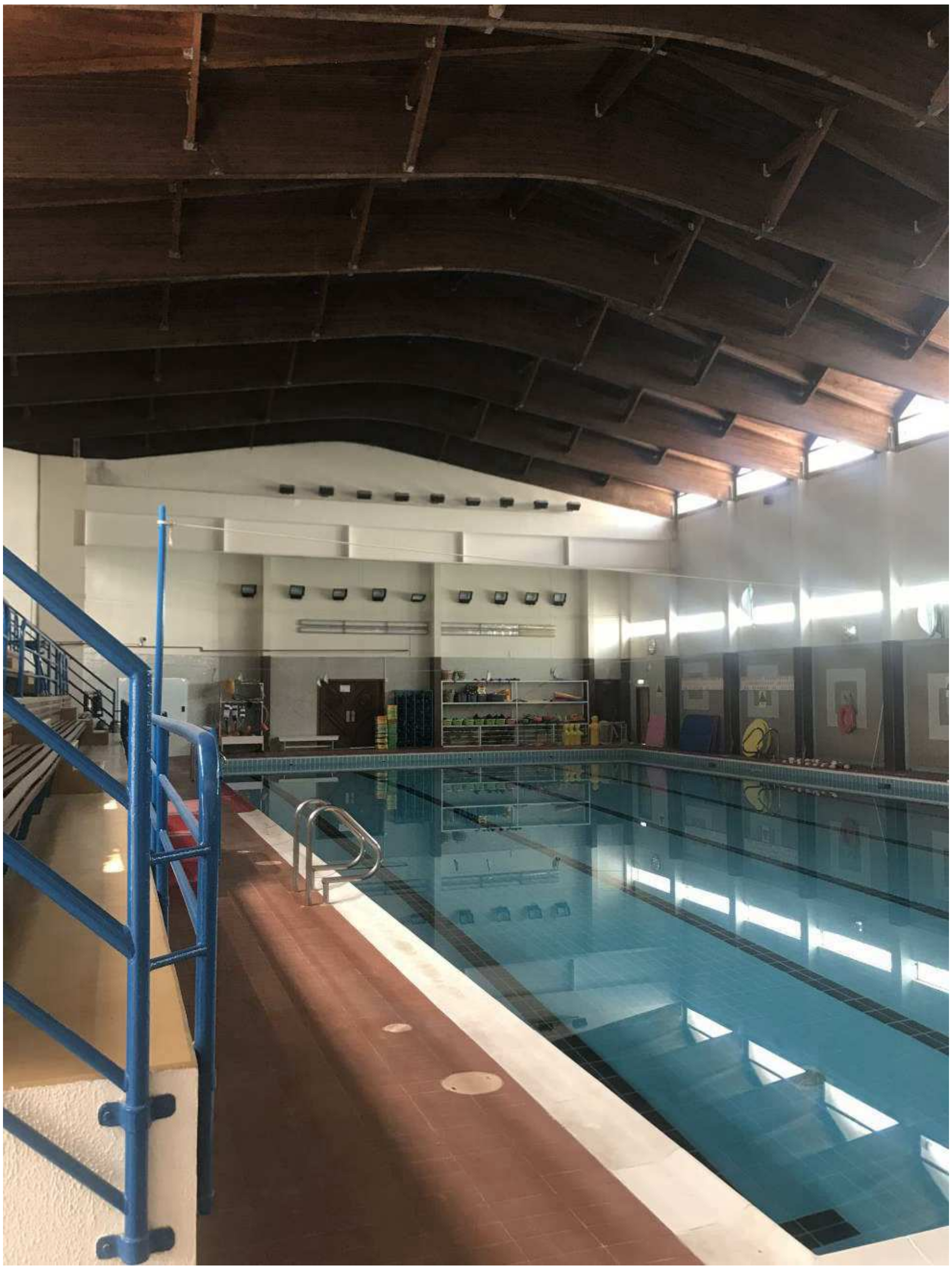


Figure 2-5 swimming pool under consideration

3 INVESTIGATION AND TESTS

3.1 Approach to Inspection

The inspection program targets studying the existing buildings in terms of performance and durability of its materials. This is achieved by

- Initial Site Survey
- Investigation, Sampling and Testing
- Final Site Investigation

3.2 Initial Site Survey

An initial site survey was made to carry out visual inspection, data and information collection on the condition of the building. Detailed planning, including structural consideration, was undertaken prior to the full survey in order to optimize all aspects of the work. Accordingly, the scope of work for overall site concrete sampling and testing works was prepared.

3.3 Investigation, Sampling and Testing

To determine the physical and mechanical properties of concrete, a comprehensive in-situ and laboratory test program was prepared. Samples for physical, mechanical and chemical analysis were obtained from representative structural elements to cover the area under investigation. Also, non-destructive testing was performed. Sampling and testing was carried out. This sampling and site testing work included:

a) Extract samples from the concrete for chloride content.
b) Conduct the resistivity test of concrete to provide the rate of steel corrosion.
c) Conduct ultrasonic test for the quality of the concrete.
d) Moisture Content of the wood
e) Thermal image test.

3.4 Final Site Investigation

In addition to the sampling and testing works, the WORKING TEAM carried out further visual inspection to confirm the outcome of the testing results. A summary of the WORKING TEAM's detailed survey observations and test results are incorporated in section 4.

The test locations are presented in figures 3-1 to 3-5.

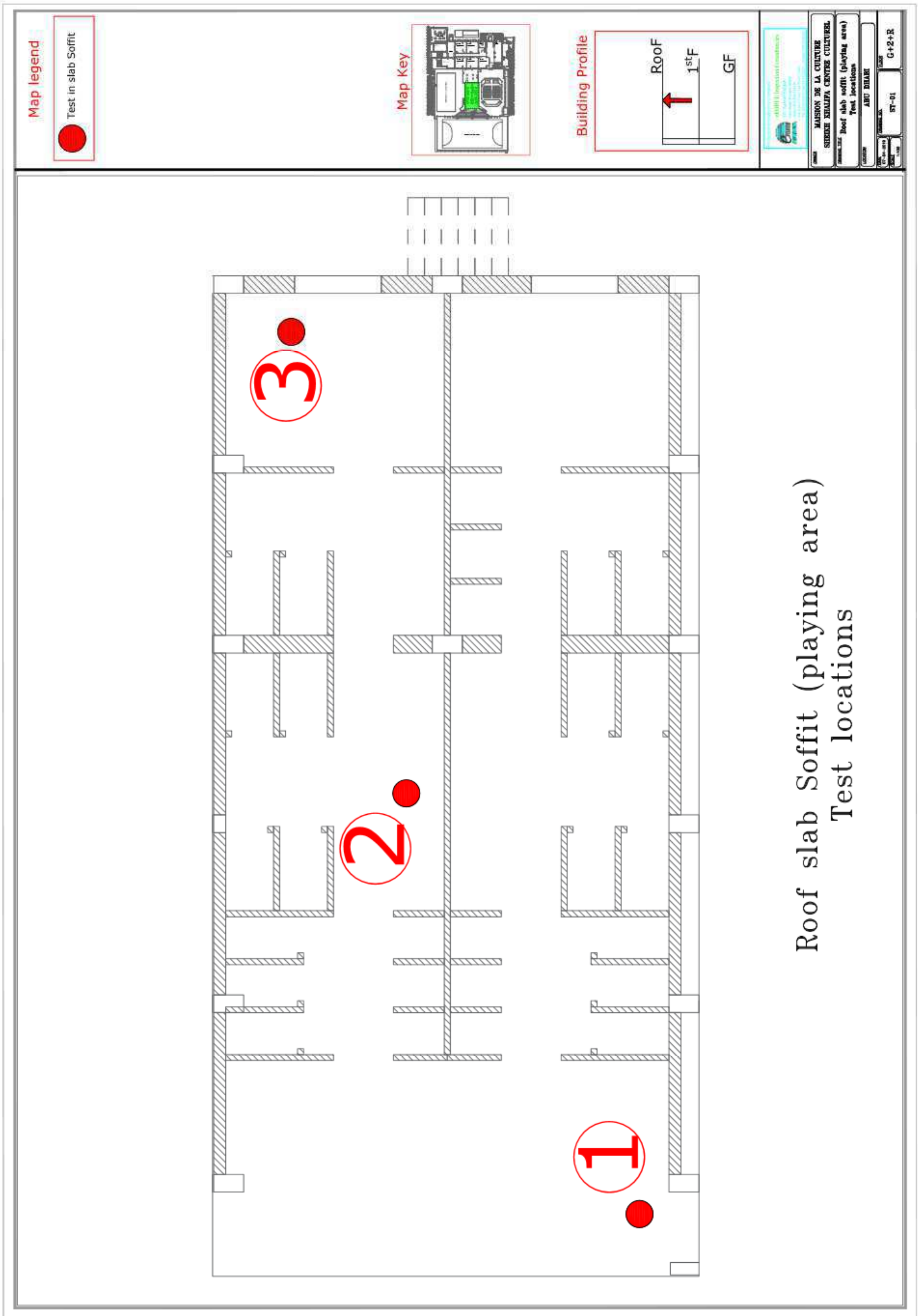


Figure 3-1 test locations in the roof slab soffit of the playing area.

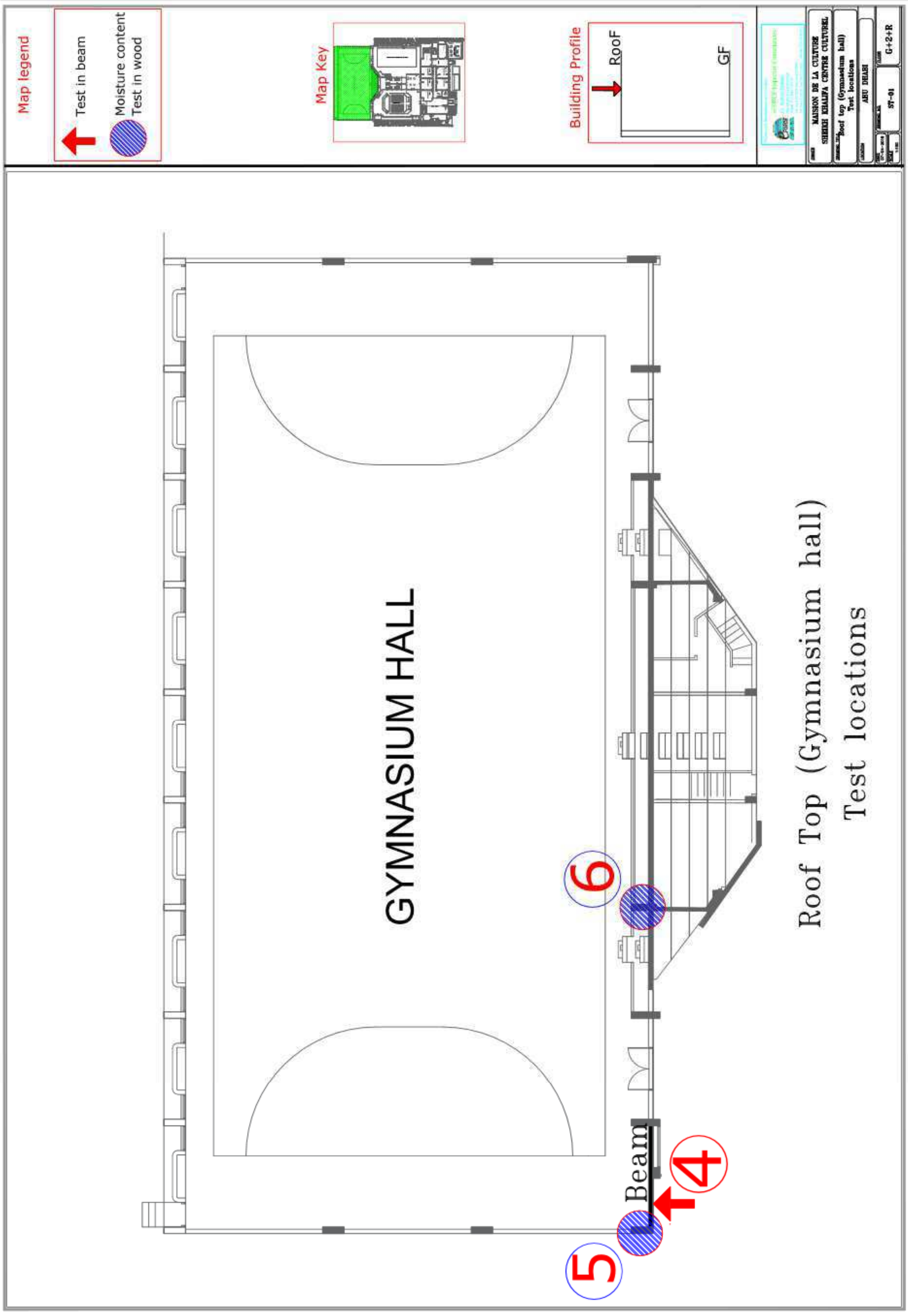


Figure 3-2 test locations in the roof top of the gymnasium

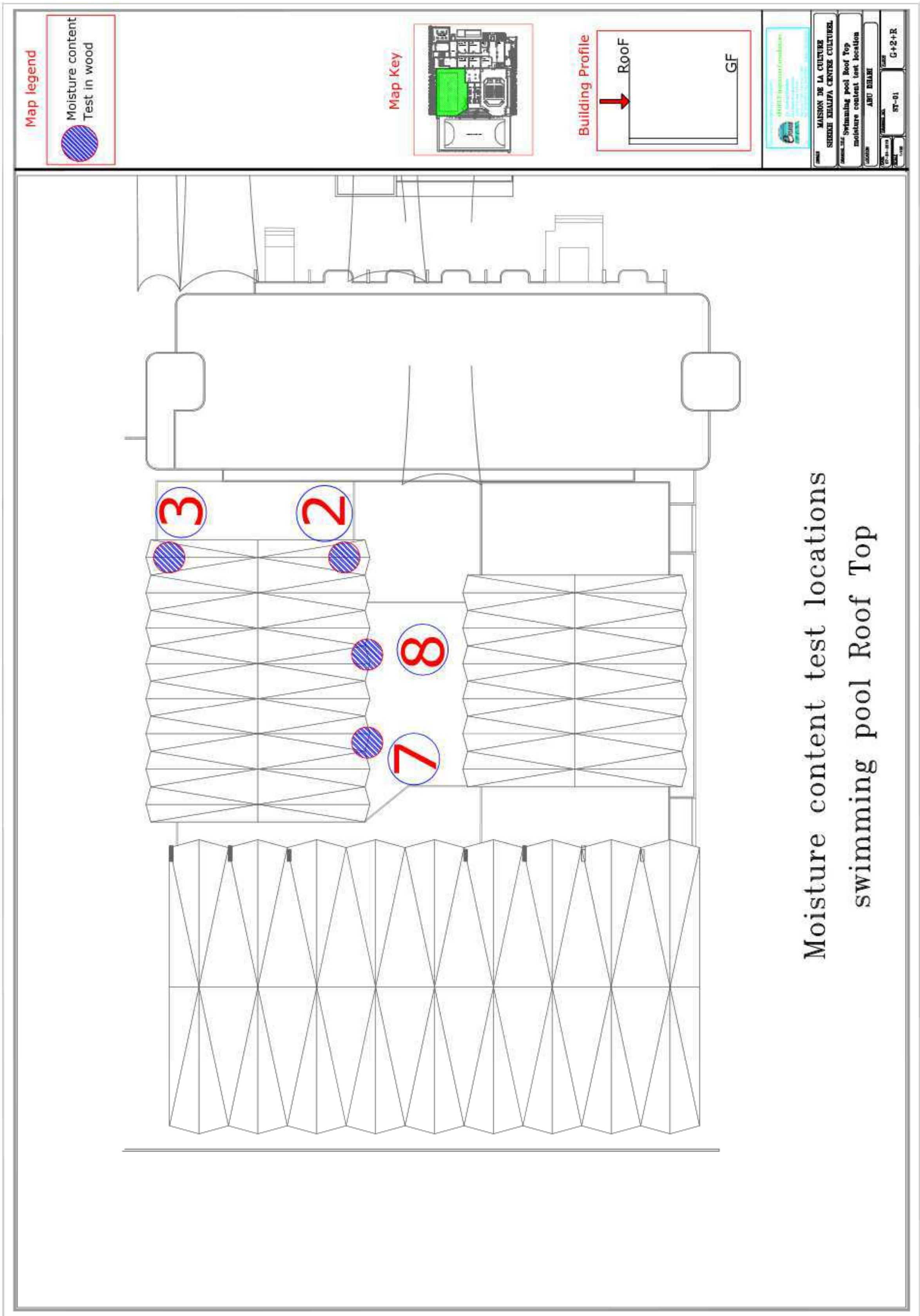


Figure 3-3 test locations in the roof of the swimming pool

4 INVESTIGATION AND TESTING

4.1 Visual Inspection

A visual inspection of the different buildings were carried out. The visual inspection observations can be summarized as follows:

For the auditorium and playing area in the first floor

- Spalled cover and corroded steel in the slab as shown in figures 4-1 to 4-5.
- Cracks in Beam as shown in figures 4-6 and 4-7.
- Delamination and sign of previous leakage as shown in figures 4-8 to 4-10.
- Sign of previous leakage as shown in figures 4-11 and 4-12.
- Cracks in columns as shown in figures 4-13 to 4-15.
- The building is surrounding by landscape work which affect on the quality of the concrete (dampness and cracks in the ground beam) as shown in figures 4-16 and 4-17.

