Condition Survey and Remedial Proposal forthe Conservation of The Chapel at the Béthanie at 139 Pokfulam Road(APA-PT2629)

Prepared by Substance Lab Limited

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The Hong Kong Academy for Performing Arts 香港演藝學院

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THE LORD WILSON HERITAGE TRUST

SUBSTANCE LAB

Chapter1
Introduction

1.1 Background of this consultancy

Substance Lab Limited has been appointed by the Hong Kong Academy for Performing Arts (hereafter APA) to carry out a throughout desk study, survey and investigation into the defects at the Chapel of the Béthanie.

Appropriate remedial proposal supplemented with an action plan is to be produced based on the study and investigation, in order to preserve and avoid further deterioration of the Chapel.

1.2 Authorship and Copyright

This report is produced by Yu Ka Sing, Hebi Chan Shuk Wa and Clive Chan Chung Yeung of Substance Lab Limited. Gesa Schwantes, Director of the Architectural Conservation Laboratory (ACLab) at The University of Hong Kong is the technical advisor on the study associated with plaster.

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1.3 Scope of the consultancy

This consultancy covers the Chapel of the Bethanie addressed at 139 Pokfulam Road, which is a declared monument under the Antiquities and Monuments Ordinance.

1.4 Objectives

The objectives of the consultancy include:

i Record and locate all the defects found at the test site
ii Conduct desktop study of past repair works
iii Investigate and identify the causes of the defects
iv Analyze if the defects are caused by the design of the building, aging of the materials or other reasons
v Suggest solutions and remedial proposalsto rectify the defects

1.5 Methodology

The investigation will be conducted in non-destructive means, including visual inspection and infrared thermography. Detailed visual survey will be carried out on every elevation and plan of the test site. The objective of visual inspection is to identify obvious defects that might include the followings:

i Defective waterproofing membrane on concrete pitched roof
ii Spalling of concrete especially at pitched roof
iii Flaking/ peeling off or powdery condition of plastering or paint
iv Water stains at ceiling vault and walls
v Cracks at columns inside Chapel
vi Water seepage, flaking and rust of metal window frames
vii Vegetation at roof parapet and pinnacles
viii Cracked floor tiles
ix Minor defects at timber frame and panels of doors

Infrared Thermography Survey will be conducted to review problematic locations in the building enclosure that are not easily identifiable by visual inspection, for example, moisture that appears at roof or along drainage pipes. Its results will help to suggest the location of defects as well as the cause of other defects.

1.6 Limitation

There is several test limitation of the infrared thermography imposed by the site conditions:

i Survey cannot be done at the face where is at the recess area or blocked/screened by any obstacles or their shadows, such as trees or adjacent buildings.
ii Survey result will be affected if the survey undertaken in high inclination/ side angles (>40°)due to site constraints or the irregularity of the façade.
iii Survey result accuracy will be affected for those external walls where no direct sunlight can be reached due to the site constraints and the sun orientation or at the narrow area, such as fins areas.

Although best effort has been made to obtain as much data as possible during the Infrared Thermography Survey, survey accuracy could be affected by the site constraints due to the above mentioned limitation.

On the other hand, under the Antiquities and Monuments Ordinance (CAP. 53), the Block Permit of Béthanie, taking material samples which involve opening up or minor destructive testing will be allowed only with the consent of the Executive Secretary.

1.7 Acknowledgement

The authors would like to thank the Lord Wilson Heritage Trust for their support of this consultancy, and Mr. Suen Leung Puifor his generous advice for the preparation of this report.

Chapter2

The Historic Site

2.1 Location

The Béthanie(伯大尼修院), No. 139 Pokfulam Roadis located on a hilltop and overlooks the Pacific Ocean to its southwest. It was surrounded by dairy pastures and is adjoined by the site of the old Dairy Farm of which a number of old Dairy Farm buildings still remain e.g. a senior staff quarters, a main office building and a cowshed in dumb-bell shape at the rear side of Béthanie. On the opposite side of Pok Fu Lam Road, there is Nazareth, now known as University Hall, which was used to be a printing house for the works from the priests in Béthanie.

2.2 Establishment

The premises was completed in 1875 by the religion order known as the Society of Foreign Missions of Paris (Société des Missions Étrangéres de Paris, 巴黎外方傳教會) as their first rest home in East Asia for the old and sick missionaries from all over Asia to recover from tropical diseases before returning to their missions. It has received some 6,000 missionaries during its service as a sanatorium. It was also a base for spreading Catholicism in Mainland China. Construction of the Béthanie was commenced in 1873 according to the design of Father Osonf and completed in 1875 under the supervision of Father Charles Patriat. It is consisted of three parts: the Chapel, the Sanatorium and the Service Wing.

Priests learnt Chinese in Béthanieand also engaged in translation and publishing works. In 1883, Father Fong and two other fathers who worked in the Béthanie founded the Nazareth Press. In the same year, other fathers started propagating Catholic faith around the Béthanie. Workers of the Press began to settle near the monastery. The Béthanie survived through the Japanese Occupation. After the establishment of People's Republic of China in 1949, many missionaries left China and lodged in Béthanie. It closed down in 1975.

2.3 Decommission and Adaptive Reuse

Closed in about a century later after its establishment, Béthanie was sold to Hongkong Land. It was subsequently taken over by the Hong Kong British Government then leased to the University of Hong Kong for about twenty years from 1978 to 1997 as the Hong Kong University Press and other departments of the University. Left vacant for about six years, in 2003 the Hong Kong SAR Government decided to restore and lease the Béthanie together with the adjacent Old Dairy Farm Cowshed Building (a Grade 2 historic building) to another tertiary education institue, the Hong Kong Academy for Performing Arts (HKAPA) for conversion into their second campus besides the existing one at Wanchai. The conversion was completed in 2006 and the Béthanie has served as the School of Film and Television of the HKAPA since then. Philip Liao and Partners Limited was the architect in charge of the conversion. They removed the flat roof built in the 1960s to reveal the original pitched roof design, which was rebuilt with glazed tiles and gable walls and serves as a dance studio. The Chapel was restored and has become one of the most popular wedding venues in Hong Kong.

2.4 Architectural Features

The Béthanie's predominant architectural style is of Neo-Gothic featuring pointed lancet windows, pointed arched colonnades to verandahs, flying buttresses, pinnacles, crockets and trefoil ornamentation to parapets. The plan is in symmetrical form with verandahs on all four sides, acting as a design feature adapted to the local hot and humid weather. Rubble and ashlar plinth wall at the basement level, ornamental balustrades and arched colonnades at the verandahs form the elevations of the building. The most impressive and striking part of the building is undoubtedly its Chapel, now named as George C. Tso Memorial Chapel. It has a ribbed and vaulted dome supported on slender Gothic style columns. It is the site of this study.

2.5 Alterations and Additions and Architectural Conservation

It should be noted that the current adaptive re-use of the Béthanie took place before the Chief Executive announced the initiatives for heritage conservation in the 2007-08 Policy Address. It was a time when no heritage conservation projects made reference to international conservation principles and best practice on the restoration of historic fabrics, use of materials, design of new additions and alterations etc.

2.6 Brief Time Line

Owner/ Operator	Year	Description
The Society of Foreign Missions	1873	Construction started for the sanatorium for old and sick missionaries and the base for spreading Catholicism in Mainland China
	1875	Construction completed
	1975	Closed Sold to Hongkong Land
Hong Kong Government	1981	Accorded a Grade 2 Historic Building
The University of Hong Kong	1978-1997	Used by the Hong Kong University Press and other departments of the University of Hong Kong
The Hong Kong Academy for Performing Arts	2003 March	Legislative Council approved funds for restoration and conversion
	2003- 2006 December	Major Alterations & Additions Works carried out for the adaptive reuse as the Pokfulam campus of the Hong Kong Academy for Performing Arts
	2008	Awarded an Honour Mention at the 2008 UNESCO Asia-Pacific Cultural Heritage Awards
	2013 Nov 22	Declared a monument
	2013-2015	Repair works to the Gothic columns at Chapel
	2015 Summer	Repair works to the Gothic columns at Chapel
	2016 Summer	Repair works to the Gothic columns at Chapel Repair works to the concrete spalling at the soffit of concrete pitched roof

Chapter3

Investigation and Findings

3.1 General Findings– Water Seepage as the Prime Cause

The internal walls of the Chapel are generally considered to be **damp** from the tactile impression. Defects such as water stains, plaster popping, flaking, and salt subflorescence are evidence that moisture present in the internal walls.