Figure 4-1 spalled cover and corroded steel at the playing area slab soffit

Figure 4-2 spalled cover and corroded steel at the playing area slab soffit

Figure 4-3 spalled cover and corroded steel at the playing area roof

Figure 4-4 spalled cover and corroded steel at the playing area roof

Figure 4-5 spalled cover and corroded steel at the playing area roof

Figure 4-6 Cracks in beam due to steel reinforcement corrosion

Figure 4-7 Cracks in beam due to steel reinforcement corrosion

Figure 4-8 Delamination and sign of previous leakage

Figure 4-9 Delamination and sign of previous leakage

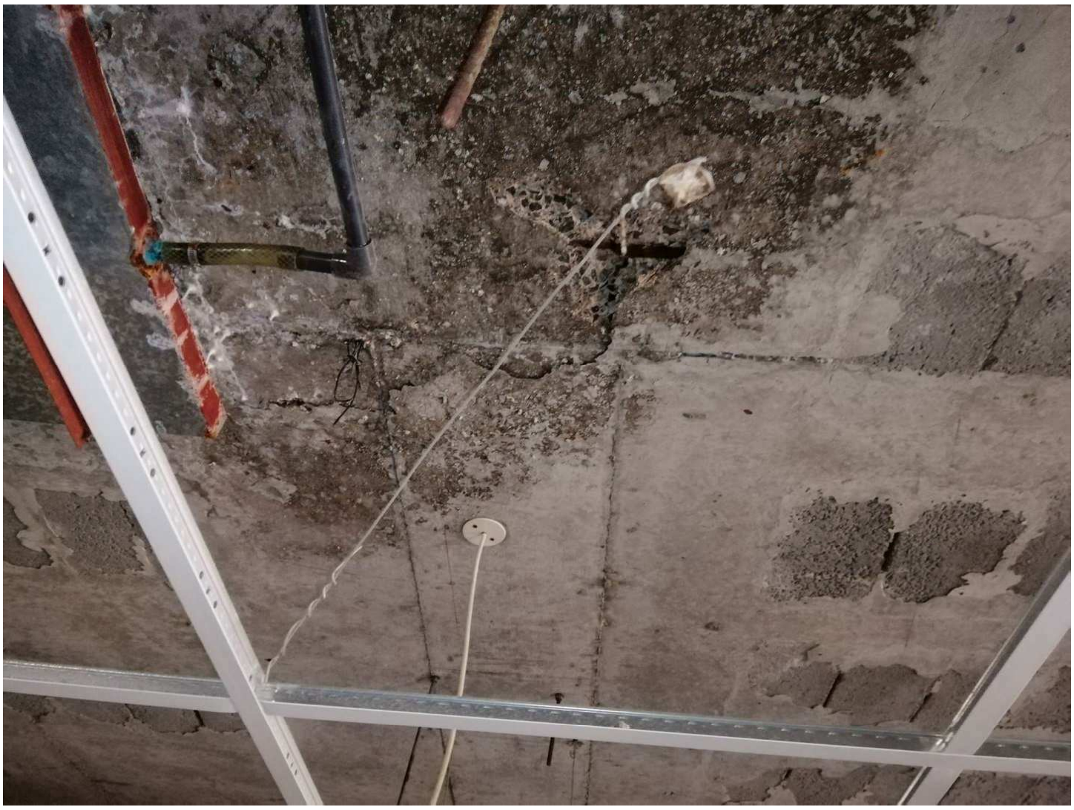


Figure 4-10 Delamination and sign of previous leakage

Figure 4-11 sign of previous leakage

Figure 4-12 sign of previous flooding of water on top of the roof

Figure 4-13 Cracks in column due to steel corrosion

Figure 4-14 Cracks in column due to steel corrosion

Figure 4-15 Cracks in column due to steel corrosion

Figure 4-16 landscape work surrounding the building causing steel corrosion

Figure 4-17 landscape work surrounding the building causing steel corrosion

For Building B

- Cracks in block wall as shown in figures 4-18 to 4-20.
- Dampness or previous dampness in slab as shown in figures 4-21 and 4-22.
- Opening in the slab which wasn't closed properly as shown in figure 4-23 and 4-24.
- Cracks between block wall and concrete elements as shown in figures 4-25 and 4-26.
- The building is surrounding by landscape work which affect on the quality of the concrete (dampness and cracks in the ground beam) as shown in figure 4-27

Figure 4-18 crack in block wall

Figure 4-19 crack in block wall

Figure 4-20 crack in block wall

Figure 4-21 Previous dampness in slab

Figure 4-22 previous dampness in slab

Figure 4-23 slab opening which not closed properly

Figure 4-24 slab opening which not closed properly

Figure 4-25 crack between block wall and concrete element

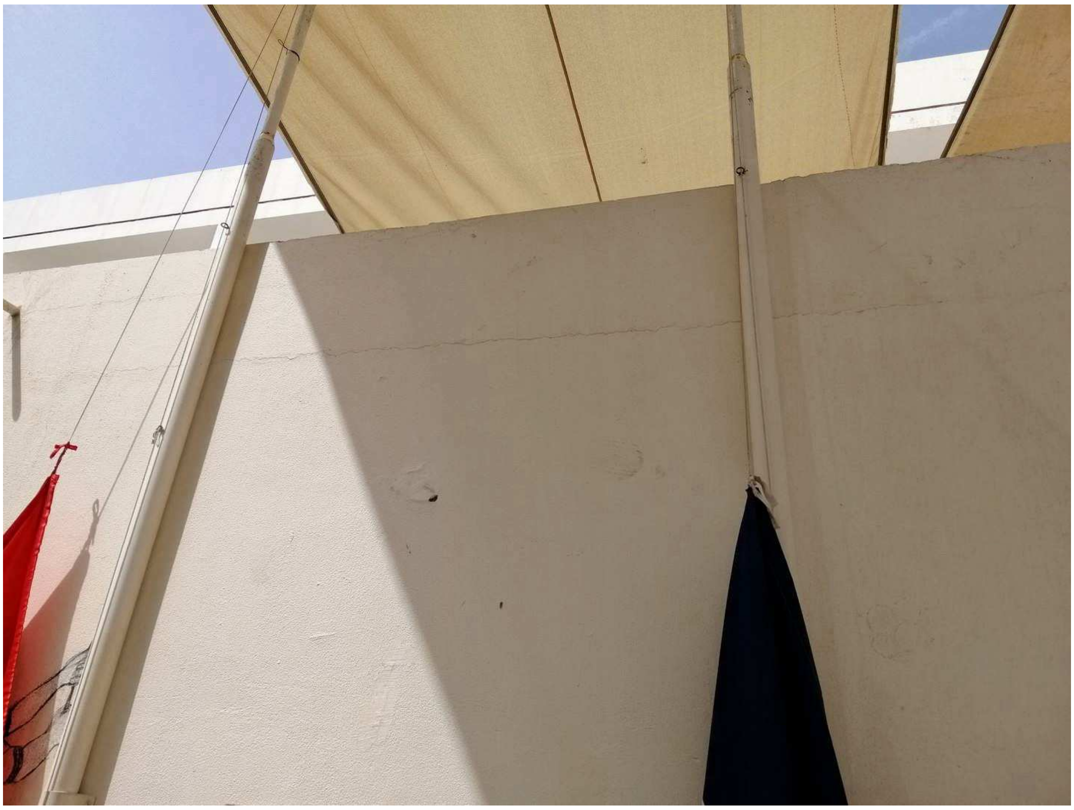


Figure 4-26 crack between block wall and concrete element

Figure 4-27 the building is surrounding by landscape

For the swimming pool

- Wet Rot damage in the wooden beam as shown in figures 4-28 and 4-29.
- Sign of previous leakage as shown in figures 4-30 to 4-32.
- Crack between block wall and concrete element as shown in figures 4-33 to 4-35.
- Cracks in concrete as shown in figures 4-36 and 4-37.
- Delamination of the concrete as shown in figures 4-38 to 4-41.
- Dampness in slab as shown in figures 4-42 to 4-43.
- Dampness in wood as shown in figures 4-44 to 4-46.
- The pool is surrounding by landscape work which affect on the quality of the concrete as shown in figures 4-47 and 4-48. As stated on site, the plantations were implemented since a year only, such landscaping can be one of the reasons that affect the quality of the concrete in addition to the deficiency in the waterproofing of the ground beams.

Figure 4-28 Wet rot damage in Wooden beam

Figure 4-29 Wet rot damage in Wooden beam

Figure 4-30 sign of previous leakage

Figure 4-31 sign of previous leakage

Figure 4-32 sign of previous leakage

Figure 4-33 Crack between block wall and concrete element.

Figure 4-34 Crack between block wall and concrete element.

Figure 4-35 crack in staircase

Figure 4-36 Cracks in concrete wall

Figure 4-37 Cracks in concrete wall

Figure 4-38 delamination in concrete wall

Figure 4-39 delamination in column

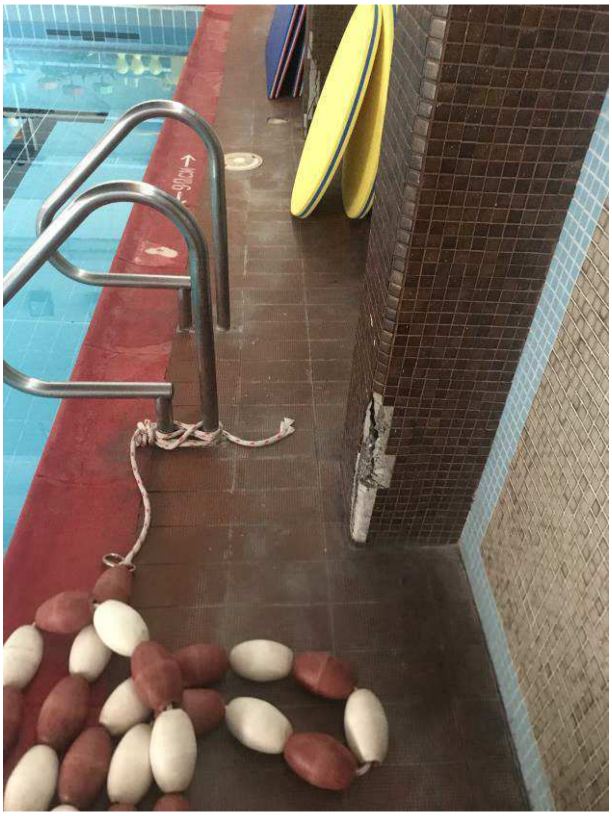


Figure 4-40 delamination in column

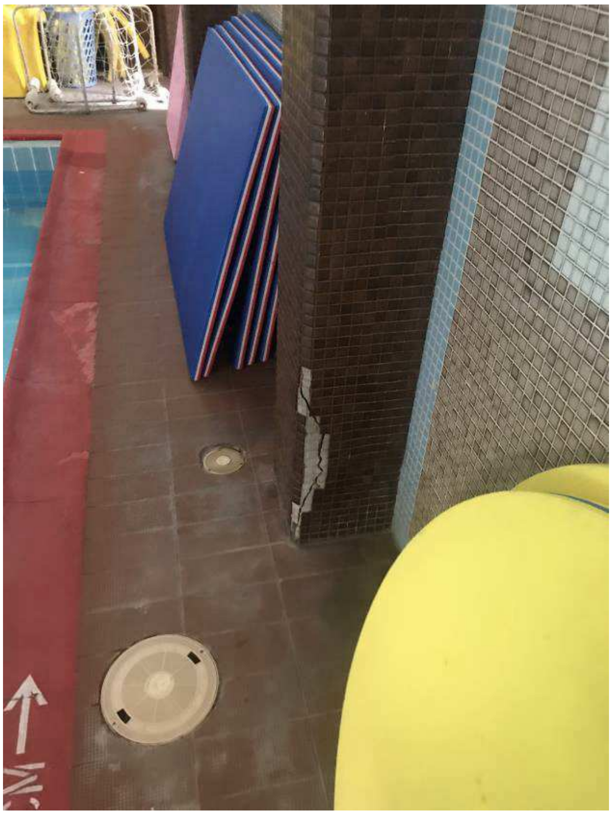


Figure 4-41 delamination in column due to steel corrosion

Figure 4-42 Dampness in slab soffit

Figure 4-43 Dampness in slab soffit

Figure 4-44 Dampness in wooden beam

Figure 4-45 Dampness in wooden beam

Figure 4-46 Dampness in wooden beam

Figure 4-47 landscaping work touching the pool which affect the quality of concrete

Figure 4-48 landscaping work touching the pool which affect the quality of concrete

For the Gymnasium Hall

- Delamination and corrosion of the reinforcement in different structural elements as shown in figures 4-49 to 4-54.
- Cracks in concrete in different structural elements as shown in figures 4-55 to 4-58.
- Cracks in block wall as shown in figures 4-59 and 4-60.
- Cracks between block wall and concrete element as shown in figures 4-61 and 4-62.
- Bulging in the floor as shown in figure 4-63.

Figure 4-49 delamination and corrosion

Figure 4-50 delamination and corrosion

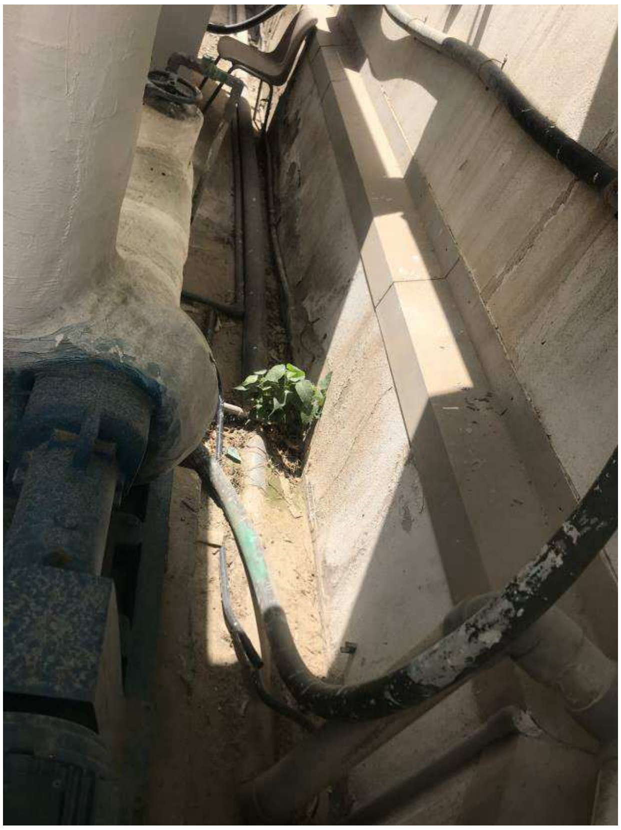


Figure 4-51 delamination and corrosion

Figure 4-52 delamination and corrosion in column

Figure 4-53 delamination and corrosion in column

Figure 4-54 delamination and corrosion in wall

Figure 4-55 Cracks in column

Figure 4-56 Cracks in column

Figure 4-57 Cracks in stands

Figure 4-58 Cracks in main beam

Figure 4-59 Cracks in Block wall

Figure 4-60 Cracks in Block wall

Figure 4-61 Cracks between Block wall and concrete element

Figure 4-62 Cracks between Block wall and concrete element

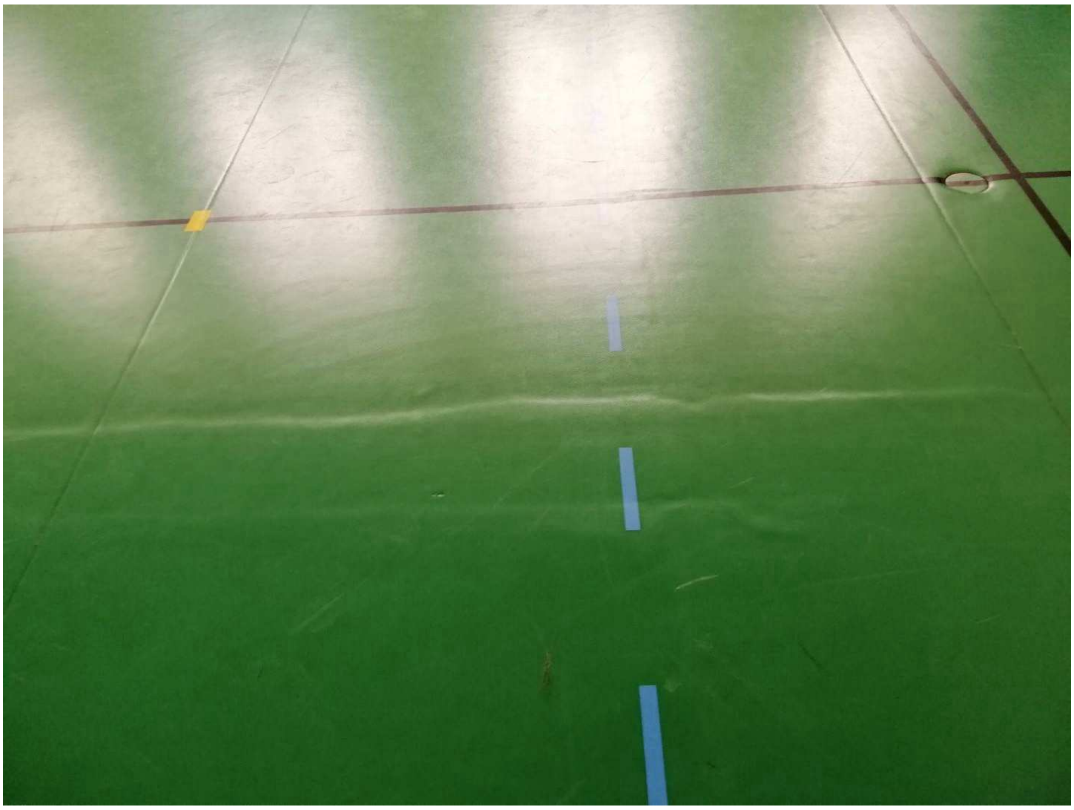


Figure 4-63 bulging in the floor

4.2 Defects Mapping

The defects marked on the plans are presented in **Appendix A** They are categorized based on the defect.

4.3 GROUND PENETRATION RADAR

The GPR was used to scan the slab determine the cavities and existing reinforcement.

Figure 4-64 The Structural scan mini HR (High Resolution) device used

During any concrete cutting, it is essential to highlight the locations of the steel reinforcements in order to avoid cutting the steel rebars as much as possible. The process of highlighting the steel reinforcement locations can be done using a Ground Penetrating Device (GPR). Generally, the device sends an array of waves into the concrete surface and then provides an image based on the reflecting waves that show the location of the objects within a concrete surface.
The direction of the radar energy as it moves into the concrete is mainly determined by the surface of the slab. The signal normally moves perpendicular to the surface, independent of the antenna position. The angle that you hold the antenna over the concrete doesn’t matter. The radar energy will still enter perpendicular to the surface.

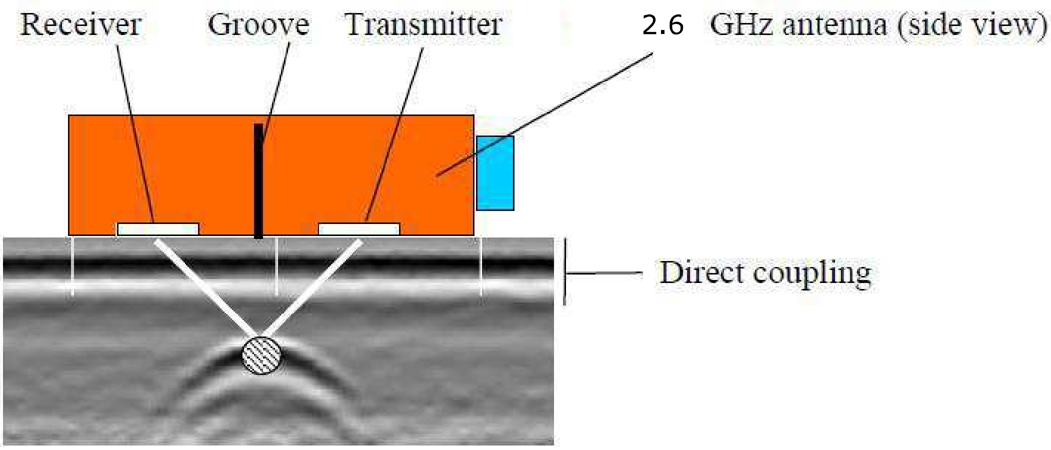


Figure 4-65 Schematic sketch for the slabs, reinforcement, and the device.

Steel reinforcing bars are the most common targets in concrete structures. Transverse rebar (i.e., rebar oriented perpendicular to the survey line) produce clean and strong hyperbolas. The strength (amplitude) of a rebar reflection increases with rebar size. On the other hand, it decreases with depth and/or presence of corrosion. Rebar size can be estimated from reflection. Strength on a comparative basis, but cannot be accurately measured. This means if two rebar are located at exactly the same depth and in exactly the same concrete, and one is brighter than the other, the brighter one is larger. How much larger is impossible to determine.

In structures with two layers of rebar, visibility of the second layer depends on the bar spacing in the first layer and on the amount of attenuation and scattering in the concrete. Staggered rebar are more likely to be visible.
A steel pipe (conduit, for instance) looks exactly the same as a steel rebar of the same diameter.

The radar signal does not penetrate metal, so there is no difference between reflections from a solid rod or a hollow metallic pipe. A large diameter conduit, duct or pipe (over 2") will have a noticeable horizontal size in the profile, but it is still unwise to attempt to find the size of the target from your radar data.