Infrared survey suggests the waterproofing membrane on the concrete pitched roof is impaired and cracked. Debonding/ delamination of the externally applied waterproofing membrane and water stains are identified on the pitched roof. Cracks also present on the concrete roof of the Corridor and the water seepage problem is obvious along the interior of the Corridor as informed by visual inspection. **Rainwater seepage** through (1) the impaired concrete roofs, both the pitched roof and the roof of the Corridor, and (2) the rusted window frames of stained glass is considered to be the root cause of defects.

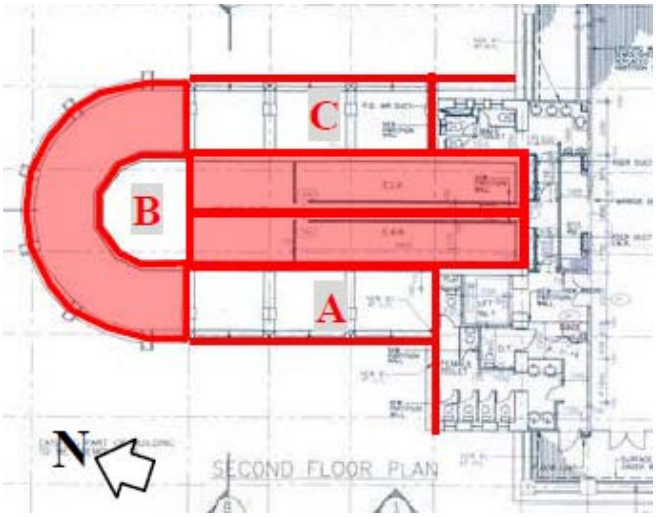
A concise and consolidated summary of the defects is provided at the end of this chapter to allow for strategic planning for defect rectification and restoration works.

3.2 Investigation by Infrared Survey and Moisture Meters

Infrared thermography and moisture tests are conducted in order to review problematic locations in the building enclosure that are hardly identifiable by visual inspection. The results help to suggest the location of defects and the causes of other defects found by visual inspection. Infrared thermography inspections and protimetermoisture test on external and internal walls of Chapel of Béthanie have been carried out by Reachable Engineering Consultants Ltd on 14, 20 and 22 August, 2016.

3.2.1 External Walls

Base on the report on external walls, there were 222 numbers of location with abnormal temperature obtained under the Infrared Thermography Inspection. 58 of the suspected defects found are located on Elevation A (West Elevation), 66 of that are located on Elevation B, while 98 of that are located on Elevation C (East Elevation).



Potential defect is identified according to its size, shape, temperature difference, materials, visible characteristics, color, etc. A five-tier system categorizing the different types of possible defects is suggested as below:

Index	Defect Type	Suspected Defects Found
I	Possible normal debonding/delamination	162
II	Possible serious/major debonding	0
U	1. Structural difference 2. Color/material difference/stain 3. Reflection 4. Uneven distributed sunlight 5. Other heat sources 6. Unidentified temperature difference	7
W	1. Suspected water stain/seepage	53
V	1. Possible defect found under visual inspection at where infrared Thermography Inspection is inappropriate to be carried out 2. Hand-reach tapping	0
Total		222

Within the total of 222 defects, 162 of them are identified as “Possible normal debonding/ delamination” (Type I), 53 of them are identified as “Suspected water stain/ seepage” (Type W), and 7 of them are identified with possibilities such as structural difference and color difference (Type U). No defect of “Possible serious/major debonding” has been recorded.

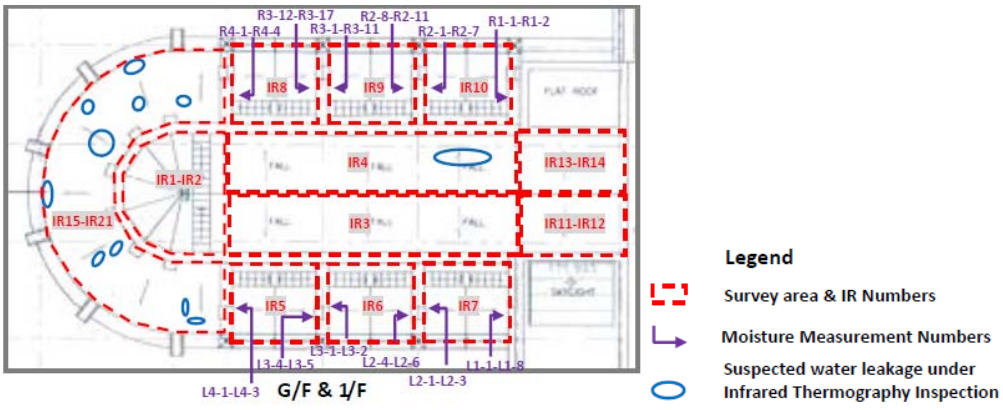
Defects of "Possible normal debonding/ delamination" are commonly found on the façade of the Chapel, which means the stucco render might possibly detach from the substrate. This finding shall be verified by percussion test when a fall arrest system is introduced. Percussion test shall cover the whole external façade in order to ascertain the extent of actual debonding and to check whether the locations identified with "Suspected water stain/ seepage" have further developed into a state of debonding.

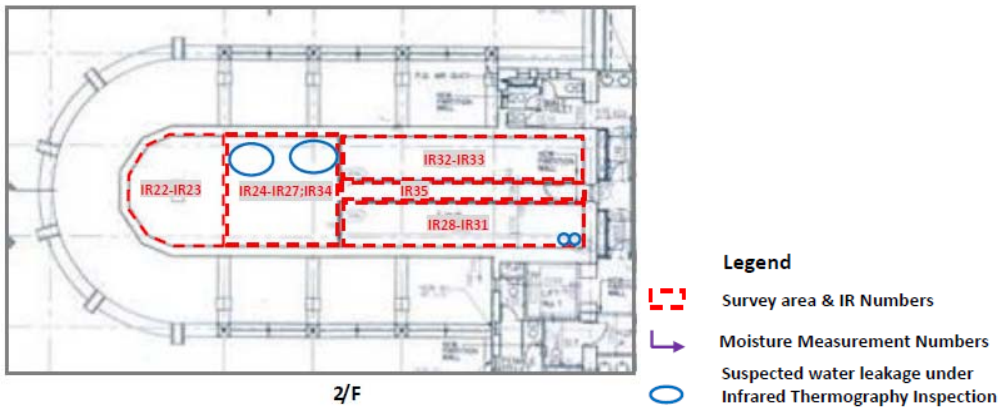
To deal with the deboned stucco, injection grouting is one of the solutions to consolidate the stucco render, yet the process to examine an appropriate grouting could be both time and money consuming. Currently there is no urgency to take any actions to the stucco render unless an actual debonding is recorded. If it happens, APA should take the chance to collect samples from the debonded plaster and carry out a plaster analysis. This information serves as a basis to decide the type of stucco and the appropriate plaster mix to follow in the future repairing. It might be even better to carry out a plaster analysis in earlier stage when a funding is available, but not to wait until an actual debond takes place (Please refer to Section 5: Action Plan).

The other defects of "Possible normal debonding/ delamination" are found at the concrete pitched roof indicating a possibility of debond of the cement render. Impaired and cracked waterproofing membrane at the pitched roof is also identified. Follow-up actions to the concrete pitched roof shall refer to Section 4.4 .