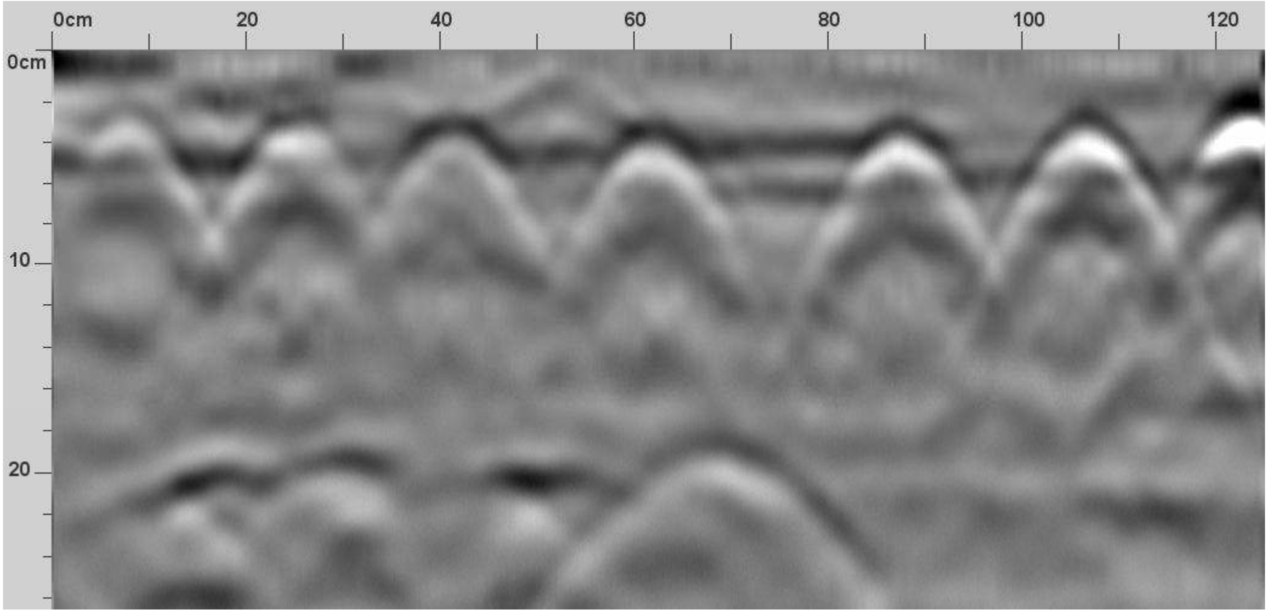


Figure 4-66 during Using GPR

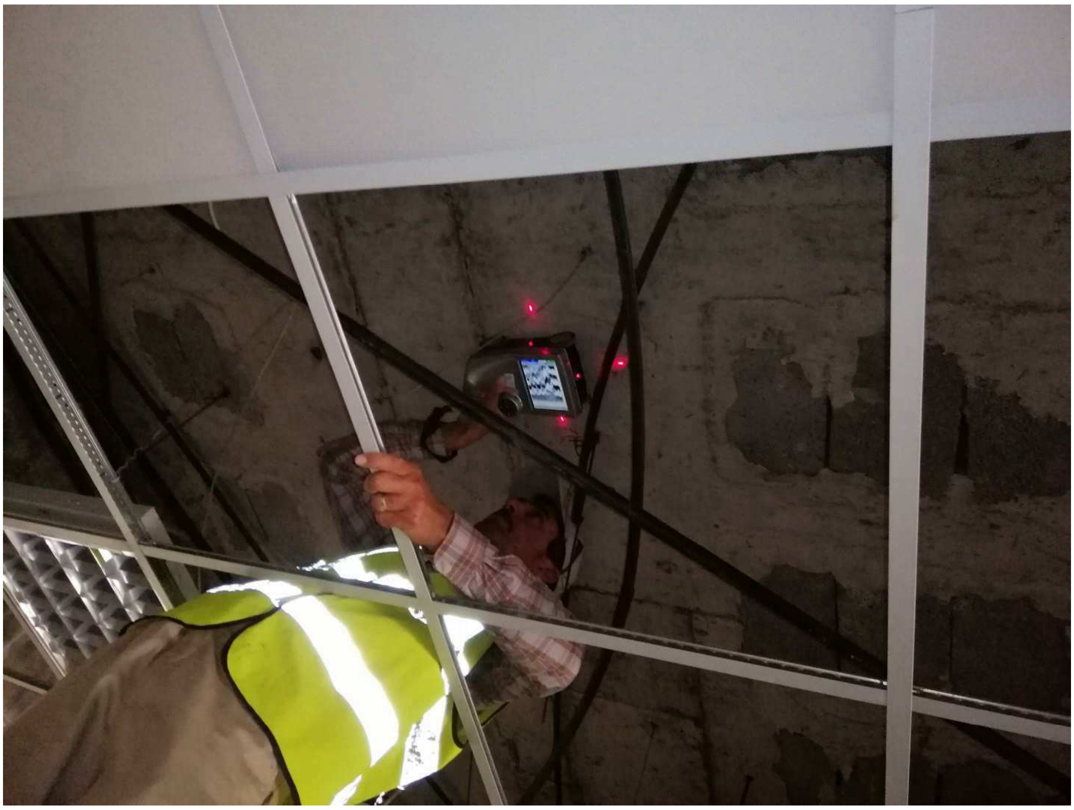


Figure 4-67 during Using GPR

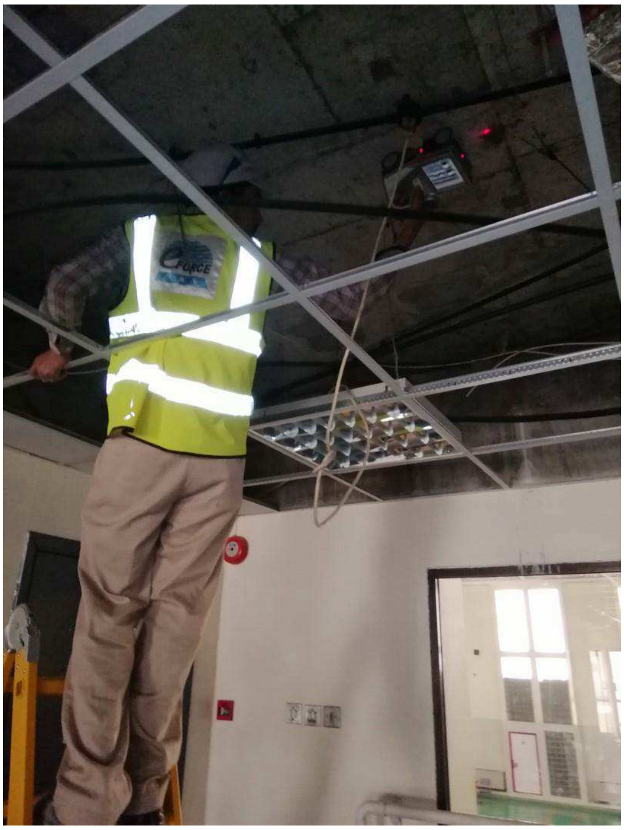


Figure 4-68 during Using GPR

4.4 Concrete Dust Samples

Dust samples were taken from six locations by the WORKING TEAM. These dust samples were taken to determine the chloride contents.

The Sherwood Model 926 (figure 4-69) is usually used for the determination of chloride ions. It is an instrumental analogue of "Argentimetry", the traditional titrimetric methods using silver nitrate reagent. Like these classic methods it relies on the chemical formation of the very insoluble salt, silver chloride.

The 926 method is based on a coulometric titration and is an absolute method where the reagent, the silver ions, is precisely and quantitatively generated at the time of the analysis by passing a constant current between donor electrodes. The end point is detected by the use of sensing electrodes which measure the change in solution conductivity which occurs when excess silver ions are present in solution.

The results were expressed as the chloride ion content (Cl^-) by weight of concrete samples (i.e. including the aggregate). These can be converted to the chloride ion by weight of cement after determination of cement content is known. The chloride ion content by weight of cement are useful, to enable comparisons to be made with recommended levels in codes of practice.

Figure 4-69 The Sherwood Model 926 device

The chloride content is critical to the life of the reinforcement. The risk that the reinforcement will rust as a result of chloride contamination depends on:

- the concentration of the chloride in the concrete
- the alkalinity of the concrete
- type of cement
- presence of chloride at the time of mixing
- penetration of chloride through the hardened concrete surface from aggressive atmosphere

Current concrete specifications, including the CIRIA "Guide to the Construction of Reinforced Concrete in the Arabian Peninsula, 2002", call for a maximum chloride content Presented in Table 4.1.

Table 4.1
Maximum chloride content according to CIRIA 2002

Type of concrete	**Max. Chloride ions (Cl^-) Content** (% by Weight of Cement)
Reinforced concrete made with Portland cements containing less than about 4% C_3A (e.g. sulphate-resisting Portland cement)	0.15
Reinforced concrete made with Portland cements containing 4% or more C_3A (OPC and ASTM types I and II usually contain more than 4% C_3A)	0.30
Unreinforced concrete	0.60

The chloride content of each increment of the concrete dust samples was determined according to BS 1881: Part 124:1988. The chloride content by total weight of the concrete, expressed as chloride ions in all the tested elements varied between 0.02% and 0.17% and the chloride ion by weight of cement varied between 0.12% and 1.08%. The results are presented in Table 4.2.

The chloride content in the concrete of the reinforced concrete elements in gymnasium under consideration was found to be higher than the limits indicating high corrosion risk. Also, it is noticed that the measured values are almost double the values provided in previous test reports on the same building. Since the chloride content is below 1.5%, replacement method in repair followed by good protection can be used. Higher than the 1.5% may need to go to cathodic protection technique. The reason behind the high values of the chloride content in the Gymnasium and its increase with time is the exposure to humid environment and water with absence of concrete protection. It looks also that the low quality of concrete (see section 4.5) is one of the reasons allow the chloride to penetrate the concrete easily. Good protection should be implemented to the concrete of the Gymnasium to avoid any future defects.

Table 4.2
Samples of Chloride Content

Test No.	Location	Depth (mm)	Chloride Content as Cl^- % by Wt. of	
			Concrete	* Cement
1	1st floor Play area	0 – 25	0.03	0.18
		25 – 50	0.03	0.18
		50 -75	0.03	0.18
2	1st floor Play area	0 – 25	0.04	0.24
		25 – 50	0.03	0.18
		50 -75	0.03	0.18
3	1st floor Play area	0 – 25	0.02	0.12
		25 – 50	0.02	0.12
		50 -75	0.02	0.12
4	Beam in Gymnasium	0 – 25	0.17	1.02
		25 – 50	0.03	0.18
		50 -75	0.03	0.18
5	Gymnasium Col	0 – 25	0.18	1.08
		25 – 50	0.10	0.6
		50 -75	0.09	0.54
6	Pool col	0 – 25	0.04	0.24
		25 – 50	0.04	0.24
		50 -75	0.04	0.24

* The chloride contents by weight of cement were calculated using the average cement content and as received concrete density of the core specimens obtained from each location.

4.5 Ultrasonic Pulse Velocity

According to BS EN 12504-4:2004: Determination of ultrasonic pulse velocity, the principle of ultrasonic pulse velocity tests can be summarized as follows:

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer held in contact with one surface of the concrete under test. After traversing a known path length in the concrete, the pulse of vibrations is converted into an electrical signal by a second transducer and electronic timing circuits enable the transit time of the pulse to be measures. Ultrasonic pulse velocity tests are used to verify the quality of concrete. Generally concrete with pulse velocity greater than 4000m/s is considered to be of good quality. Table 4.3 shows the velocity criterion for concrete quality grading for direct transmission, table 4.4 for in-direct transmission.

Table 4.3
Velocity Criterion for Concrete Quality Grading (Direct)

No.	Pulse Velocity in core probing (m/sec.)	Concrete Quality Grading
1	Above 4500	Excellent
2	3500 to 4500	Good
3	3000 to 3500	Medium
4	2000 to 3000	Poor
5	Less than 2000	Very poor

Table 4.4
Velocity Criterion for Concrete Quality Grading (in-direct)

No.	Pulse Velocity in core probing (m/sec.)	Concrete Quality Grading
1	Above 4000	Excellent
2	3000 to 4000	Good
3	2500 to 3000	Medium
4	1500 to 2500	Poor
5	Less than 1500	Very poor

The test results of four (4) tests at different locations are presented in Table 4.5 (Figures 4-70 to 4-72). The ultrasonic pulse velocity of the existing concrete in the building ranged between 421 to 1880 m/s on average 1274 m/s, which is lower than the 1500 m/s. In general, the concrete quality is very poor. The results indicate the bad workmanship of the concrete which require good level of concrete protection.

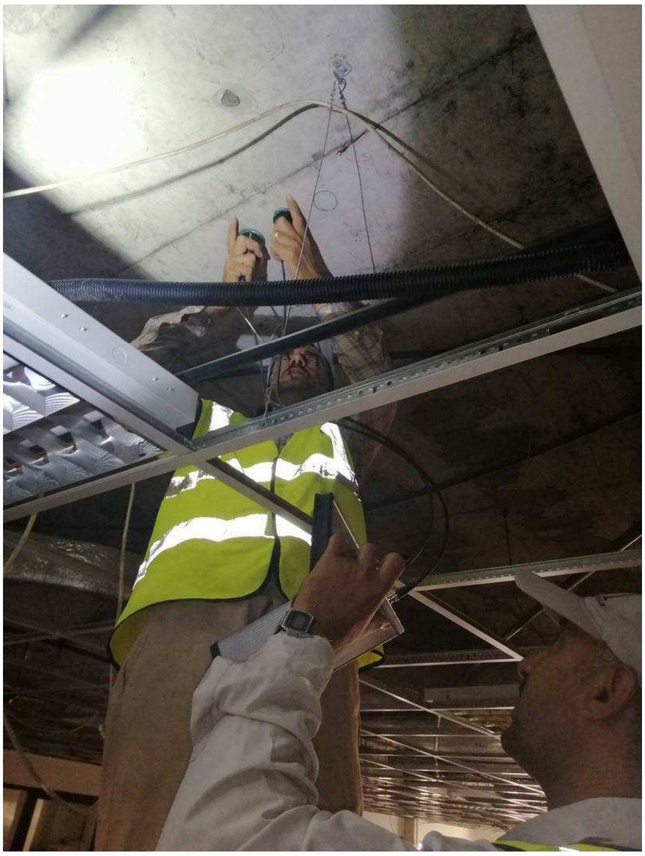


Figure 4-70 During measuring the Ultrasonic Pulse Velocity -Indirect

Figure 4-71 During measuring the Ultrasonic Pulse Velocity –Indirect

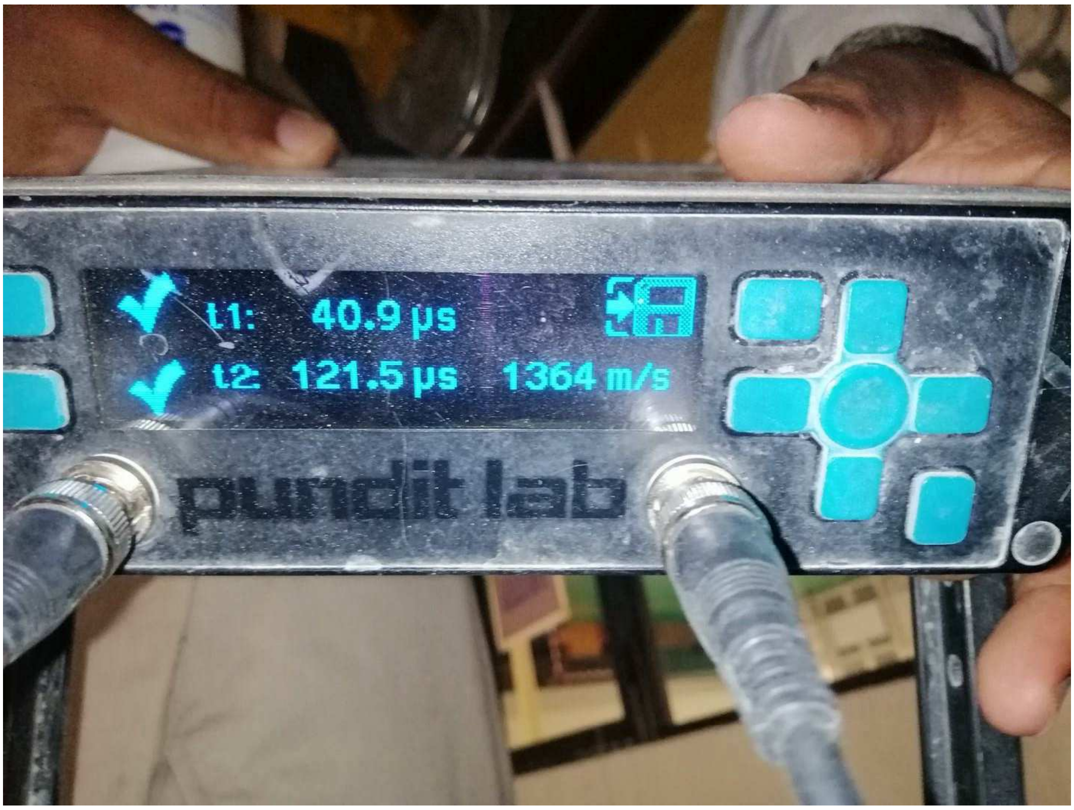


Figure 4-72 During measuring the Ultrasonic Pulse Velocity –Indirect

Table 4.5
Summary of the Ultrasonic Pulse Velocity tests

Location No.	Ultrasonic pulse velocity (m/sec.)
1	1880
2	1273
3	1523
4	421

4.6 Electrical Resistivity Measurements of Concrete Surface

The corrosion of steel in concrete is an electro-chemical process which creates a current flow causing metal to dissolve so that it is possible to assess the probability of reinforcement corrosion by evaluating the electrical resistance of the concrete. Electrical current is passed through the outer probes & the potential drop is measured by the inner probes. From the current & voltage drop measurements, the resistivity of concrete can be measured. This resistivity can be related to quality of concrete.

Surface resistivity measurement provides extremely useful information about the state of a concrete structure. Not only has it been proven to be directly linked to the likelihood of corrosion and the corrosion rate, recent studies have shown that there is a direct correlation between resistivity and chloride diffusion rate. The versatility of the method can be seen in these example applications:

- Indication of corrosion rate
- Correlation to chloride permeability
- On site assessment of curing efficiency
- Determination of zonal requirements for cathodic protection systems
- Identification of wet and dry areas in a concrete structure
- Indication of variations in the water/cement ratios within a concrete structure
- Identification of areas within a structure most susceptible to chloride penetration
- Correlation to water permeability of rock

The Concrete Resistivity Meter (Figure 4-73) replaced the Rapid Chloride Permeability Test and Surface Resistivity for ASTM C1202 and AASHTO T277.

Figure 4-73 The concrete Resistivity Meter

The Surface Resistivity (SR) test is a much quicker and easier test for estimating concrete permeability. It is a proven and mature test method which can replace the more laborious rapid chloride permeability test. The State of Louisiana has designated this test method as LATR 233.

A current is applied to the two outer probes and the potential difference is measured between the two inner probes. The current is carried by ions in the pore liquid (Figure 4-74). The calculated resistivity depends on the spacing of the probes.

Resistivity ρ = 2πaV/I [kΩcm]

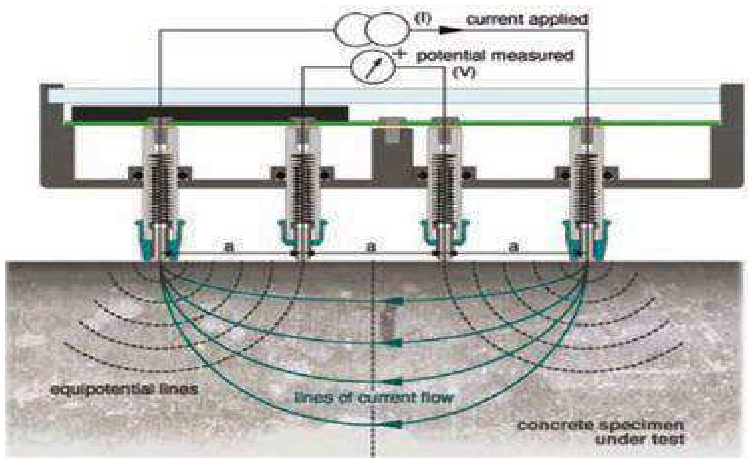


Figure 4-74 Concept of concrete resistivity

The interpretation of resistivity measurements is given in Table 4-6 which can be used to determine the likelihood of corrosion.