3.2.2 Internal Walls

Based on the report on internal walls, sign of suspected water leakage concentrated at the ceiling of the Corridor. Most of the signs of water leakage are not visually identifiable, except for IR17 and IR20 that obvious water stain and peeling off of plaster are observed. Such finding is expectable since obvious cracks present on the concrete roof of the Corridor. The infrared themorgraphy survey also suggests "Possible normal debonding/ delamination" and "Suspected water stain/ seepage" on the concrete roof of the Corridor. The remaining defects identified include one particular spot at the vault and two particular spots at the ceiling of the concrete pitched roof above the vault.





Protimeter moisture test is also carried out and a total of 56 testing points are located on 8 different walls in the Chapel. All testing areas show reading lower than 30, i.e. indication of "relative high" moisture reading. Although the protimeter moisture test suggests that the moisture readings of internal walls are not high, yet the internal walls are considered to be damp from the tactile impression. The findings and the suggestions will be covered by Section 3.

Wall R1	Test Point	R1-1	R1-2									
	Reading	7.8	8.6									
Wall R2	Test Point	R2-1	R2-2	R2-3	R2-4	R2-5	R2-6	R2-7	R2-8	R2-9	R2-10	R2-11
	Reading	7.7	16.6	19.6	10.8	8.5	16.8	16.2	7.6	8.8	8.9	8.2
Wall R3	Test Point	R3-1	R3-2	R3-3	R3-4	R3-5	R3-6	R3-7	R3-8	R3-9	R3-10	R3-11
	Reading	8.1	10.7	16.0	11.5	11.5	9.8	17.9	8.7	15.8	15.4	19.8
Wall R3	Test Point	R3-12	R3-13	R3-14	R3-15	R3-16	R3-17					
	Reading	7.2	8.6	14.5	14.3	6.7	9.7					
Wall R4	Test Point	R4-1	R4-2	R4-3	R4-4							
	Reading	9.0	6.4	6.9	7.7							

Wall L1	Test Point	L1-1	L1-2	L1-3	L1-4	L1-5	L1-6	L1-7	L1-8			
	Reading	14.3	14.4	12.0	8.1	7.1	6.3	8.1	7.2			
Wall L2	Test Point	L2-1	L2-2	L2-3	L2-4	L2-5	L2-6					
	Reading	11.8	7.8	10.1	11.8	8.6	8.5					
Wall L3	Test Point	L3-1	L3-2	L3-3	L3-4	L3-5						
	Reading	6.9	11.3	12.0	11.1	11.3						
Wall L4	Test Point	L4-1	L4-2	L4-3								
	Reading	8.7	7.5	8.3								

The full reports of Infrared Thermography Inspection and Protimeter Moisture Test on external and internal walls of the Chapel of the Béthanie made by Reachable Engineering Consultants Ltd. have been incorporated in Annex A for reference.

3.3 Investigation by Visual Inspection

Visual inspections have been carried out on 13-14 July and 14 September 2016 to record defects observed at the Chapel of the Béthanie. Inspections cover the both the interior and exterior of the Chapel, including the attic area above the vault.

Generally, vegetation is commonly found at the exterior of the Chapel, mainly at the roof parapets and flying buttresses. Cracks and spalling are recorded at localized areas. Water stains concentrated at the two sides of the flying buttresses and the edges of windows. Obvious cracks are observed along the roof of the Corridor, which is believed to be the cause of various water stains in the interior. Extensive flaking of plaster with a few spots of spalling are recorded at the attic area. The interior of the Chapel is recorded with various defects including water stains, rusting of windows, minor cracks on columns and walls, and some flaking and popping of plaster, which altogether suggest water seepage is happening here and there within the Chapel.

The defects identified have been numbered and set out in table format for easy reference. Descriptions of defects with estimated extent, possible causes and recommendations to refer to are all summarized in the table. Note that the cause of defect usually is a combination of few factors rather than just one.

The defects are shown according to the following order:

1. Exterior (EXT)
   - 1.1 West Elevation
   - 1.2 East Elevation
2. Ceiling Slab (CEI)
   - 2.1 West Side
   - 2.2 East Side
3. Interior (INT)
   - 3.1 West Elevation
   - 3.2 East Elevation
   - 3.3 Corridor

Defects identified have been categorized into 8 types (see below). Each defect has its own numbering, showing its location and type of defect, and provide cross-referencing with the defect mapping plans. For example EXT-W-VE1, means it is the first vegetation (VE) defect found on the West Elevation (W) of the Exterior (EXT) of the Chapel.

Types of Defects	**Abbreviation**
Crack	CR
Damage	DA
Discoloration	DS

Flaking	FL
Rusting	RU
Spalling	SP
Vegetation	VE
Water Stain	WS

The tables summarizing all identified defects with mapping plans have been incorporated in Annex B for reference.

3.4 Concise Summary of Major Causes of Defects

Building fabrics deteriorate with the course of time, thus regular maintenance and long-term maintenance are always needed. Unfortunately, in the case of Béthanie, it is **more than a maintenance issue,** but involve **careful and delicate design input.**

3.4.1 The Major Causes of Defects

As described in the earlier sections, the presence of moisture in the built fabrics is the issue that has to be tackled. The seepage of water into the interior and absorption of moisture by the built fabrics can be summed up in the following four causes:

- Aging of water-proofing membrane
- Serious concrete spalling on the underside of concrete pitched roof
- Level of roof gutter is lower than the drain points on the pitched roof
- Lack of maintenance of the pitched roof
- Failure of the design of stained glass window frames for the egress of water

a. Aging of Water-Proofing Membrane

The existing water-proofing membrane has aged and debonded from the concrete pitched roof. It has also cracked. Thus it failed to act as an effective guard to prevent water from enter into the building. Moreover, the membrane was applied more than ten years ago and its warranty has expired.

b. Serious Spalling on the Underside of Concrete Pitched Roof

The concrete pitched roof had spalled seriously in the past and had been repaired in patches for a few times already. As seen on site during summer 2016, the soffit of the roof was repaired again by the removal of spalled concrete and cement touch-up. However, the structural integrity of the pitched roof slab might have degraded through the years, its structural capacity might not fulfill the current codes. Only a pitched roof with sound concrete can provide a good water barrier to protect the heritage building.

c. Level of Roof Gutter

The level of roof gutter is lower than drain points on the pitched roof. Rain water cannot leave the roof until it reaches the drain points. When it is not evaporated by sun it will continue to accumulate and stay on the roof. Such lengthened duration of the pool of water will seek any possible cracks or voids in the concrete and eventually enter into the interior. This is a design issue of the building services system of the historic building and requires a comprehensive design to improve the performance of the drainage system.

d. Lack of Maintenance of the Pitched Roof

The pitched roof is inaccessible, there is no safe access for maintenance works.

e. Failure of the Design of Stained Glass Window Frames

The stained glass of the Chapel is covered by another layer of glass for protection. However this additional layer has no weep hole for the egress of water that has been trapped between the two layers of glass. The water continues to pool and corrode the window frame resulting in flaking of the frames. Continuous corrosion of the frame results in deformation and may exert danger to users. The issue could not be solved without a revised window frame design. As it is related to the stained glass, it is truly a work that requires skilled labour to carry out.

Please refer to the corresponding sections in Chapter 4 for the necessary repair works for the five issues discussed above.

3.4.2 Holistic Restoration Approach

To sum up **a holistic restoration approach** should be sought that does not only require regular maintenance of the precious and heritage built fabrics such as the renewal of the water-proofing system, but also imminent upgrading of the design of the building services systems such as the drainage system. To facilitate maintenance in the long-run, the pitched roof has to be accessible and it could be entertained by the incorporation of the fall-arrest system on the roof.

These maintenance works and building services' upgrading works should not be carried out separately but in an integrated manner. For example, without re-design and modification of the level of the roof gutter, a renewed water-proofing membrane is deemed ineffective as rain water will continue to accumulate until it reaches the drain points. Fall-arrest system to the inaccessible pitched roof is also needed to allow regular maintenance of the roof as well as rectification of new defects found on the roof. As the fall-arrest system will be fixed onto the concrete pitched roof and involves structural modification of the pitched roof, it should be installed first before the renewal of the water-proofing membrane.