Table 4.6
Likelihood of corrosion as function of the concrete resistivity

No.	Concrete resistivity	Interpretation on Corrosion
1	ρ ≥ 100 kΩcm	corrosion is unlikely - Low corrosion rate
2	ρ = 50 to 100 kΩcm	risk of corrosion is low - Low to moderate corrosion rate
3	ρ = 10 to 50 kΩcm	risk of corrosion is moderate - High corrosion rate
4	ρ ≤ 10 kΩcm	risk of corrosion is high - Very high corrosion rate

The test results of four (4) locations are shown in Table 4-7.

Table 4.7
Concrete resistivity

Location No.	Resistivity (kΩcm)	Interpretation on Corrosion
1	408	corrosion is unlikely - Low corrosion rate
2	1537	corrosion is unlikely - Low corrosion rate
3	348	corrosion is unlikely - Low corrosion rate
4	35.3	risk of corrosion is moderate - High corrosion rate

The resistivity tests showed low corrosion rate for all the tested locations, except for point 4 which showed a high corrosion rate.

Figure 4-75 During measuring the resistivity

4.7 Moisture content in wood

A fundamental fact is that wood is hygroscopic. This means that wood, almost like a sponge, will gain or lose moisture from the air based upon the conditions of the surrounding environment. But not only does wood gain or lose moisture, but it will also *expand or contract* according to the magnitude of such changes; and it is this swelling and shrinking in finished wood products—often referred to as the wood's movement in service that is responsible for so much mischief and so many malfunctions in woodworking. The amount of water in a given piece of wood is expressed as a percentage of the weight of the water as compared to its ovendry weight. Some species of trees, when they are initially felled, may contain more water by weight than actual wood fiber, resulting in a moisture content (MC) over 100%.

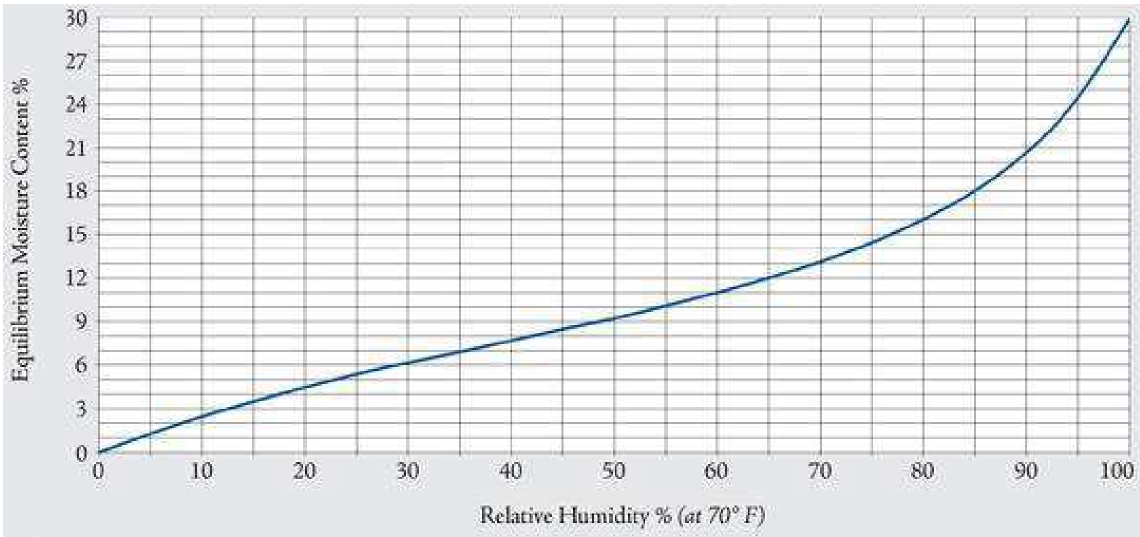
Moisture Content % = (weight of water / ovendry weight of wood) x 100

As a piece of wood dries, it first loses its free water and dips below the fiber saturation point (FSP). This FSP corresponds to roughly 30% MC in most wood species. (The FSP may be roughly ±3% MC depending on the wood species, but 30% MC is the commonly-accepted average). Regardless of whatever MC the wood begins at when green, (anywhere from 35% MC to over 200% MC depending on the species), it begins to lose bound water (and dimensionally shrink) when the weight of the remaining water is at a ratio of approximately 30% to the theoretical weight of the oven dry wood.

It should be noted that in real-world situations, the FSP is never uniformly reached throughout the thickness of a piece of lumber. A moisture gradient develops where the outside (shell) is drier, with the interior (core) still wet and playing catch-up.

As the MC of wood drops below the FSP, it will continue to lose moisture until it eventually stabilizes at a value that is commensurate with the surrounding moisture in the air. This is known as the point of equilibrium moisture content, or simply EMC. The EMC will change based upon the fluctuating temperature and relative humidity of the surrounding air.

In addition to the fundamental fact that wood is hygroscopic, perhaps the most crucial concept to understand regarding wood and moisture is the link between relative humidity and equilibrium moisture content.



From studying the included chart, several important points pertaining to the relationship between relative humidity (RH) and equilibrium moisture content (EMC) emerge.

- The chart tops out at 30% EMC, which is equivalent to the FSP. Short of physically submerging a piece of wood underwater, it's not possible to go back and exceed the FSP once all the free water has been lost.
- The plotted line is not flat (linear), and 50% RH is not comparable to the midpoint value of 15% EMC. (50% RH actually equates to just over 9% EMC).
- There is a noticeable increase in the slope of the line, especially in the 85% to 100% RH range. This means that wood will swell to a significantly greater extent if it is exposed to prolonged humidity in excess of 85% RH.
- Conversely, the line is somewhat flatter in the range of 20% to 55% RH. Humidity changes that happen in this window have a slightly gentler effect on EMC, and hence results in smaller amounts of shrinking and swelling.
- Although the values given in the preceding chart are for RH at 70° F, changes in temperature—assuming the same humidity level—only have a moderate effect on EMC, typically amounting to ±1% MC within a normal climatic range of 30° F to 110° F.
- Most interior buildings are kept between 30 to 60% RH, corresponding to 6 to 11% EMC. Exterior values can be much more variable depending on locale and season, but averages typically range from 30% to 80% RH, corresponding to 6 to 16% EMC.
- It can be very useful to make mental notes of common humidity levels and their corresponding EMC. For instance, furniture and other interior woodwork should usually be constructed with an intermediate target of 8% EMC, which is achieved by storing lumber at approximately 40 to 45% RH. For exterior projects, a target of about 12% EMC is a good compromise, which equates to lumber stored at 65% RH.
- Using lumber that is within the median EMC range for a given locale prevents the Goldilocks syndrome: the wood is not too dry, (which might lead to subsequent swelling in the humid summer), and not too wet, (which might lead to checking and splitting in the dry winter). In this way, the wood is most likely to remain as close as possible to its intended size and shape.

The moisture content test was checked for seven locations as shown in figures 4-76 to 4-81 the results are shown in table 4-8.

Figure 4-76 during checking the moisture content

Figure 4-77 during checking the moisture content

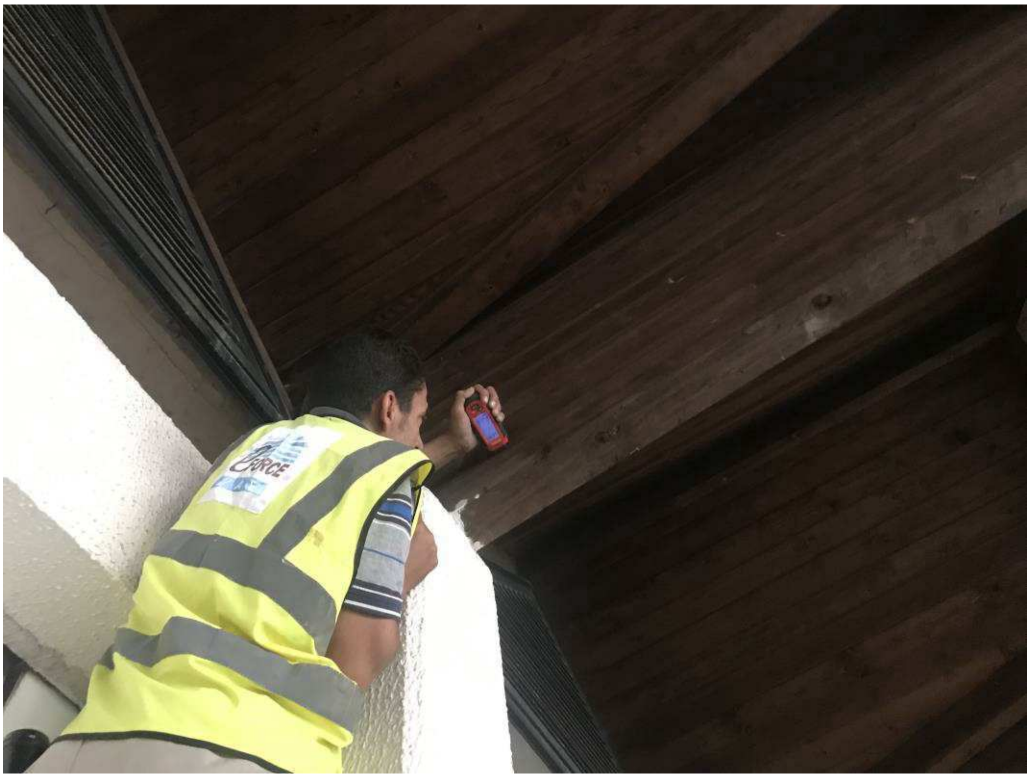


Figure 4-78 during checking the moisture content

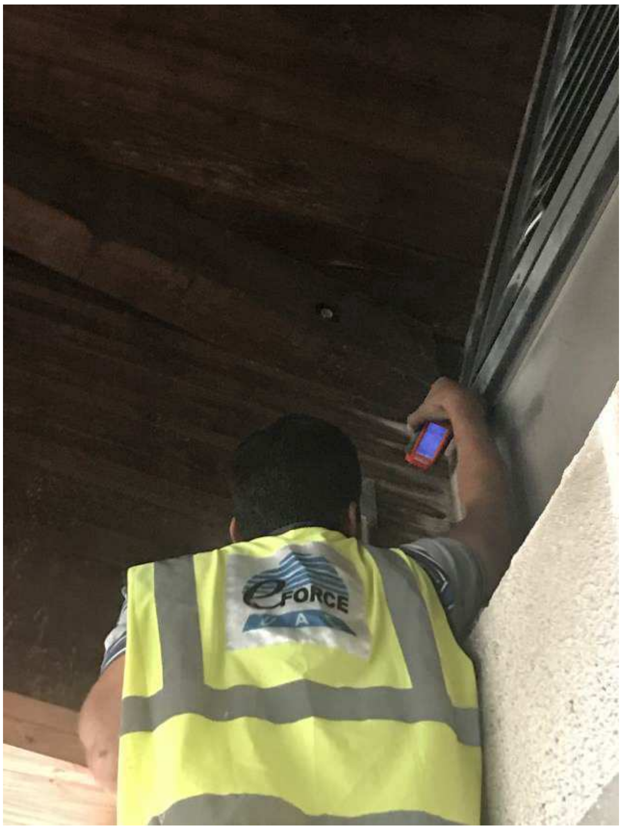


Figure 4-79 during checking the moisture content

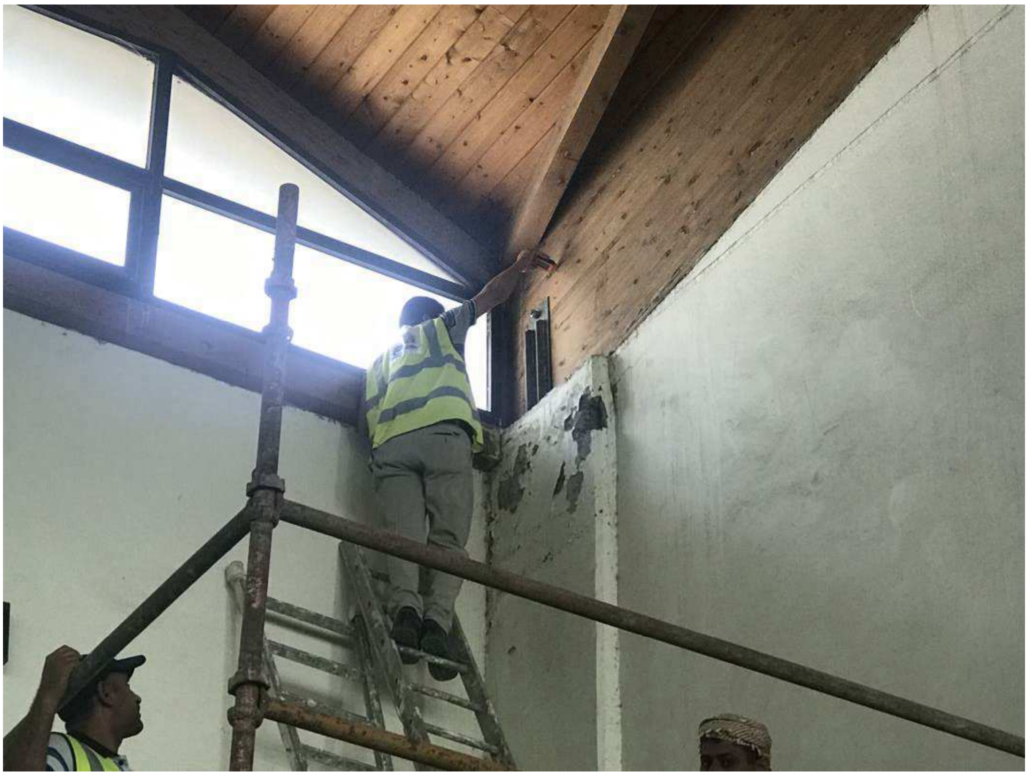


Figure 4-80 during checking the moisture content

Figure 4-81 during checking the moisture content

Table 4.8
Moisture content results in wood

No.	Location	Moisture content
1	Auditorium	5.5%
2	Swimming pool	8.9%
3	Swimming pool	11.4%
5	Gymnasium	13.4%
6	Gymnasium	16.6%
7	Swimming pool	18.5%
8	Swimming pool	14.5%

As per **BS 5268** for the average moisture content required of the external uses 20%. All the results are below 20%.

4.8 Thermo graphic Images

The presence of moisture in building envelopes, either from leakage or condensation, can have serious consequences. With infrared images, water damage is easily detected. An infrared camera helps pinpoint water intrusion, find moisture beneath the surface, and document dryness with accuracy and confidence

Any thermo graphic survey can show differences in apparent temperature of areas within the field of view. To be useful, a thermo graphic survey must systematically detect all the apparent defects and assess them against criteria agreed between the thermographer and the client. It must reliably discount those anomalies that are not real defects, evaluate those that are real defects and report the results to the client. On that count, the process generally consists of the following key steps.

Step 1: Selecting the critical acceptable temperature parameter
Step 2: Selecting maximum acceptable defect area
Step 3: Measuring surface temperature difference caused by the defect
Step 4: Measuring area of the defects

The Thermography images over the crack were taken to check if there is any internal dampness.

The Infrared Imaging Camera (Fluke TIR32) was used as per the following specifications:

Imager are handheld, infrared imaging cameras for use in many applications. These applications include equipment troubleshooting, preventive and predictive maintenance, building diagnostics, research and development, and gas leak detection.

The Imager displays thermal images on a high-visibility, industrial-quality LCD touch screen suite for quality analysis and reporting.

Powerful high-performance features make troubleshooting fast and easy
Thermal imaging is a technology that aids in the detection of hidden moisture behind walls, ceilings and floors. It also helps diagnose a variety of other home-performance problems such as missing insulation, air leaks or thermal bridges.

When it comes to hidden moisture, the imaging technology is detecting the cooler wet spots behind a wall. The coldest spots help locate the source of the problem. This is far more effective than tearing out walls, which can result in the release of hazardous substances.

From thermal graphic test (figure 4-82 and figure 4-83) the wooden beam of the swimming pool is fully dried.

Figure 4-82 during conducting thermal image test over the damaged beam

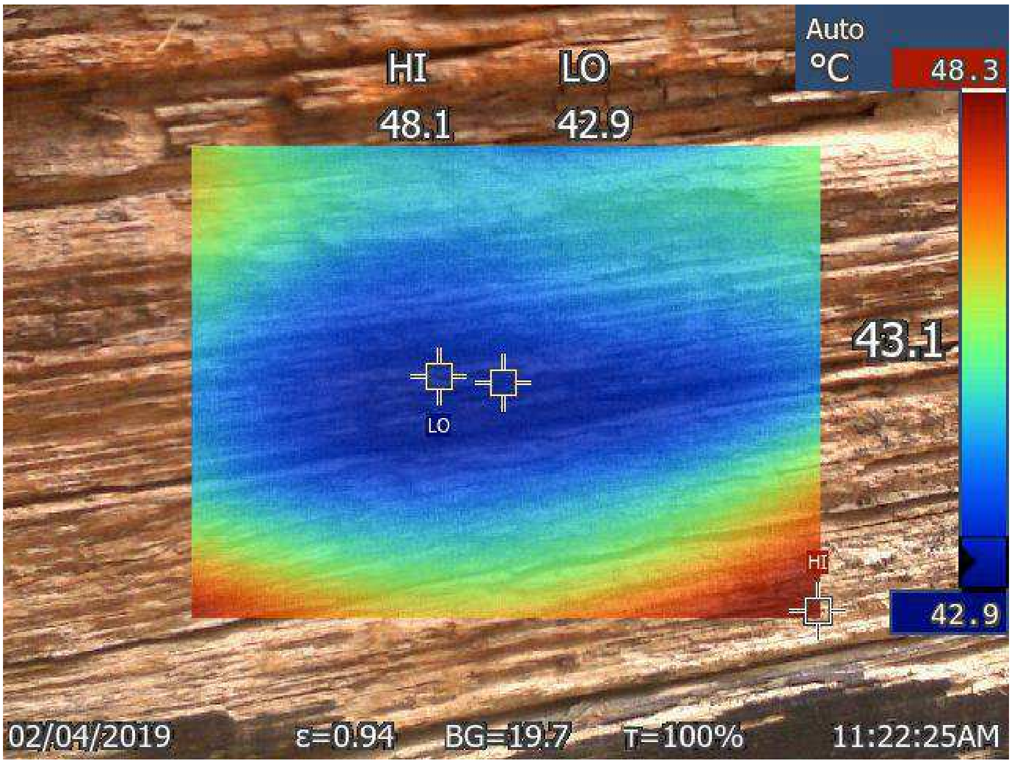


Figure 4-83 thermal image test over the damaged beam

5 EVALUATION OF PREVIOUS TEST RESULTS

APAVE consultant conducted several tests and presented respected report. To analyze such tests results, the following was found:

5.1 Concrete Cores Test

A total of 19 were taken from different locations of the buildings: 8 cores from the gymnasium columns, 8 Cores from the swimming pool columns and 3 cores from auditorium columns.

According to the ACI Code ACI 318M-14, ACI 214.4R-10 and ASTM C42

To calculate the equivalent cylinder compressive strength for a "Normalized" sample with a ratio Length/Diameter of 1, multiply the core result by a correction factor defined by the ratio Length/Diameter as per ASTM C42 (section 7.9):

Ratio of Length to Diameter (L/D)	Strength Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.10	0.91
1.00	*0.87*

* *the highlighted factor is interpolated*

For the concrete of the columns of the gymnasium

The estimated cube design strength f_{cu} can be calculated from the estimated in-situ cube strength as follows:

Specimens	1	2	3	4	5	6	7	8
Test Location	Gym col	Gym col	Gym col	Gym col	Gym col	Gym col	Gym col	Gym col
Measured compressive strength (N/mm²)	6	16.5	11.5	11	9.5	8	7	16
L/D	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Correction factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Corrected *fc'*	5.75	15.8	11	10.56	9.1	7.7	6.7	15.4

For the gymnasium columns

(AVG/0.85) = (10.25/0.85) = 12

(Min/0.75) = (5.75/0.75) = 7.7

Take Min of both, so (***fc'*= 7.7**)

F_{cu} = fc'/0.8 = 7.7/0.8 = 9.6

Table 7 — Compressive strength classes for normal-weight and heavy-weight concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength $f_{ck,cube}$ N/mm^2
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

As per the BS.EN 206 table for the average cube strength and comparing the *fc' to obtain the F_{cu} value:*

For the gymnasium columns

F_{cu} = 10 N/mm^2

For the concrete of the columns of the swimming pool

The estimated cube design strength f_{cu} can be calculated from the estimated in-situ cube strength as follows:

Specimens	9	10	11	12	13	14	15	17
Test Location	Pool col	Pool col	Pool col	Pool col	Pool col	Pool col	Pool col	Pool col
Measured compressive strength (N/mm^2)	13	14	11.5	13	11	21	8.5	8
L/D	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Correction factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Corrected *fc'*	12.5	13.4	11	12.5	10.5	20.1	8.2	7.7

For the swimming pool

(AVG/0.85) = (12/0.85) = 14

(Min/0.75) = (7.7/0.75) = 10.3

Take Min of both, so (***fc'*= 10.3)**

F_{cu} = fc'/0.8 = 10.3/0.8 = 13

Table 7 — Compressive strength classes for normal-weight and heavy-weight concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength $f_{ck,cube}$ N/mm^2
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

As per the BS.EN 206 table for the average cube strength and comparing the *fc′ to obtain the F_{cu} value:*

For the swimming pool columns

F_{cu}= 15 N/mm^2

<u>For the concrete of the columns of the auditorium columns</u>

The estimated cube design strength f_{cu} can be calculated from the estimated in-situ cube strength as follows:

Specimens	18	20	22
Test Location	auditorium columns	auditorium columns	auditorium columns
Measured compressive strength (N/mm^2)	6	10	14.5
L/D	1.5	1.5	1.5
Correction factor	0.96	0.96	0.96
Corrected *fc′*	5.76	9.6	14

For the auditorium columns

(AVG/0.85) = (9.76/0.85) = 11.5

Take Min of both, so (***fc′*= 7.7**)

(Min/0.75) = (5.76/0.75) = 7.7

F_{cu} = fc′/0.8 = 7.7/0.8 = 9.6

Table 7 — Compressive strength classes for normal-weight and heavy-weight concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength $f_{ck,cube}$ N/mm^2
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

As per the BS.EN 206 table for the average cube strength and comparing the *fc′ to obtain the F_{cu} value:*

For the auditorium columns

F_{cu}= 10 N/mm^2

From the above test results and analysis of the test results, the concrete strength of the columns of the auditorium and the gymnasium and the swimming pool are very low and need strengthening.

5.2 Depth of Carbonation

The test results for all the locations showed that the depth of carbonation is Nil in all the tested cases which is an indication that the reinforcing steel is protected in that case and the corrosion of the reinforcement is not due to the carbonation.

5.3 Concrete Dust Samples

Current concrete specifications, including the CIRIA "Guide to the Construction of Reinforced Concrete in the Arabian Peninsula, 2002", call for a maximum chloride content and sulphate Presented in Table 5.1

Table 5.1
Maximum chloride and sulphate content according to CIRIA 2002

Type of concrete	***Max. Chloride ions (Cl^-) Content*** *(% by Weight of Cement)*	***Max. Sulphate (SO_3) Content*** *(% by Weight of Cement)*
Reinforced concrete made with Portland cements containing less than about 4% C_3A (e.g. sulphate-resisting Portland cement)	*0.15*	*All cases 4.0, including the sulphate ion in the cement*
Reinforced concrete made with Portland cements containing 4% or more C_3A (OPC and ASTM types I and II usually contain more than 4% C_3A)	*0.30*	
Unreinforced concrete	*0.60*	

* The chloride contents by weight of cement were calculated using the average cement content and as received concrete density of the core specimens obtained from each location.

5.3.1. Chloride Content in Dust Samples

The chloride content of each increment of the concrete dust samples was determined according to BS 1881: Part 124:1988. The chloride content by total weight of the concrete, expressed as chloride ions in all the tested elements varied between 0.02% and 0.08% and the chloride ion by weight of cement varied between 0.12% and 0.42%. The results are presented in Table 5.2.

The chloride content in the concrete of the reinforced concrete columns under consideration was found to be higher than the limits indicating high corrosion risk.

Table 5.2
Samples of Chloride Content

Test No.	Location	Depth (mm)	Chloride Content as Cl^- % by Wt. of	
			Concrete	* Cement
1	Gymnasium	0 – 25	0.05	0.30
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
2	Gymnasium	0 – 25	0.06	0.36
		50 – 75	0.02	0.12
		125 – 150	0.02	0.12
3	Gymnasium	0 – 25	0.06	0.36
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
4	Gymnasium	0 – 25	0.05	0.30
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
5	Gymnasium	0 – 25	0.04	0.24
		50 – 75	0.02	0.12
		125 – 150	0.02	0.12
6	Gymnasium	0 – 25	0.06	0.36
		50 – 75	0.02	0.12
		125 – 150	0.02	0.12
7	Gymnasium	0 – 25	0.05	0.30
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
8	Gymnasium	0 – 25	0.04	0.24
		50 – 75	0.02	0.12
		125 – 150	0.02	0.12
9	Swimming pool	0 – 25	0.07	0.42
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
10	Swimming pool	0 – 25	0.06	0.30
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
11	Swimming pool	0 – 25	0.08	0.48
		50 – 75	0.05	0.30
		125 – 150	0.02	0.12
12	Swimming pool	0 – 25	0.07	0.42
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
13	Swimming pool	0 – 25	0.06	0.36
		50 – 75	0.04	0.24
		125 – 150	0.02	0.12

Continue Table 5.2
Samples of Chloride Content

Test No.	Location	Depth (mm)	Chloride Content as Cl^- % by Wt. of	
			Concrete	* Cement
14	Swimming pool	0 – 25	0.08	0.48
		50 – 75	0.04	0.24
		125 – 150	0.02	0.12
15	Swimming pool	0 – 25	0.07	0.42
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12
17	Swimming pool	0 – 25	0.07	0.42
		50 – 75	0.04	0.24
		125 – 150	0.02	0.12
20	Swimming pool	0 – 25	0.05	0.30
		50 – 75	0.04	0.24
		125 – 150	0.02	0.12
22	Swimming pool	0 – 25	0.04	0.24
		50 – 75	0.03	0.18
		125 – 150	0.02	0.12

* The chloride contents by weight of cement were calculated using the average cement content and as received concrete density of the core specimens obtained from each location.

5.3.2. *Sulphate Content in Dust Samples*

The sulphate content of the concrete dust samples was determined according to BS 1881: Part 124 : 1988. The sulphate content by total weight of concrete, expressed as SO_3 varied between 0.30% and 0.40%. When expressed by weight of cement, the sulphate content varied between 1.8% and 2.4%. The results are presented in Table 5-3.

The sulphate content was found to be within normal limits according to CIRIA "Guide to the Construction of Reinforced Concrete in the Arabian Peninsula, 2002", (Table 5-1) indicating low probability to have concrete deterioration due to internal sulphate attack.

Table 5.3
Samples of Sulphate Content

Test No.	Location	Depth (mm)	Sulphate Content as SO_3 % by Wt. of	
			Concrete	* Cement
1	Gymnasium	0 – 25	0.38	2.28
		50 – 75	0.34	2.04
		125 – 150	0.32	1.92
2	Gymnasium	0 – 25	0.36	2.16
		50 – 75	0.33	1.98
		125 – 150	0.32	1.92
3	Gymnasium	0 – 25	0.37	2.22
		50 – 75	0.34	2.04
		125 – 150	0.32	1.92
4	Gymnasium	0 – 25	0.33	1.98
		50 – 75	0.32	1.92
		125 – 150	0.30	1.80
5	Gymnasium	0 – 25	0.36	2.16
		50 – 75	0.34	2.04
		125 – 150	0.32	1.92
6	Gymnasium	0 – 25	0.37	2.22
		50 – 75	0.33	1.98
		125 – 150	0.32	1.92
7	Gymnasium	0 – 25	0.37	2.22
		50 – 75	0.35	2.10
		125 – 150	0.33	1.98
8	Gymnasium	0 – 25	0.36	2.16
		50 – 75	0.34	2.04
		125 – 150	0.32	1.92
9	Swimming pool	0 – 25	0.40	2.40
		50 – 75	0.34	2.04
		125 – 150	0.30	1.80
10	Swimming pool	0 – 25	0.35	2.10
		50 – 75	0.33	1.98
		125 – 150	0.31	1.86
11	Swimming pool	0 – 25	0.39	2.34
		50 – 75	0.36	2.16
		125 – 150	0.33	1.98
12	Swimming pool	0 – 25	0.35	2.10
		50 – 75	0.33	1.98
		125 – 150	0.30	1.80
13	Swimming pool	0 – 25	0.34	2.04
		50 – 75	0.32	1.92
		125 – 150	0.30	1.80

Continue Table 5.3
Samples of Sulphate Content

Test No.	Location	Depth (mm)	Sulphate Content as SO_3 % by Wt. of	
			Concrete	* Cement
14	Swimming pool	0 – 25	0.39	2.34
		50 – 75	0.36	2.16
		125 – 150	0.33	1.98
15	Swimming pool	0 – 25	0.38	2.28
		50 – 75	0.35	2.10
		125 – 150	0.32	1.92
17	Swimming pool	0 – 25	0.36	2.16
		50 – 75	0.33	1.98
		125 – 150	0.30	1.80
20	Swimming pool	0 – 25	0.38	2.28
		50 – 75	0.34	2.04
		125 – 150	0.32	1.92
22	Swimming pool	0 – 25	0.35	2.10
		50 – 75	0.33	1.98
		125 – 150	0.32	1.92

*The sulphate contents by weight of cement were calculated using the average sulphate content and as received concrete density of the core specimens obtained from each location.

5.4 STEEL TESTS RESULTS

- Tensile and bend test of steel bars were done as per ASTM A 615/A 615M-16 in seven (7) locations (two in the swimming pool, three in the gymnasium and two in the auditorium).
  The results were found to meet with the specification limits.

- Chemical analysis tests of the steel were conducted in seven locations to check the chemical contents of a sample and learn the composition, structures, and material properties from the atomic scale up to molecule scale.
- As per ASTM A 615 The results were found to meet with the specification limits.

6 REMEDIAL WORK

The remedial work should be divided into two parts: The required strengthening and the required repair.

6.1 Required Strengthening and pre design

The columns of the auditorium, Gymnasium and swimming pool should be strengthened by either CFRP wrapping 4 layers of 600 gm/m^2 or using concrete enlargement with 100 mm thickness all around the four sides of the columns using concrete C50 and reinforcement T16@150 vertical and T10@150 Horizontal.

The Wooden beams of the swimming pool roof should be strengthened by special injection then CFRP wrap at soffit of the beams as well as side wrapping.

6.2 Required repair

Before repairing the defects, it is recommended to:

- Replace all waterproofing of the auditorium, swimming pool, gymnasium and the playing area (Dojo).
- Isolate the landscape around the buildings to avoid damage in the adjacent concrete elements.

The required repair is as follows:

- Repair of cracks at the block work as per the procedure stated below.
- Repair of cracks between structural elements and blockwork as per the procedure stated below.
- Repair of cracks in structural elements or cold joints as per the procedure stated below.
- Repair of areas showing concrete delamination or spalling using either patch repair or micro concrete after treating the corroded reinforcement as per the procedure stated below. In case the repair is from the soffit, shotcrete can be used instead of the micro concrete under pressure.
- Repair of moist/previous leakage damages using either patch repair or micro concrete after treating the corroded reinforcement as per the procedure stated below. In case the repair is from the soffit, shotcrete can be used instead of the micro concrete under pressure.
- Repair the areas showing dampness as per the procedure stated below.
- Protect all concrete elements at the basements, Ground and basement with two layers of corrosion inhibitor such as Sika FerroGard 903 Plus in the areas of solid firm concrete then return any plaster followed by ant carbonation paint.

6.3 Scenarios

The suggested scenarios are as follows:

- Repair the soffit of the Playing area (Dijo).
- Isolate the landscape around the buildings to avoid damage in the adjacent concrete elements.
- Repair of the defects at the ground beams and the lower portion of the columns at the Swimming pool.
- Repair of the defects at the lower and top portion of the columns at the Gymnasium and the auditorium.
- Repair the ends of the Wooden beams of the swimming pool and auditorium roof.
- Repair of the beams and slabs soffit of the Gymnasium basement.

- Replace all waterproofing of the auditorium, swimming pool, gymnasium and the playing area (Dojo).
- Repair the areas showing dampness as per the procedure stated below.
- Repair of cracks at the block work as per the procedure stated below.
- Repair of cracks between structural elements and blockwork as per the procedure stated below.
- Repair of cracks in structural elements or cold joints as per the procedure stated below.
- Repair of areas showing concrete delamination or spalling using either patch repair or micro concrete after treating the corroded reinforcement as per the procedure stated below. In case the repair is from the soffit, shotcrete can be used instead of the micro concrete under pressure.
- Repair of moist/previous leakage damages using either patch repair or micro concrete after treating the corroded reinforcement as per the procedure stated below. In case the repair is from the soffit, shotcrete can be used instead of the micro concrete under pressure.
- Strengthen the wooden beams of the swimming pool area
- Strengthen the columns of the auditorium, Gymnasium and swimming pool.
- Protect all concrete elements at the basements, Ground and basement with two layers of corrosion inhibitor such as Sika FerroGard 903 Plus in the areas of solid firm concrete then return any plaster followed by ant carbonation paint.

6.4 Procedures of Repair

The procedures of the repair will be as follows:

Repair of Cracks in Block Walls

In case of exterior walls:

- Chase out the crack in a V-shape to the full depth of the crack or minimum of 30 mm whichever is greater. The V notes shall be of equal depth and width. Chased V- section shall be thoroughly cleaned from any contamination, oil, grease, dirt, dust or fire particles of concrete. Air compressor and mechanical water jet shall be used for cleaning. Wall surface shall be allowed to dry thoroughly before proceeding with the works.
- Fill the chase V-shape with Jotun Blockfiller or ReCon AP from Conmix

- Apply Jotashield Penetrating Primer or ResiGard Acrylic from Conmix
- Apply Jotashield Topcoat Silk or MoyaShield Uflex from Conmix to with stand the harsh Middle East Climate.

In case of interior walls:

- Remove existing render / plaster in strips of 150 mm width, or either side where cracks or openings occur in block wall and clean the surface from dust, loose materials etc.
- Chase out the crack in a V-shape to the full depth of the crack or minimum of 30 mm whichever is greater. The V notes shall be of equal depth and width. Chased V- section shall be thoroughly cleaned from any contamination, oil, grease, dirt, dust or fire particles of concrete. Air compressor and mechanical water jet shall be used for cleaning. Wall surface shall be allowed to dry thoroughly before proceeding with the works.
- Fill the chase V-shape with a thixotropic epoxy resin fairing coat (CONCRESSIVE 2200 or ReCon FCE from Conmix or Nitomartar FC from FOSROC or similar approved) or acrylic filler such as Mapeflex AC4.
- Fix galvanized expanded metal lath (minimum 7.5 Kg/m^2) bridging covering 100mm on each side, as manufactured by EXPAMET or similar approved with galvanized nails at intervals not exceeding 300mm on both sides.
- Reinstate render / plaster with EMACO S22NB or EMACO S88CT from BASF or ReCon GP from Conmix or Sikarep from SIKA or Rendroc HB from FOSROC or similar approved.
- Paint completed repairs to match existing.

Repair of Crack between Block-Walls/Concrete Column or Beam

- Remove existing plaster and painting along the column height covering 150mm on each side of the crack.
- Open the crack between the block wall and the concrete member (beam or column).
- Install galvanized steel mesh at the distance between the wall and the concrete member.
- Fill the distance between the block wall and the concrete member with acrylic sealant such as Mapeflex AC4.
- Reinstate plastering and painting.

Repair of Concrete Crack by Injection

Using MasterInject 1315 from BASF as low viscosity epoxy resin or equivalent

- Identify and mark the cracks.
- Remove all grease, oil, dust, residual curing compound, mould release agent or other contaminant that could impair adhesion of the injection ports.
- Close the cracks with epoxy putty to a band width of about 10cm (i.e 5 cm on each side of the crack).
- Install flat packers at a distance of 20-50cm using epoxy putty (MasterBrace ADH 2200
- Inject a two part solvent free low viscous, epoxy injection resin MasterInject 1315 into the cracks by using a high-pressure electric injection machine. The injected resin will fill the cracks completely and will bond them permanently. (Inject from the lowest point or furthest point towards the center checking for resin coming out of the next hole along).
- The next day i.e. after 24 hours, remove the packers and the epoxy putty and reprofile the holes.

Patch Repair for areas below 200x200mm and depth less than 40 mm

1. Identify the area where the work will be executed.
2. Hammer sound test and mark off the areas of hollow sounding.
3. All defective concrete shall be removed by suitable mechanical means and cut back to a sound base.
4. Edges of the area for repair must saw cut to a depth of not less than 10 mm to avoid feather edging.
5. The chipped surface must be cleaned. All surfaces to be treated must be firm and free from dust, laitance or any loosely adherent material.
6. Where rebar is corroded, clean and remove rust prior to the application of the rebar primer.
7. When completed, the primer shall be applied immediately to prevent the formation of further rust. It shall be applied to all exposed cleaned rebar. The primer shall be allowed to fully cure but should not be exposed to the elements for longer than necessary before application of the repair material.
8. The rebar primer shall be Zincrich epoxy primer, Nitoprime Zincrich. It shall be thoroughly mixed as per the instruction of the manufacturer and applied by brush.
9. The surface to be treated shall be blow clean. Ensure that all irregularities and the area behind the rebars are fully coated.
10. Presoak the concrete with water.
11. The repair mortar shall be single component high performance non-shrink cementitious repair mortar system, Renderoc TGXtra. Repair mortar shall be thoroughly mixed with appropriate water content until a smooth, even consistency is obtained and mixing shall be done mechanically. When mixed, the repair mortar shall be applied as required immediately in a continuous operation ensuring that no air is entrapped during the application.
12. It shall be cured and cleaned for the protective coating.

Repair of defected areas and depth more than 40 mm using Micro concrete

1. Hammer sound test and mark off the areas of hollow sounding.
2. All defective concrete shall be removed by suitable mechanical means and cut back to a sound base.
3. Edges of the area for repair must saw cut to a depth of not less than 5 mm to avoid feather edging. Where rebars are corroded, concrete shall be removed to around the full diameter of the bars and cut back to depth of 25-30 mm behind the bars.
4. The chipped surface must be cleaned. All surfaces to be treated must be firm and free from dust, laitance or any loosely adherent material.
5. Where corroding rebars have lost more than 30% of cross-sectional area a new length of rebars shall be added to compensate for the loss in cross-sectional area.
6. Prior to the application of the rebar primer, the complete area shall be clean. When completed, the primer shall be applied immediately to prevent the formation of further rust. It shall be applied to all exposed cleaned rebar, making sure that the back of the rebar is properly coated. The primer shall be allowed to fully cure but should not be exposed to the elements for longer than necessary before application of the repair material.
7. The rebar primer shall be Zincrich epoxy primer, Nitoprime Zincrich. It shall be thoroughly mixed as per the instruction of the manufacturer and applied by the brush.
8. Presoak the concrete surface with water.
9. Install formwork as soon as the presoaking of water will be completed. Formwork shall be constructed from smooth-faced good quality plywood sheet. Formwork shall be properly fixed so that no movement will occur during or after placement of repair mortar. Joints in the formwork and gaps between the existing structure and the formwork shall be sealed to prevent leakage of grout.
10. The repair mortar shall be single component high performance shrinkage controlled polymer modified fluid microconcrete, Renderoc LAXtra. Repair mortar shall be thoroughly mixed with appropriate water content until a smooth, even consistency is obtained and mixing shall be

done mechanically. When mixed, the repair mortar shall be poured / applied as required immediately in a continuous operation ensuring that no air is entrapped during the application.