On top of the above, the restoration works have to be well-designed by professionals including but not limited to Architect, Building Services Engineer, Structural Engineer, Heritage Consultant etc. Such works when involving the built heritage fabrics have to be carried out by skilled and experienced craftsman and workers that have sound experience on related works.

Chapter 4

Defects Rectification Proposal

4.1 Description

This Defects Rectification Proposal could be read in two parts. Part 1 refers to Section 4.2 to Section 4.4, in which suggestions and recommendations will be provided according to three major materials identified in the Chapel, including (1) plaster with brick substrate,(2) concrete, and (3) metal window frame. These sections will cover the cause(s) of identified defects, suggest remedial methods and/or recommend further test, investigation or documentation to be carried out in future.

Part 2 refers to Section 4.5, in which proposed remedial measures to cure the root cause of most of the defects, i.e. water seepage, will be suggested to prevent further damages to the building fabrics in a long run. Recommendations on new works/ installations to facilitate **long-term maintenance** of the Chapel will also be included. The last Section 4.6 will suggest general maintenance works to be carried out for the preventing further deterioration of the Chapel.

4.2 Remedial Proposal for Plaster with Brick Substrate

Type of defects relating to plaster and brick include the following:

4.2.1 Cracks
4.2.2 Water Stains
4.2.3 Flaking of Plaster
4.2.4 Vegetation
4.2.5 Damage
4.2.6 Others

4.2.1 Cracks

Cracks identified could be generally categorized into four types:
- Hairline cracks on internal columns
- Hairline cracks on internal walls
- Hairline cracks on external facade
- Minor cracks on external buttresses

4.2.1(a) Recommendations for – hairline cracks on internal columns:

The hairline cracks appeared on internal columns are found in random directions indicating that structural concern is unlikely. From information provided by APA, repairing works to 4 columns have once been carried out in 2015 and new cracks appeared to one of the repaired column in the summer of 2016. By studying the photo records of repairing work of columns done earlier in 2013 and also in 2015, the columns have been repaired in patches piece by piece. Different mixes of plaster applied in different stages might cause different expansion resulting in cracks. Due to insufficient documentation of past repairing works, this possibility is to be further investigated.

To repair the hairline cracks on columns, it is suggested that cracks to be widened and deepened to provide a key for repairing. Pure lime plaster, i.e. lime putty with well graded sand (around 1 part slaked lime : 1.5~2part sand or 1 part quicklime :3 part sand), could be used to fill up the cracks. Yet the said repairing work is only for cosmetic purpose. In a long run, investigation on the plaster composition shall be carried out to confirm whether the presence of various mix of plasters is the cause of repetitive cracking. Percussion test and open-up investigation would help to confirm whether various mix of plasters is present. It is suggested to start the open-up investigation along the previous cracks of the 4 columns (according to the Completion Report submitted by Milestone Builder Engineer Limited in 2015), each with no more than 5 openings in reference to the photo records and percussion. The open-

up investigation of 4 columns plus percussion test of the rest shall be sufficient to provide a clearer picture.

If the presence of various mix of plasters is confirmed to be the cause of defects, complete removal of the later-applied repair plaster patches and re-rendering of the column with a plaster mix compatible with the original lime plaster will be the only solution to get rid of the reoccurrence of hairline cracking. Normally pure lime plaster in a ratio of 1 part slaked lime : 1.5~2part sand or 1 part quicklime : 3 part sand would be an acceptable mix. Yet it is still a decision of the contractor depending on the materials used and the actual site situation.

It is also suggested that full documentation of repairing works should be carried out in future to serve as reference. Information to be documented should include: condition survey of defects, open-up condition (if applicable), weather condition when works being carried out (temperature, moisture content), materials used, proportion of mix, thickness of coats, detailed description of the working procedure, curing time for each coat, initial observation after application, and so on.

Since open up investigation is considered as a kind of destructive test, such work should be carried out after obtaining consent from the Executive Secretary.

4.2.1(b) Recommendations for – hairline cracks on internal walls:

The internal walls of the Chapel are generally considered to be damp from the tactile impression. Moisture is a major factor which makes plaster instable and reactive to any slight thermal expansion or movement in building. It is also noticed that some cracks appear at the intersection of different materials, which is sometimes unavoidable due to the differential thermal expansion between materials. For example a crack appears underneath a window frame where a timber board cover is added (refers INT-W-CR12). Such defect is considered to be insignificant it is recommended that no actions shall be taken unless for cosmetic purpose.

Re-cracking of plaster (refersINT-C-CR6, INT-C-CR7) may need further open-up inspection to check whether such crack is induced by the crack in substrate or by some embedded installations such as conduits.

Before any repair work is carried out the source of damage, the water seepage from the roof and windows, has to be fixed (Please refer Section 4.4 &4.5 for further recommendations). Any cosmetic repair done without eliminating the source of damage will result in future reoccurrenceof the same damage. When the seepage problem is fixed, re-plaster hairline cracks with limewash.

4.2.1(c) Recommendations for –hairline cracks on external facade:

Few hairline cracks are noticed on the external façade of the Chapel, which could be a result of slight thermal expansion or movement. Such defects do not impose immediate harm to the building, yet further expansion shall be avoided to minimize the chance of water seepage.

Various types/mixes of stucco are presented on the external façade suggesting that the façade have been repaired by stages and synthetic materials have been used. It is also considered that the structured render could be a later addition.

To fill up minor cracks, repainting of the stucco is recommended. Historically whitewashing is suitable to fill up minor cracks on stucco. Yet the most important factor to consider when repainting a previously painted surface is that whether the new paint is compatible with any coating that are already applied on the surface. The paint used currently could be emulsion paint and it is suggested to continue to use it for repairing.

Again, it is important to document all details of the repairing works in future, which could help tracking the extent of previous work, what materials have been used and whether they are compatible to be continued to use in future. Such information could also help consultants to analyze cause of defects and the necessity to remove works done previously.

4.2.1(d) Recommendations for–minor cracks on external buttresses:

Minor cracks at external buttresses appear at the bond line between new and old stucco (refers EXT-W-CR3. EXT-E-CR5). Generally, stucco of a harder mix will not be physically compatible with a softer mix as the differing expansion and contraction rates of different materials would normally cause stucco to crack.

It is also noticed that these buttresses interface with later-added concrete slab and water pipes where water are retained/not drained away effectively. Moisture at these locations is forced to evaporate through the weak/cracked spot and therefore water stain and organic growth appear along the cracks.

The cracks at external buttresses, although visually obvious, do not impose danger at this moment. Removal of the incompatible plaster and re-plaster with a compatible stucco mix could be carried out after the drainage problem is solved. To avoid future cracking along the bond line, analyze on the composition of the original mix shall be carried out.

4.2.2 Water Stains

Water stains identified could be generally categorized into four types:

- Plaster popping and flaking of internal walls
- Yellow water stains on internal walls and vault
- Black water stains on flying buttresses
- Suspected water leakage at low level of internal walls

4.2.2(a) Recommendations for –plaster popping and flaking of internal walls:

Plaster surface popping and flaking is found at localized areas of internal walls(refersINT-W-WS12, INT-E-WS3, INT-E-WS9). Plaster surface popping is caused by the presence of unslaked lime in the plaster mix. Small particles of unslaked lime absorb moisture from the air which slowly continues to slake after plaster have been applied and expand. The resulting expansion causes the plaster to "blow" leaving small conical holes in the plaster surface. The popping could happen in 1 to 2 years after the application, or even longer, depending on the moisture content. Since plaster popping appears only at localized areas, it is believed that plaster with unslaked lime came from previous re-plaster work.

Some plaster surface is observed to be powdery is a result of salt subflorescence and efflorescence. Sometimes soluble salts may be inherent in the plaster mix due to contamination of constituents, for example, by sea sand. With penetration of water to walls, the salts are dissolved and transported in the pores of the bricks, mortar and plaster. Towards the surface of the plaster the water evaporates and the salt crystallizes. Salt crystals forming within the pores of the material cause disruption of the plaster and result in powdering or crumbling. Efflorescence, salt crystals forming on the surface are less destructive but may result in powdering or flaking paint. Such powdery plaster shall be removed until all signs of damp or salt are clear.

It is also noticed that synthetic paint finishes are present from earlier maintenance works resulting in poor evaporation. Subsequent paint finishes were added causing problems with adhesion and permeability. It is recommended to remove such layers during further repair works.

Note that the root cause of plaster surface popping, flaking or powdering is the presence of moisture. Water seepage problem from the roofs or from the windows must be solved or any repairing would only be temporary dress up. Once the water seepage problem is cured, the walls could be re-plaster with a use of pure lime putty plaster and paint with limewash.

It is also suggested that the contractor should carefully examine the quality of materials used for the plaster prior to use in the future. Warranty to rectify defects caused by inferior materials used shall form part of a contract if considered necessary.

4.2.2(b) Recommendations for – yellow water stains on internal walls and vault:

Water stains are mostly found on the internal walls at the Corridor and also on localized areas around the windows. Obvious cracks are found along the concrete roof of the Corridor which is the prime cause of water seepage. To cure this problem, repairing of concrete roof and the waterproofing membrane must be carried out (Please refer to Section 4.4 for further recommendations).

Some water stains appear with bubbling, is a result of presence of synthetic materials in the paint which is impermeable and elastic in nature, causing moisture to be trapped underneath the paint layer (refers INT-W-WS5, INT-W-WS10, INT-E-WS2, INT-C-WS6).Such paint is not the cause of defect, yet it is still recommendable to remove impermeable paint in future maintenance work and replace with pure limewash (i.e. limewash without any synthetic materials) in order to maintain a breathable nature and a consistency of materials for all the interior plaster.

Rusting is observed at window frames of Chapel, suggesting that spaces exist around the edges of window frames where water seeped through. Rainwater even poured in from three of the window as recorded in mid-October 2016. The water tightness of windows must be improved to keep away rainwater. The rusting and water seepage problems implied a failure of water tightness of the window frames. It is recommended that these window frames to be reconstructed with effective diversion of rainwater (Please refer to Section 4.2. for further recommendations).

One water stain is spotted at the vault of the Chapel (refers INT-E-WS7), which might be a result of water leakage from the concrete pitched roof above. Infrared thermography survey suggests that abnormal moisture was found only at this particular area but not the other parts of the vault, indicating that such leakage is localized. Open-up investigation helps to confirm whether a crack is present at this particular location and whether repairing work to the substrate is necessary. But the most important thing to do is to resolve the leakage problem of the roof (Please refer to Section 4.4 for further recommendations).

4.2.2(c) Recommendations for – black water stains on flying buttresses:

Black and vertical water stains are found on the external flying buttresses or along areas where the external walls adjoining the flying buttresses (refers EXT-W-WS1). These black stains are formed due to the running rainwater at these locations over a long period of time plus a lack of periodic maintenance.

To remove such water stains, a low-pressure water jet, supplemented by scrubbing with soft bristle brushes and possibly non-ionic detergent is suggested. Acidic solvent shall be avoided as it may dissolve lime-based stucco. Any proprietary cleansing solvent or poultice could only be used with careful testing. Rinse the stucco surfaces completely with water after application of any kind of cleansing solvent.

4.2.2(d) Recommendations for –suspected water leakage at low level of internal walls:

Water stains are found at low level of localized areas of the Chapel (refers INT-W-WS9, INT-E-WS4) but not serious. To ascertain the cause of such defect shall subject to open-up investigation at a later stage. The walls where stains are found are later-added timber board covers which are not originally building fabric. In future, open-up investigation is suggested to confirm whether there is leakage from the windows which have been partially covered up in the interior by timber boards that contain water stains.

4.2.3 Flaking of Plaster

4.2.3(a) Recommendations for –flaking of plaster (due to workmanship):

Flaking of plaster due to workmanship is rarely found in the Chapel (refers INT-W-FL1). It could be a result of insufficient thickness of finish plaster which leads to uneven suction. Or the paint layer was applied on a contaminated (i.e. dirt and grease) layer.

Since such defect is insignificant, repairing could be carried out at once during general maintenance of the interior plaster works. It is still recommended to use pure limewash in order to maintain a breathable nature and a consistency of materials for all the interior plaster.

4.2.4 Vegetation

4.2.4(a) Recommendations for –vegetation:

Vegetation mainly appears at the roof parapet and flying buttresses on the west elevation (refers EXT-W-VE1, EXT-E-VE1). The west elevation has been surrounded by other plantations and receives less direct sunshine. It provides a more satisfactory environment for the vegetation to grow. Vegetation normally appears at fissures at mortar joints or area of detached render, where moisture is trapped and mortars contain mineral salts that support their growth.

To remove vegetation, it is suggested that all the roots and tendrils are removed thoroughly and carefully without damaging the brick substrate. Fissures found at those vegetation locations shall be filled to prevent future penetration of vegetation. Removal of existing plants may also remove part of the mortar from the joint. Such joints shall be re-pointed after cleaning the joints from the broken mortar. Periodic checking is necessary to fill up fissures and to remove any appearing vegetation already in an early stage.

Removal of vegetation and periodic maintenance shall be considered together with the drainage issue of the roof and the introduction of a fall arrest system (Please refer Section 4.4 for further recommendations).

4.2.5 Damage

4.2.5(a) Recommendations for –damage:

Damage of plaster is noticed at low level of wall or column (INT-W-DA1, INT-E-DA1). They appear to be minor issue, which was probably created by physical crash of hard object. Such defects could be avoided by site management, for example, by the provision of proper protection to building fabrics when trolley or movable platform is used.

Since such defect is insignificant, repairing could be carried out at once during general maintenance of the interior plaster works. Pure lime plaster and paint with limewash is recommended for repairing.

4.2.6 Others

Apart from the defects mentioned in Section 4.2.1 to 4.2.5, it was observed that the stuccos of the external façade and the paint of the internal walls have been repaired or repainted many times that it is hard to ascertain the mix of plasters and paints used originally. For the sake of conservation of the Chapel and possibly the other parts of the building, it is recommended to carry out plaster analysis on the exterior stuccos, and paint analysis on the internal walls.

For the exterior stuccos, an investigation of the plaster layer (s) could verify whether earlier plaster layers are still present underneath the existing plaster surface. A detailed investigation of the plaster could give valuable information about the chronology of later plaster applications and identification of the original plaster mix which was first applied on the external façade. The investigation provides the basis for future plaster analysis when choosing the mix of plaster for repair/replastering. The plaster investigation is to be carried out in-situ. Several facade areas are investigated by making small openings (10-20mm is necessary due to the big aggregate in the plaster). These openings should be done in areas shielded from weathering where intact and less deteriorated plaster can be expected. In case an original (early) facade plaster can be found, 1-2 openings of minimum 100x100mm is suggested to study the revealed layer.
Plaster analysis, i.e. laboratory test of cement(if any):lime:aggregates distribution, could be the second step. Such analysis could ensure similar plaster mix and grains are chosen for the repair materials.

For the internal walls, the existing color scheme of the decorative mouldings does not seem to be original according to our site observation and comparison with historic photos. Paint finish investigation could be carried out to find out the design, type and color of paint used originally. It could also verify whether inappropriate paint layer(s) has/have once been applied and help deciding whether such layer shall be removed. This investigation is to be carried out on site by opening up representative locations in decorative mouldings by scraping the paint layer with a sharp knife (scalpel). The number of sampled areas has to be determined by detailed study of different decorative mouldings present. But since most of the decorative mouldings are repetitive throughout the Chapel, the sampled areas shall basically cover areas as shown in Fig. 1 &2. Small openings of 10-15mm will be required, with 2-3

locations which a larger opening (maybe 40x 100mm) is needed to investigate the color, paint application technique, covering power and color tone of the original paint finish in order to match a tone for restoration.

Since open up investigation is considered as a kind of destructive test, such work should be carried out after obtaining consent from the Antiquities Authority.