11. A minimum curing time of 24 hours should be allowed before removing/stripping the formwork.
12. The surface shall be clean for any contamination from formwork.

Repair of Dampness

Using Cementitious Waterproof coating such as Nitocote CM210 from Fosroc or equivalent

- Surfaces which are receiving the coating should be water jetted / sweep blasted to remove the laitance, oil, grease, dirt or any other form of the foreign matter which could affect the adhesion (any sharp edges, protrusions, imperfections in levels to be ground and / or made good by the client free of charge, basic surface to be made acceptable to yourselves as the coating will assume the profile of the substrate).
- Vacuum Clean the surface to remove the dust and dirt.
- Prime the surface using water and if it is high porosity substrates, more priming is required.
- After priming roller apply the elastomeric, cementitious coating with inherent crack- bridging ability of Nitocote CM210 @ 0.50 Lts / Sqm.
- Apply the final coat of the same Nitocote CM210 @ 0.50 Lts / Sqm and allow it to cure.
- The surface should be used after sufficient curing of 3 days.

7 EMERGENCY MEASURES

The emergency measures from the above mentioned repair and strengthening are as follows:

- Repair the soffit of the Playing area (Dijo)……Already done.
- Isolate the landscape around the buildings to avoid damage in the adjacent concrete elements.
- Repair of the defects at the ground beams and the lower and top portion of the columns at the Swimming pool.
- Repair of the defects at the lower portion of the columns at the Gymnasium and the auditorium.
- Repair the ends of the Wooden beams of the swimming pool and auditorium roof.
- Repair of the beams and slabs soffit of the Gymnasium basement.

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Repair and Strengthening Expert