Fig. 1&2 Sampling locations suggested by the Architectural Conservation Laboratory (ACLab), the University of Hong Kong

4.3 Remedial Proposal for Concrete

Type of defects relating to concrete include the following:

a. Cracks
b. Spalling

4.3.1 Cracks

Cracks identified could be generally categorized into three types:

- Hairline cracks
- Serious cracks on roof of the Corridor
- Cracks at the interface of concrete pitched roof and partition walls

4.3.1(a) Recommendations for –Hairline cracks:

The hairline cracks are found near vent holes on the exterior walls and soffit of roof slab that structural concern is unlikely. For the cracks near the vent holes, which are very minor, are believed to be a result of thermal expansion between different materials. And for cracks under the soffit of roof slab, they are believed to be caused by shrinkage of concrete during curing and poor workmanship.

For hairline cracks near the vent holes, as no water seepage is observed through the cracks, it is recommended that such cracks should be made good during general maintenance of the rendering on the exterior walls.

For shrinkage of concrete under the soffit of roof slab, it is recommended that no actions have to be taken, unless for cosmetic reason. If cosmetic repairing is considered necessary, application of lime wash would suffice. However regular inspection of these hairline cracks should be carried out to check whether such cracks have further developed and/or adversely affected by other defects e.g. concrete spalling at areas nearby.

Failure of past concrete repair is usually found under the soffit of roof slab. The defects are caused by inappropriate use of plaster plus poor workmanship. Such defects could be avoided by close monitoring of site works, for example, to check if the plaster is evenly applied onto the walls. Since such defects are insignificant, repairing could be carried out during general maintenance. The whole plaster at identified locations should be hacked off to receive new plaster.

4.3.1(b) Recommendations for –Serious cracks on roof of the Corridor:

Serious cracks are found on the roof of the Corridor. They are believed to be a result of past installation of lighting system and direct exposure to sun.

The cracks on the exterior roof, although visually obvious, do not seem to impose danger at this moment. Instead of cosmetic repair, such cracks should be made good to avoid water ingress, either by injection of epoxy(a temporary measure) or by open-up of the roof to carry out concrete repair. The latter is recommended as it does not only repair the cracks but and also provides the window to investigate if the substrate is sound. Stains of rust found nearby the fixing of roof lighting fixtures implies the presence of moisture that might have damaged the reinforcement bars of the roof slab.

Despite the fact that such cracks on the concrete has been repaired by the application of cement, it should note that such repair is made without thorough checking of the concrete of roof, the condition of reinforcement and renewing of the existing waterproofing membrane. It should only be treated as a temporary measure(Please refer Section 4.5 for further recommendations).

4.3.1(c) Recommendations for –Cracks in between pitched roof and partition walls:

Cracks at the interface of concrete pitched roof and partition walls are mainly created by poor workmanship material shrinkage. They are minor defects and could be repaired during general maintenance.

4.3.2 Spalling

4.3.2(a) Recommendations for –spalling:

Spalling of concrete are found in both the exterior and the interior, mainly due to the corrosion of reinforcement bar. Damaged or defective concrete has to be completely hacked off till sound substrate is exposed. Rust found on the reinforcement bars have to be removed. A new reinforcement bar has to be added and tied to existing bars when the removed portion has seriously impaired the integrity of the system. Subsequently loosened debris and dust should then be removed to allow adequate bonding with new cement patches. Anti-rust primer should be applied on the exposed reinforcement prior to the application of new cement mortar to prevent future rusting. Finally cement mortar should be applied to provide a sound cover to the reinforcement.

4.4 Remedial Proposal for Window Frame

4.4.1 Rusting

4.4.1(a) Recommendations for – rusting:

Rusting of metal window frames is commonly found on the windows of the Chapel. It is brought about by the deterioration of paint i.e. the loss of the protection to metal thus result in oxidation. Serious deformation of the metal frames of a few windows is also found. In addition water has also managed to enter the interior through three of the windows during heavy rain, or by means of condensation i.e. water moisture form water droplets on the stained glass which is cooler than the external air.

Such window frames and windows were added on the exterior to provide a protective barrier to the stained glass. Besides routine maintenance of their painting system to prevent rusting from occurring, and replacement of loss putty for the holding of window panels, redesign of such enclosure should be seriously considered as the current design does not allow water that has entered the space between the two window planes from being drained away. It is hardly possible to prevent moisture from entering the space between the two glass planes, not even with the use of triple glazing, due to the porous nature of stucco and old structure, thus allowing the in/out of moisture is the most effective solution.

In short all the window frames should be replaced by a newly designed system that allows the evaporation of moisture (by means of tiny vent holes at the top) and drainage of water (by means of a fall at the window base and drain holes at the bottom).

4.5 Remedial Proposal on Roof

4.5.1 Water-ingress

4.5.1(a) Recommendations for – water-ingress:

Water-ingress is suspected at large areas on the pitched roof, certain localized areas right below the roof as well as inside the Chapel, as demonstrated by the results of infra-red scanning and presence of stains and efflorescence. Unfortunately neither results by visual inspection nor can infra-red scanning inform the exact location and extent of all the cracks or weak areas of the building precisely. The ultimate solution is the enhancement of the water tightness properties of the roof by the application of waterproofing membrane on the outer surface of the concrete roof, as the first and most efficient barrier to rain.

The waterproofing membrane to be used on the concrete pitched roof of the Béthanie can be sheet based or liquid applied. It should possess high UV stability as it is not covered by a solid and opaque finishes but paint. The membrane should have at least a ten-year warranty.

Prior to the application of the waterproofing membrane, the existing waterproofing membrane and alienated materials on the concrete surface should be removed to guarantee a good bonding between the concrete surface and the membrane.

4.5.2 Drainage of Rain Water

4.5.2 (a) Recommendations for Roof Drainage Design

The pitched roof

The existing gradient of the pitched roof can allow efficient runoff of rainwater. To complete the entire rain water drainage system of the roof, the gutters along the edge of the roof should be so designed that its fall can channel away the water collected smoothly. Moreover the drain points to which water is channeled must be of a decent size. They must be strategically located and should be adequate in quantity.

The gutters and drain points

It is noted on site that there are only three numbers of drain points at the edge of the pitched roof that are covered by vertical grating to avoid blockage. However they are constructed at a higher level than the gutter meaning water will be accumulated until reaching the drain point and be drained away.

Vegetation

The presence of vegetation along the gutter is a solid evidence of the presence of water that facilitates the growth of plant. The roots of plants have found their way into cracks or weak points of the host structure thus damage the host structure further. Their early removal, with the help of a proper fall-arrest system, to provide a safe access, is necessary followed by repair and make-good of the gutters. However the ultimate issue is an efficient drainage system that can drain away rain water smoothly.

Drain pipes Connecting the Drain Points on the Roof

The existing drain pipes to which the drain points on the pitched roof are connected are believed to have routed to the interior and concealed. It has rendered the maintenance of the drainage pipes and inspection of their condition impossible. In the future repair and maintenance exercise, a survey should be carried out to record the as-built levels and routing of such pipes. If possible they should be exposed or provided with access panels for easy inspection and maintenance.

4.5.3 Roof Lighting

Lighting fixtures have been installed on the concrete roof with exposed conduits to highlight the architectural features on roof. They are necessary to enhance the architectural value of the building.

It is recommended that in future repair works, the existing lighting should be strategically located so the fixtures and conduits thereof would not be visible to visitors on the ground level. It is also hoped that the conduits to be installed on the roof can be minimized to reduce the mechanical fixings used on the roof, so to avoid rust, cracks and spalling on concrete.

4.5.4 Maintenance

It is noted that currently there are steps constructed on the concrete pitched roof probably for the maintenance of the pitched poof. To facilitate the future repair and maintenance works, it is recommended that a proper fall-arrest system is to be constructed in parallel to the ridgeand on both sides of the pitched-roof for the use of future workers on the roof.

It is necessary to investigate if the roof can support the loading requirement of a fall-arrest system. If not, localized strengthening of the concrete roof structure and the structural capacity of the Chapel should be carried out.