Appendix A

Defects Mapping

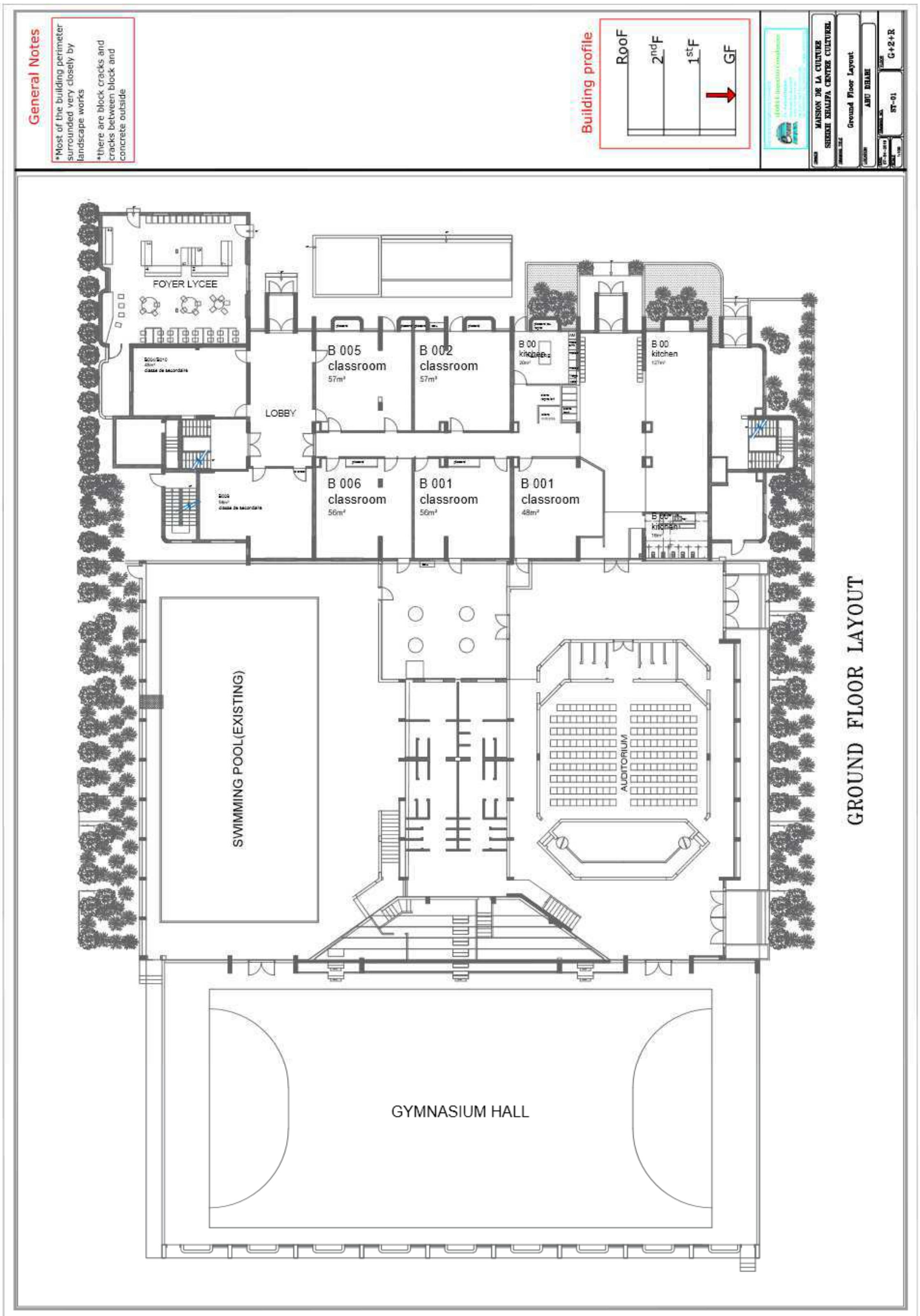

Figure A-1 ground floor layout of Building B

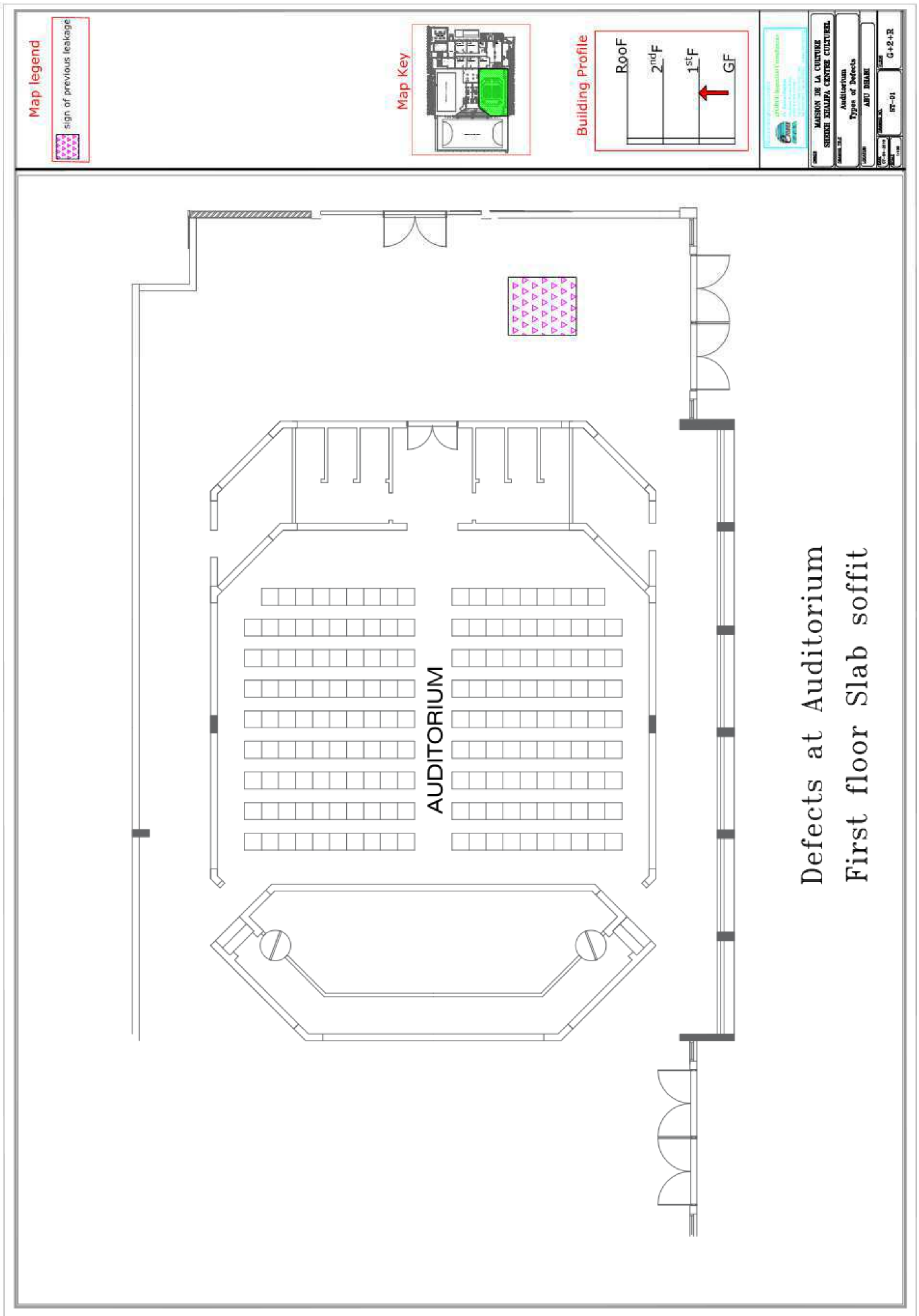

Figure A-2 Defects in auditorium slab soffit

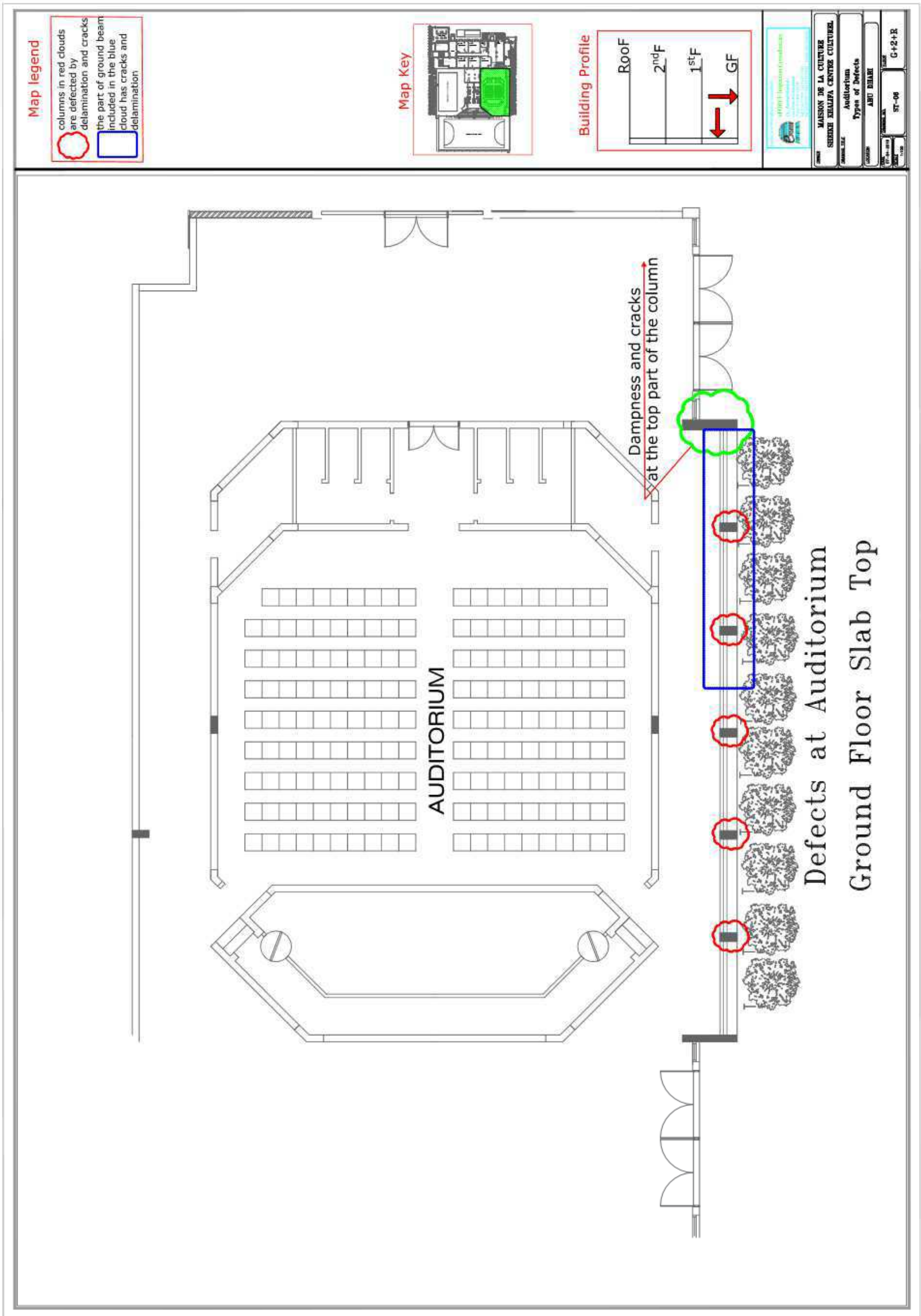

Figure A-3 Defects in auditorium slab top

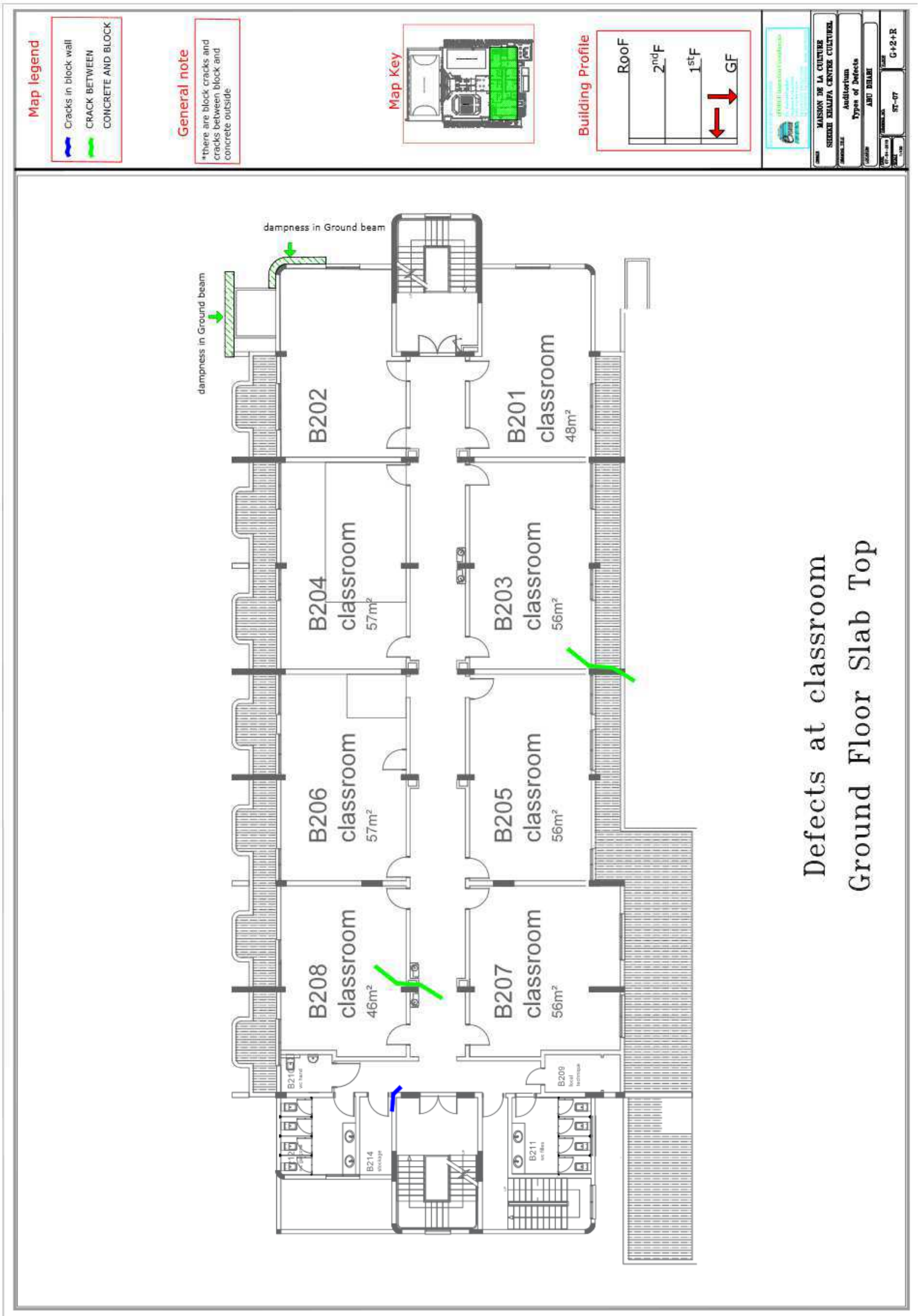

Figure A-4 defects in Classroom building in ground floor slab top

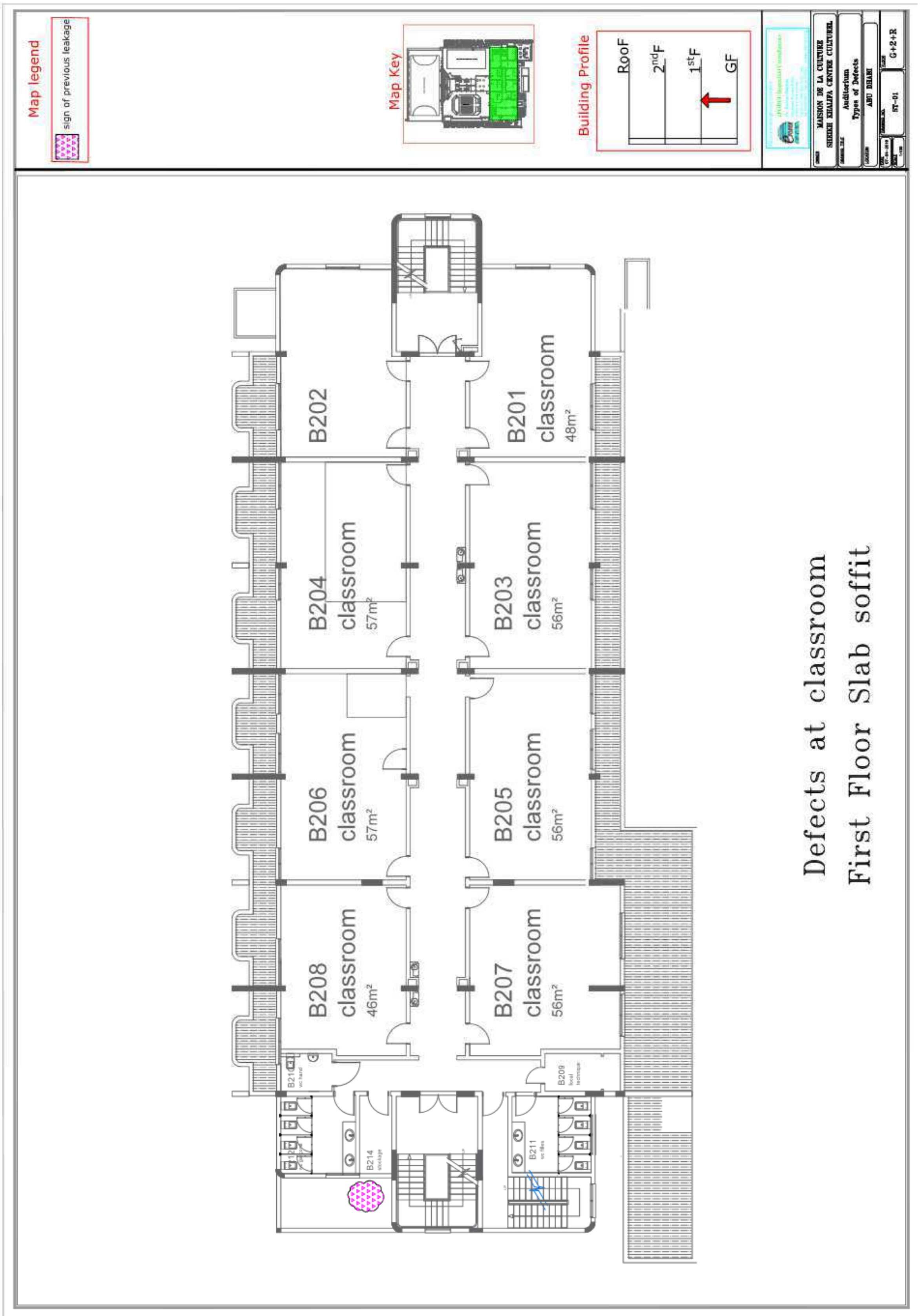

Figure A-5 defects in Classroom building in first floor slab soffit

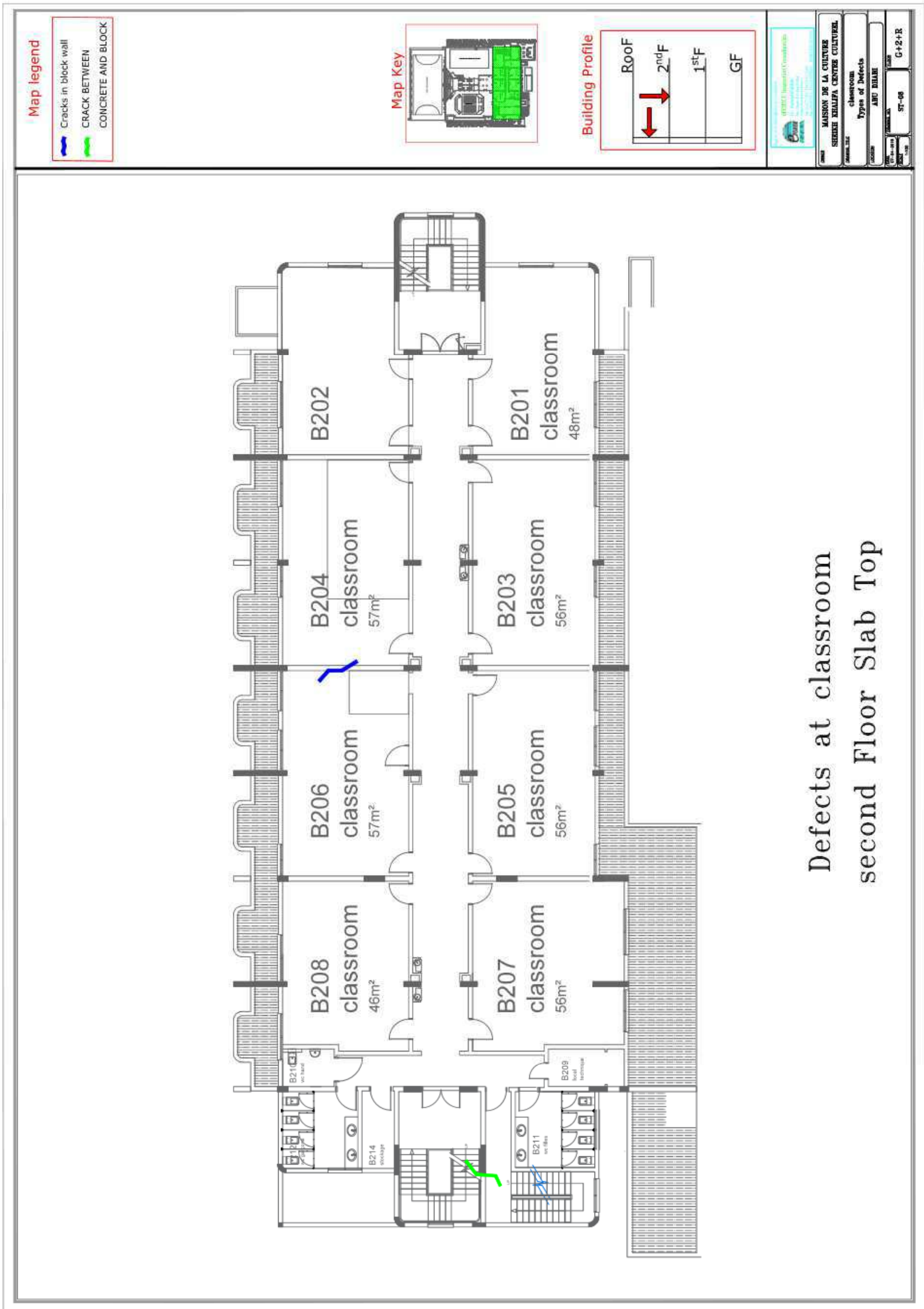

Figure A-6 defects in Classroom building in second floor slab top

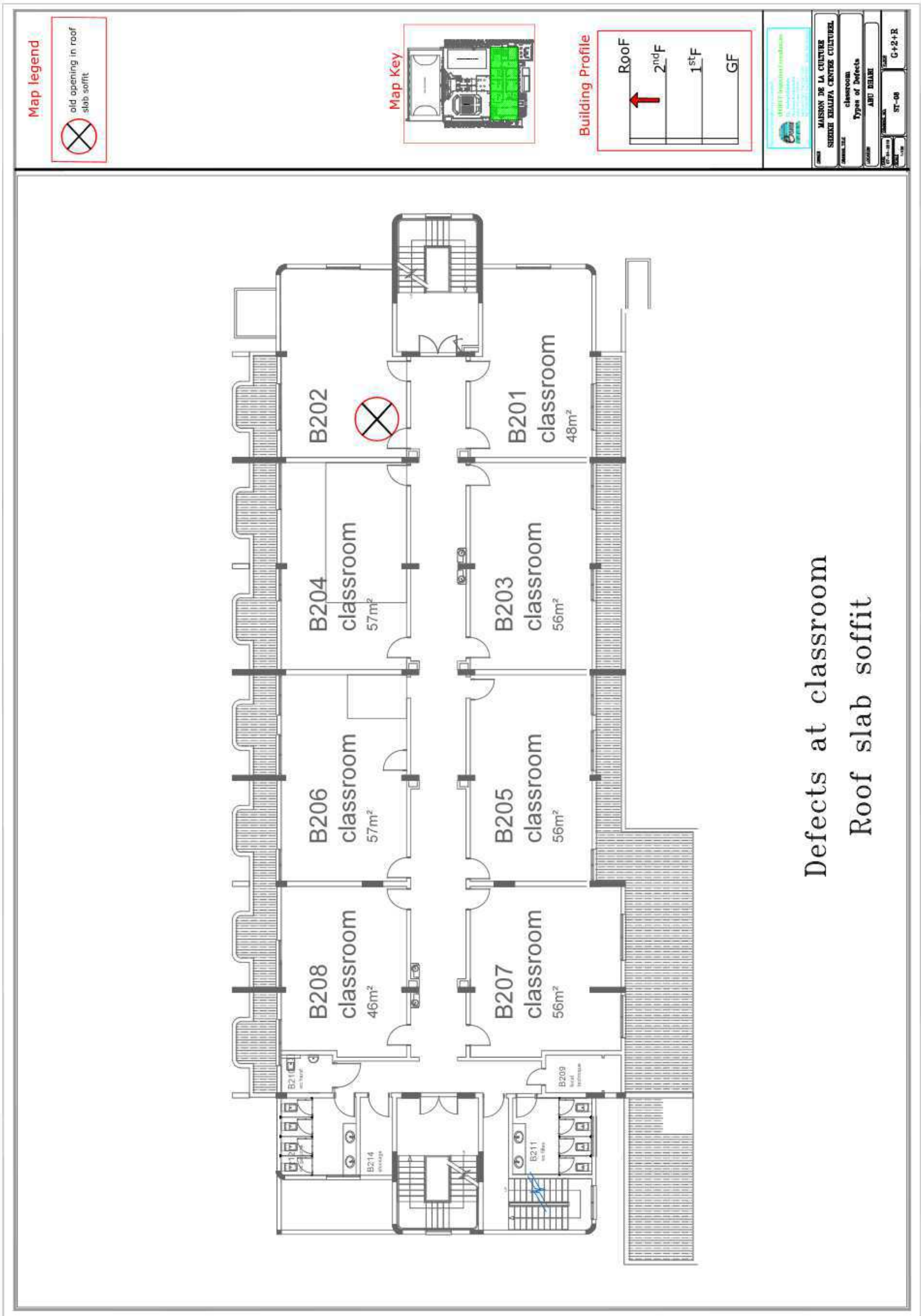

Figure A-7 defects in Classroom building in roof slab soffit

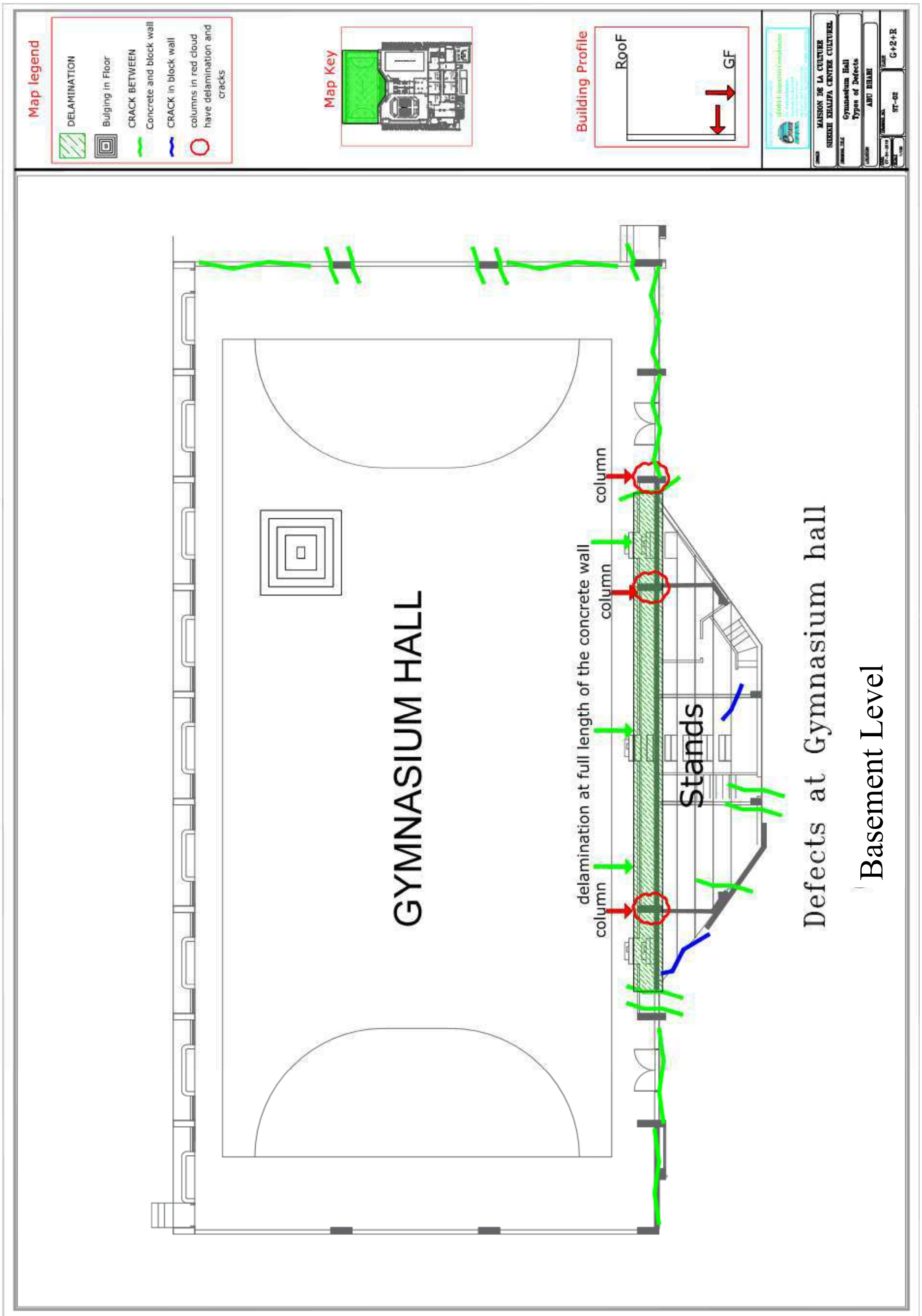

Figure A-8 defects in gymnasium in basement level

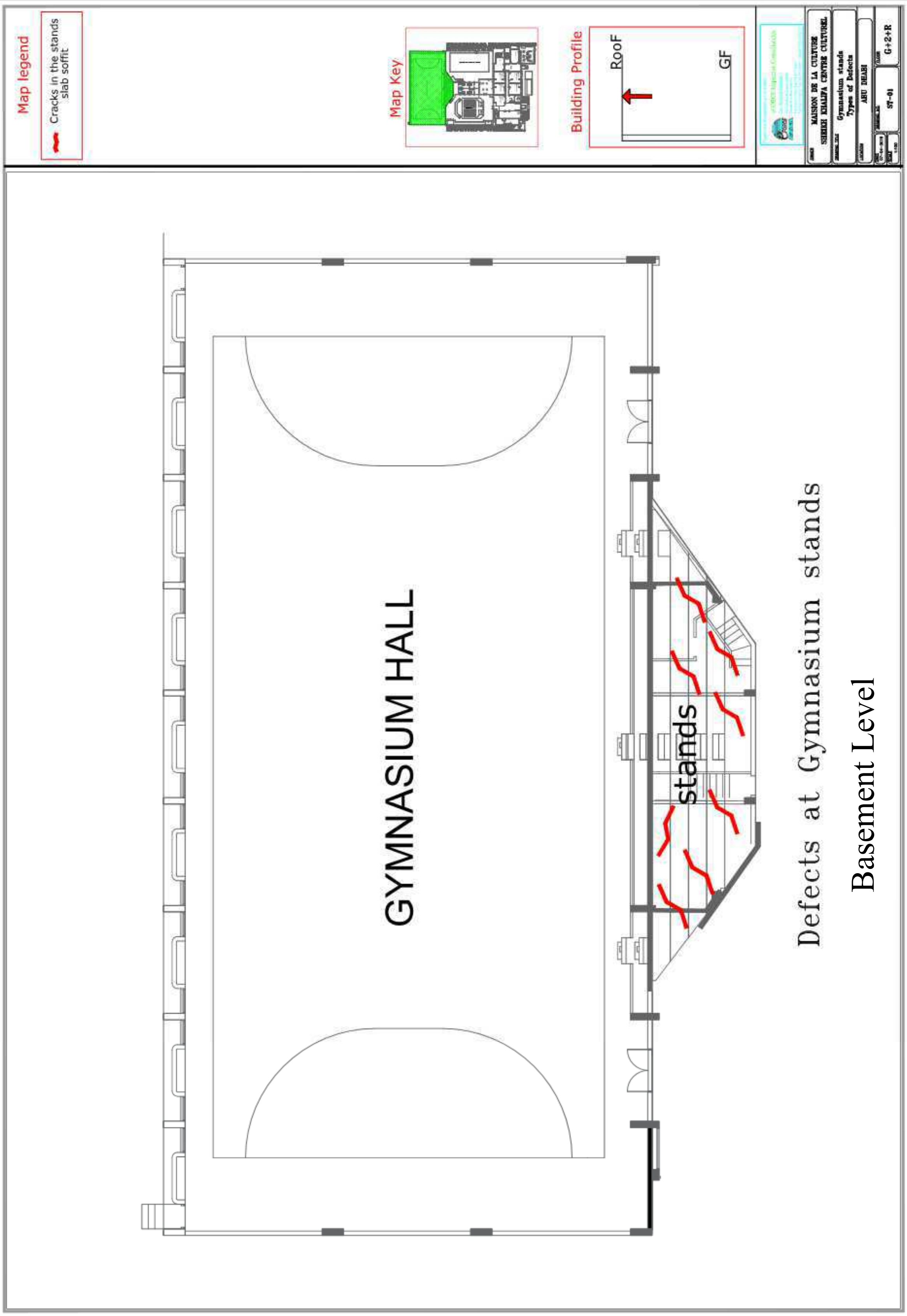

Figure A-9 defects in the basement soffit of the gymnsium

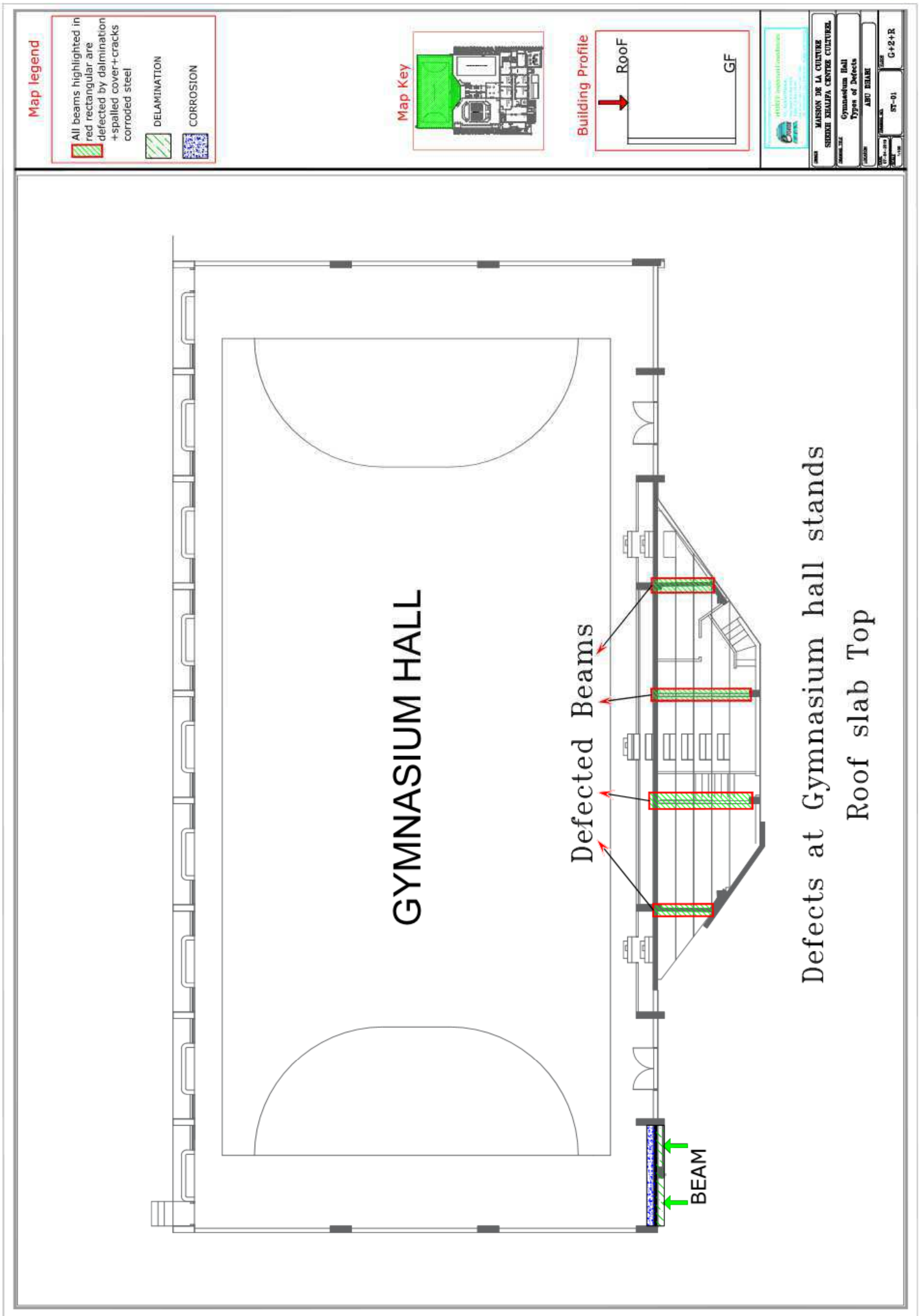

Figure A-10 Defects in gymnasium in roof level from top.