4.5.5 Future Repair to the Roof

Should repair works to the roof are to be carried out, the following sequence of works and steps should be followed:

1. Conduct open-up of the concrete roof to investigate its structural capacity by detailed assessment of the existing condition of the structural reinforcement
2. Investigate if the roof can cater for the weight of the new waterproofing system, external paint and fulfill the loading requirement of a new fall-arrest system
3. Redesign the roof drainage system that involves the fall of gutters, location and quantity of roof drain points, routing of water drainage pipes etc.
4. Remove existing water-roofing membrane and alienated materials
5. Repair any spalling found at the concrete surface
6. Carry out localized concrete strengthening works and install the fall-arrest system
7. Replace lighting fixtures and the conduits thereof on roof if necessary
8. Make good of the concrete surface
9. Apply the new UV resistance waterproofing membrane
10. Finish the membrane with UV resistant PU paint

4.5.6 Stabilization of Decorative Features at Roof Level

The decorative features such as the pinnacles on roof are built with bricks and covered by rendering for a smooth appearance. Hammer tapping test should be carried out to record the areas that demand stabilization. Should defects are found at the decorative features, they should be stabilized by using mortar of similar properties of the original one. This is to guarantee that natural breathing of the bricks can be maintained so to sustain their lifespan. When necessary, stainless steel reinforcement should be embedded into these features to enhance their stability.

4.6 Recommendations on General Maintenance

Apart from the repair works suggested in Section 4.1- Section 4.5, the following general maintenance duties are recommended to be carried out periodically to prevent deterioration of the historic fabrics in a long run. Yet most of these maintenance works could only be carried out with a provision of fall-arrest system.

1. Check daily temperature and maintain a relatively constant indoor and outdoor temperature for the Chapel in order to enhance the stability of interior plastering.
2. Check, record and repair leaks in the roofs, downpipes and drains to prevent water seepage at early stage.
3. Check, record and repair broken/rusted windows and sealant to prevent water seepage at early stage.
4. Check gutters, downpipes and drains to keep away litter that might obstruct proper water drainage.
5. Check walls and roofs to keep away vegetation that might eventually create large cracks and thus water seepage.
6. Check, record and repair cracks at external stucco render to prevent further expansion and thus water seepage.

Chapter 5

Action Plan

To conclude the findings from the condition survey, water ingress is considered to be the major issue that threatens the conservation and integrity of the Chapel. Thus the most urgent matter is to deal with the water seepage problem from the two concrete roofs and the windows. The repairing of deteriorated or cracked plaster (both interior and exterior) could be carried out after when the water seepage problems are solved.

The waterproofing work of the concrete pitched roof shall be considered together with the installation of a fall-arrest system , as strengthening of roofs might be necessary to support the new installation, which is best to be carried out before applying a new waterproof membrane. Also the installation of fall-arrest system might create new openings/anchor points which shall take waterproofing into account. On the other hand, when considering a new waterproofing system for the concrete roof of the Corridor, it is important to investigate the possibility to relocate the light fixings to reduce the chance of water seepage in future.

To rectify the defects identified and to better preserve the authenticity of the Chapel, it is suggested to carry out the following works and investigations inpriority set out in the table. Priority “High” refers to investigations/works that might affect building’s integrity or structural stability and should be dealt with as soon as funds available. “Medium” refers to investigations/works that are also important to maintain the overall integrity of the building but not as urgent as those investigations/works ranked as high. Yet it is still recommended these works to be carried out at the earliest possible. “Low” refers to investigations/works with least urgency and could be carried out during general maintenance.

Investigations		
Task		**Priority**
1(a)	Study the structural capacity of the pitched concrete roof for the installation of a new waterproofing system and a fall arrest system	High
1(b)	Study the possibility to relocate the light fixings on the concrete roof of the Corridor	High
1(c)	Plaster investigation on the exterior stucco	Medium
1(d)	Paint investigation on the interior plaster	Medium

Works		
Task		**Priority**
2(a)	Install a fall arrest system	High
2(b)	Remove the existing waterproofing membrane of the two concrete roofs; repair defects and reinstall a new membrane; relocate the light fixings on the concrete roof of the Corridor if practical	High
2(c)	Redesign and relocate the gutters and drain points	High
2(d)	Redesign and replace the rusted window frames	High
2(e)	Check and stabilize pinnacles on roof	Medium
2(f)	Remove vegetation and fill up cracks and fissures	Medium
2(g)	Repair concrete with spalling and cracks at the ceiling slabs	Medium
2(h)	Repair cracks at exterior stucco render	Medium
2(i)	Repair internal render/plaster with cracks, stains, popping, flaking, or damage	Low

It is also suggested to carry out the following periodic maintenance to identify issues in early stages and to prevent further deterioration of the Chapel. Generally the works are recommended to be carried out twice a year: in March to ensure the building fabrics are secure for the typhoon season; and in September to identify major repairs to be carried out during the dry season.

Periodic Maintenance		
Task		**Schedule**
3(a)	Check temperature and maintain a relatively constant indoor and outdoor temperature	Daily
3(b)	Check, record and repair leaks in the roofs, downpipes and drains	Twice a year, preferably March and September
3(c)	Check, record and repair broken/rusted windows and sealant	Twice a year, preferably March and September
3(d)	Check gutters, downpipes and drains to keep away litter	Twice a year, preferably March and September
3(e)	Check walls and roofs to keep away vegetation	Twice a year, preferably March and September
3(f)	Check, record and repair cracks at external stucco render	Twice a year, preferably March and September

Annex A

Infrared Thermography & Protimeter Survey Reports

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REPORT OF

INFRA-RED THERMOGRAPHY INSPECTION AT THE EXTERNAL WALL INVESTIGATION OF

BETHANIE
NO. 139, POK FU LAM ROAD, HONG KONG

Location	:	**Bethanie** **No. 139 Pok Fu Lam Road, Hong Kong**
Survey Dates	:	**14th July & 20th August, 2016**
Report Date	:	**13th September, 2016**
Report Ref. No.	:	**I16-038**
Client	:	**Substance Lab Limited**

REPORT PREPARED BY

REACHABLE ENGINEERING CONSULTANTS LTD.
CERTIFIED INFRARED THERMOGRAPHER LEVEL II
NO.2011MY29N010
(INFRARED TRAINING CENTRE – SWEDEN)

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Appendix A Summary of Findings

Appendix B IR Images Findings

Appendix C Site Photos at the Pitch Roof

1. INTRODUCTION

We were commissioned to carry out Infra-red Thermography Inspection at the external wall of Bethanie, No. 139 Pok Fu Lam Road, Hong Kong using Infrared Technology to investigate the potential delamination of the external wall.

2. KEY PERSONNEL AND EQUIPMENT USED

Operation Team	Ms. Tsoi Lai Yin and Mr. Chung Sheung Chi
Equipment Used	Thermography System: TP8s Series (8-14μm wavelength, 0.08°C at 30°C Sensitivity) Wind Speed Measuring Device: Lutron AM-4202 Humidity Measuring Device: Chino HN-CHNR Temperature Measuring Device: UNI_T UT325 Digital Camera

3. SURVEY METHODOLOGY

Every object above absolute zero emits Infra-red energy. Thermograph is a process by which differences in the heat can be converted into a thermal image by application of the use of specialized scanning cameras.

Under certain ambient condition, buildings with surface defects in the form of debonding render, mosaic tile or delaminating concrete emit differing amounts of infra-red radiation. When the surface is heating up by the sun or environment, areas that are defective will show up as a result of their differential transmittance of infra-red radiation, it indicates that there anomalies inside behind the surface finishes. Further attention is recommended.

ASTM D4788 which provides guidelines on Testing Bridge Deck Delamination using Infra-red Thermography is used as reference as far as possible.

The methodology is reference to HKCI:TM1, Detection of Building Surface Defect by Infrared Thermography.

Interim Technical Guidelines on The Inspection, Assessment and Repair or Buildings for the Building Safety Inspection Scheme (BSIS), published by Buildings Department was used as our guidelines, where applicable.