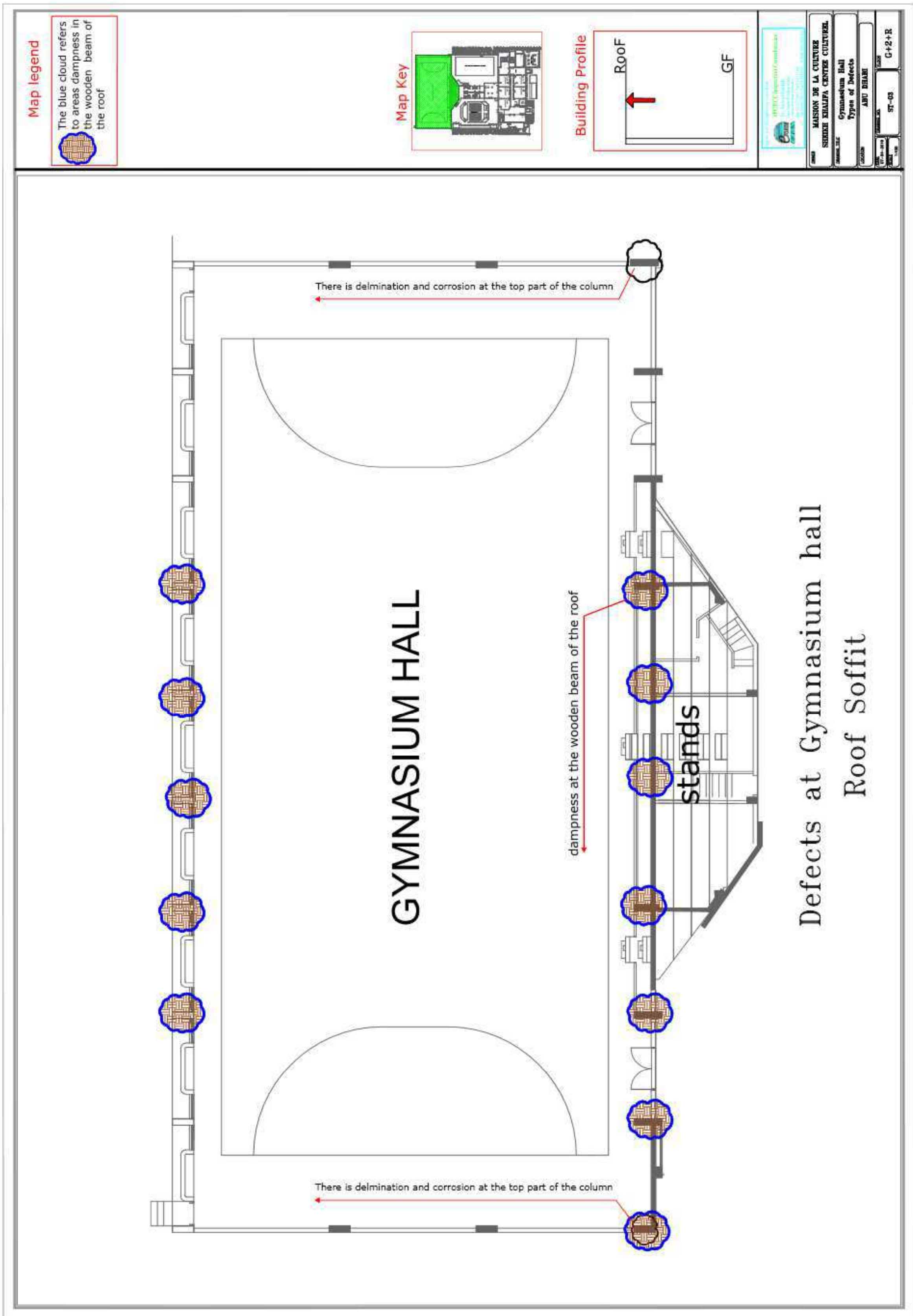

Figure A-11 Defects in gymnasium in roof level from soffit.

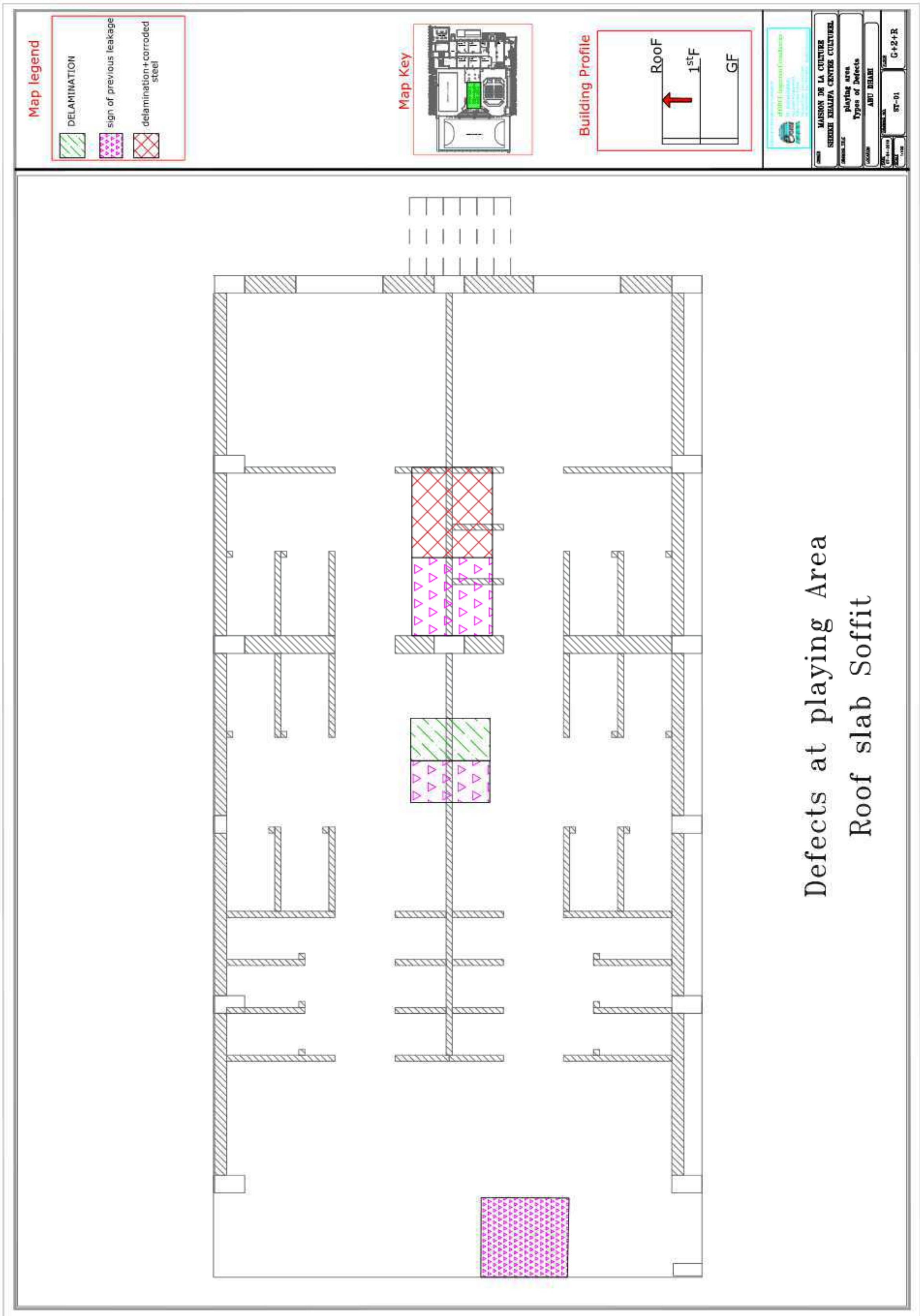

Figure A-12 Defects in playing area in roof slab soffit.

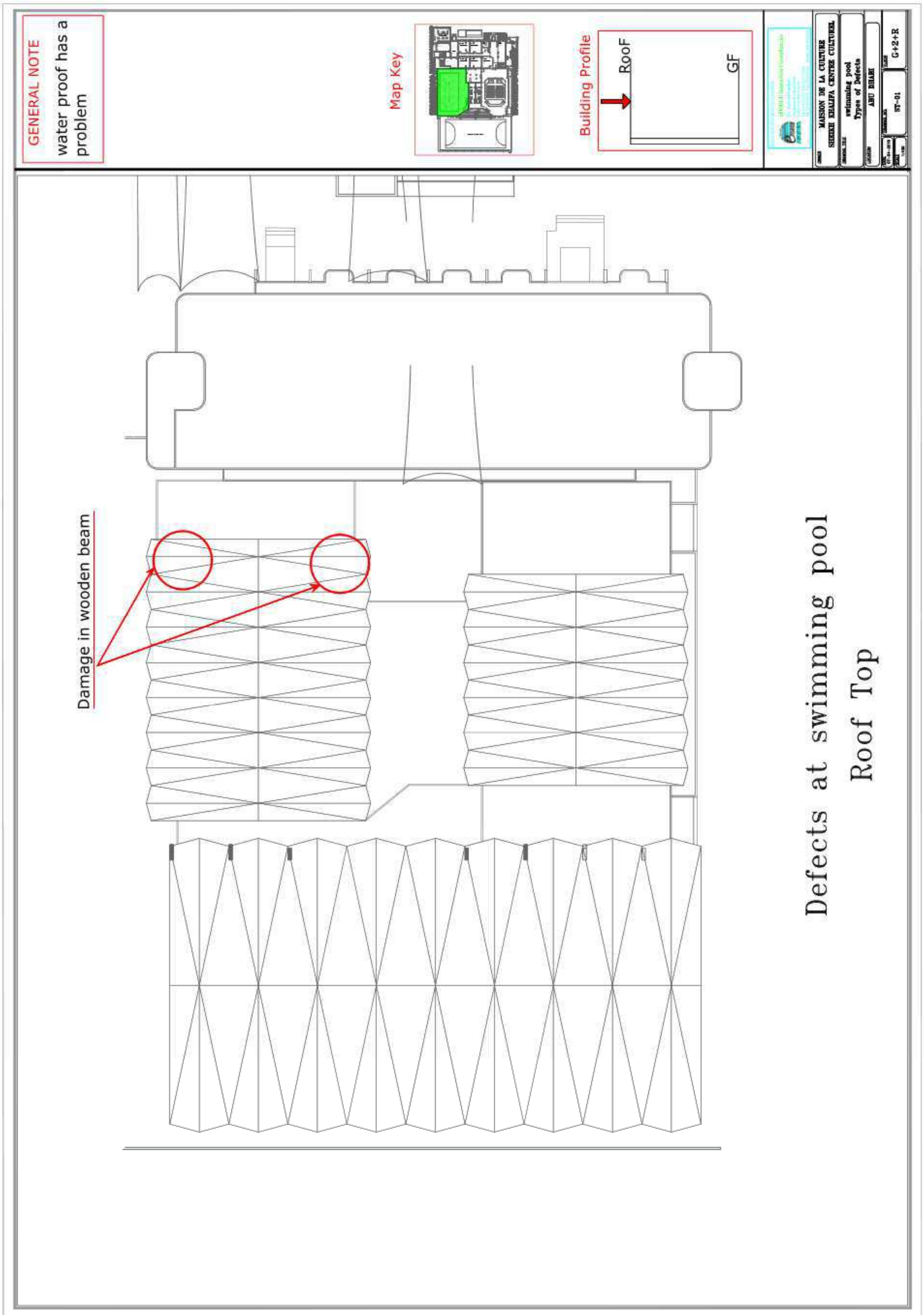

Figure A-13 Defects of swimming pool in roof level from top

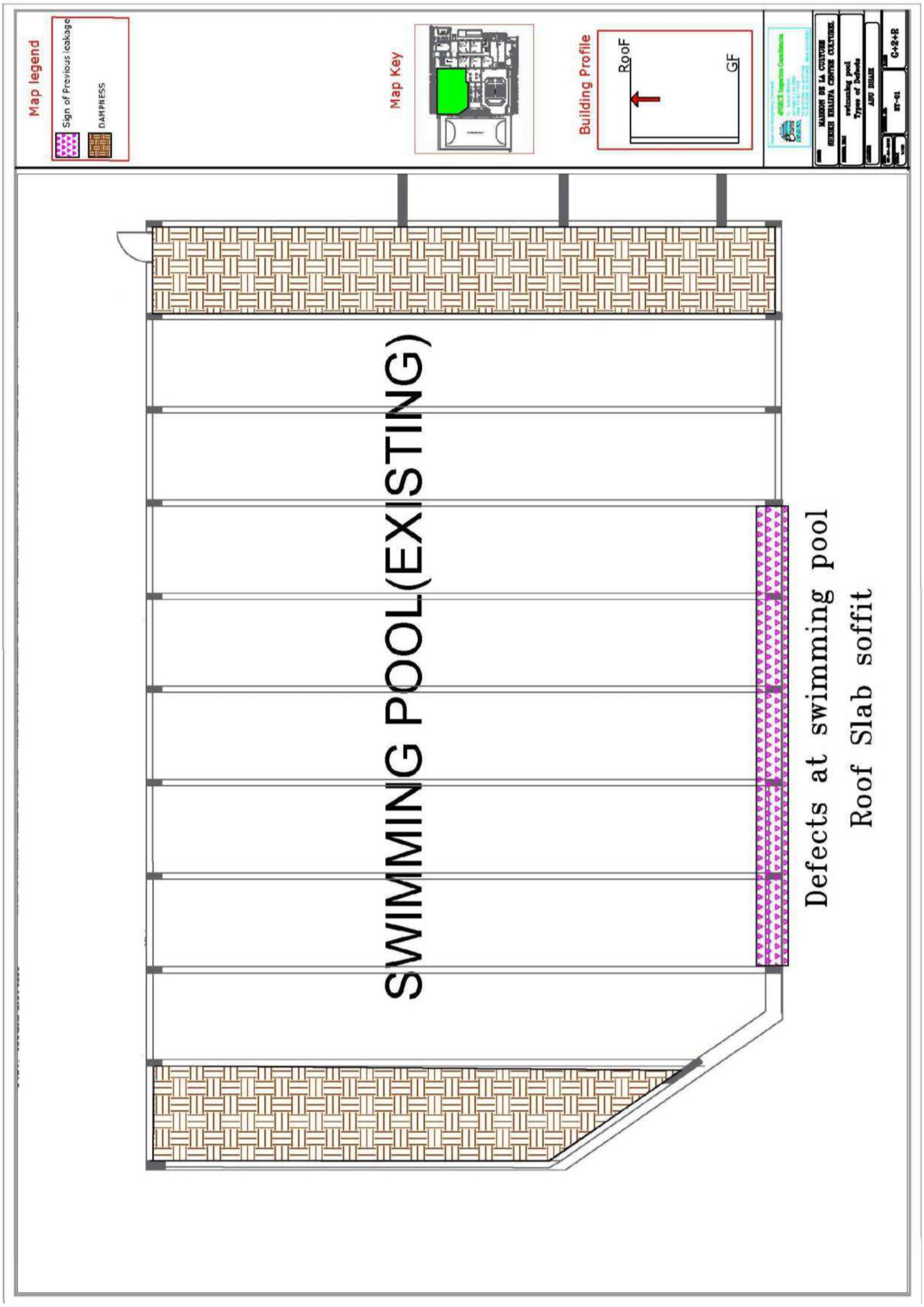

Figure A-14 defects in swimming pool roof slab soffit

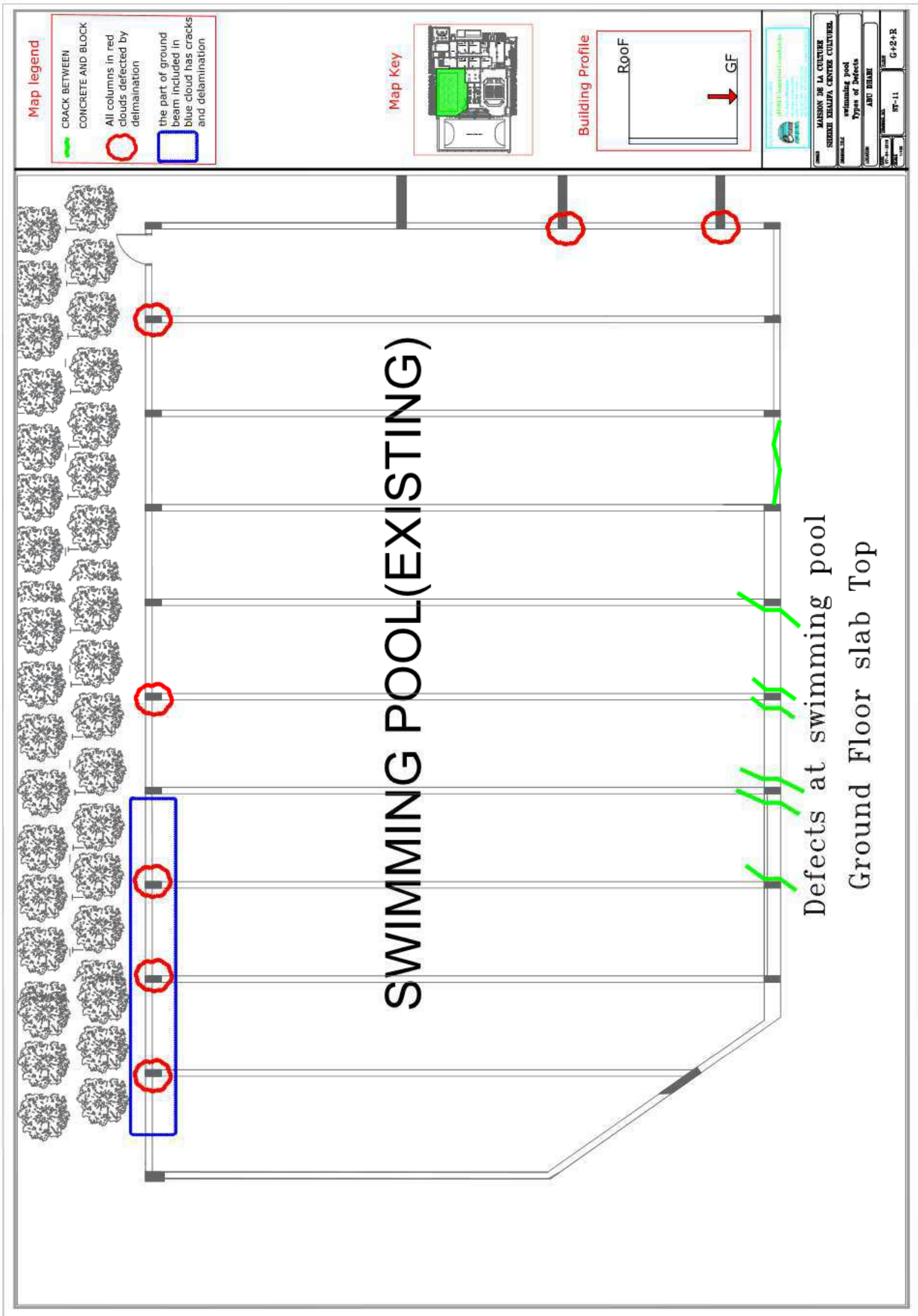

Figure A-15 defects in swimming pool ground slab top