Potential defect is identified according to its size, shape, temperature difference, materials, visible characteristics, colour, etc.. Four-tier system termed 'normal debonding (delamination)', 'serious debonding', 'unidentified source' and 'possible defect under visual inspection' is used to indicate severity of defects found and they are stated as Type 'I' , 'II', 'U' and 'V' respectively.

Recommendation on different types of possible defects is suggested as below:

Index	Defect Type	Recommendation
I	Possible Normal Debonding/Delamination	Should carry out general repair or perform regularly monitoring and checking
II	Possible Serious/Major Debonding	Should carry out immediate repair or precaution work
U	1. Structural difference 2. Colour/material difference/stain 3. Reflection 4. Unevenly distributed sunlight 5. Other heat sources 6. Unidentified temperature difference	Further verification by other methods or should perform regular monitoring and checking
W	1. Suspected water stain/seepage	Further verification by other methods or should perform water proofing reinstatement
V	1. Possible defect found under visual inspection at where Infrared Thermography Inspection is inappropriate to be carried out 2. Hand-reach Tapping	Further verification by other methods or should perform general repair/ Regular monitoring and checking

Results of other test methods could be read in conjunction with the findings of this report. Some inevitable site constraints might have affected the survey result, e.g.

scaffolding, too high project or side angle, shadows of other buildings/structures and shadows of vegetation growth, screened objects, recess area which were casting on the elevations of the building. Notwithstanding these site constraints, we are satisfied with that our survey on the unaffected areas was sufficiently extensive as to enable us to formulate our conclusion on the general condition of the building.

4. SURVEY CONDITION, PROCEDURE AND LIMITATIONS

4.1 Survey condition

The survey conditions and procedure were in reference to ASTM D4788 and HKCI: TM1. The information of the atmospheric temperature, relative humidity and weather were retrieved from the weather record of Hong Kong Observatory and onsite record. The survey condition for Infrared Thermography Inspection was shown as below.

Date	*Temperature (°C)	*Relative Humidity (%)	#Weather
20 August 2016	26.9-32.1 (Hong Kong Park)	69-97	Sunny Period

* http://www.hko.gov.hk/wxinfo/dailywx/dailywx.shtml
# http://www.hko.gov.hk/wxinfo/rainfall/rf_record_uc.shtml

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Daily Extract of Meteorological Observations , August 2016

Year 2016 Month 8 Go

Day	Hong Kong Observatory							
	Mean Pressure (hPa)	Air Temperature			Mean Dew Point (deg. C)	Mean Relative Humidity (%)	Mean Amount of Cloud (%)	Total Rainfall (mm)
		Absolute Daily Max (deg. C)	Mean (deg. C)	Absolute Daily Min (deg. C)				
01	998.8	31.6	29.5	26.8	24.9	76	85	4.6
02	995.9	29.5	27.1	25.1	25.0	88	93	121.0
03	1006.3	27.8	26.8	26.1	25.5	93	86	17.3
04	1008.7	28.6	26.9	26.1	26.0	94	82	20.9
05	1008.3	32.3	29.3	27.0	26.0	83	58	Trace
06	1005.0	33.2	30.0	27.4	25.4	77	36	0.0
07	1002.8	33.4	30.4	28.2	26.4	80	61	0.0
08	1003.0	33.4	30.5	28.6	26.3	79	83	0.0
09	1001.8	32.7	29.2	26.1	26.1	83	83	33.5
10	1002.6	29.3	26.7	24.7	25.1	91	90	39.8
11	1003.2	29.9	27.2	25.2	24.8	87	85	42.1
12	1001.3	29.4	28.1	26.9	25.5	86	86	0.4
13	999.8	32.3	28.8	27.1	25.9	84	71	Trace
14	998.3	29.4	27.3	25.8	25.4	90	89	25.7
15	997.4	28.4	26.6	25.6	25.3	93	88	19.1
16	996.0	26.9	26.2	25.5	25.4	96	88	49.9
17	993.7	28.0	26.5	25.3	25.8	96	89	40.9
18	996.3	28.7	27.0	25.9	25.9	94	88	50.9
19	1003.0	31.3	28.2	26.5	26.4	90	84	10.5
20	1004.7	32.4	29.2	27.4	26.8	88	74	3.8

Back

Daily Extract of Meteorological Observations , July 2016

Year 2016 Month 7 Go

Day	Hong Kong Observatory								King's Park	Waglan Island^	
	Mean Pressure (hPa)	Air Temperature			Mean Dew Point (deg. C)	Mean Relative Humidity (%)	Mean Amount of Cloud (%)	Total Rainfall (mm)	Total Bright Sunshine (hours)	Prevailing Wind Direction (degrees)	Mean Wind Speed (km/h)
		Absolute Daily Max (deg. C)	Mean (deg. C)	Absolute Daily Min (deg. C)							
01	1008.9	33.0	30.1	27.7	26.0	79	78	3.4	5.3	190	21.9
02	1009.1	32.0	29.4	26.9	26.0	82	86	20.8	2.7	200#	21.9
03	1008.7	31.5	29.4	27.3	25.8	82	84	2.7	1.8	190	25.1
04	1006.6	33.0	30.1	28.0	25.9	78	83	3.8	6.8	180	33.0
05	1007.5	32.6	29.0	25.8	26.5	87	88	9.8	5.4	130	22.5
06	1008.4	28.8	27.3	24.7	26.0	93	88	33.6	0.5	130#	24.8#
07	1005.9	34.0	30.2	27.9	25.6	77	53	Trace	10.5	270#	11.3#
08	1001.0	34.2	31.0	28.1	25.9	75	46	0.0	10.4	280	23.5
09	999.0	35.6	31.5	26.4	26.4	75	57	10.3	10.0	280	25.0
10	1000.3	31.3	28.6	26.2	25.0	81	88	1.7	2.5	240	18.8
11	1002.2	31.1	28.9	26.1	26.1	85	89	11.7	2.4	240	19.8
12	1003.8	29.0	28.1	27.0	25.1	84	88	0.1	0.0	230	16.3
13	1005.0	31.7	28.6	25.6	26.1	87	82	35.2	2.2	160	12.6
14	1006.8	30.3	28.9	26.4	26.2	86	83	10.2	0.2	230	14.3
15	1007.0	33.0	30.2	28.6	26.4	81	78	1.0	6.2	230#	22.4#
16	1008.1	33.2	30.6	29.0	26.4	79	69	0.3	8.5	240	25.1
17	1008.5	33.2	30.6	29.0	26.2	78	69	0.0	9.2	230	23.7

Daily Extract of Meteorological Observations, July & August 2016
(Source from: www.hko.org.hk)

4.2 Survey Procedure

A. General

1. For thermography at the external wall, the work is suitable under fine weather, low wind speed (not higher than 6.5m/s) and continuous significant rainfall record in a week prior to this survey. (This is different to TM1 recommended as the client concerns if any water trapped behind the building finishes instead of finishes delamination).

B. On site test procedure

2. Select a suitable inspection locations outside the building such that there is no or minimum obstruction between the infrared camera and the external wall to be examined.

3. On-site verification of the thermography camera for surface temperature measurements compare the surface temperature readings recorded at selected at least 3 points at the surface to be inspected and the temperature recorded in thermograms for the same part of surface. If the temperature different is less than or equal to 2°C, the test can be carried out. Otherwise adjust and recalibrate the thermography camera.

4. Set and adjusted the infrared camera according to the purposes for its use. For example, the temperature range shall be set to cover the surface temperature being studied.

5. Set up and adjust the infrared camera to an optimal focus distance and view angle. To obtain an effective thermogram, the distance between the infrared camera and the target shall be less than 300m and the angle of inclination is less than 40°. Relocation of the infrared camera shall be made, if better thermography point is available.

C. Image Output and Secondary Processing

1. Process the image by provided Infrared Thermography Software.

2. Distinguish between temperature difference due to the peeling, water trapped and noise.
3. Identify the abnormality from the image and results of the supplement investigation.
4. Mark the result on the plans in Appendix A and the analysed Infrared Images were indicated in Appendix B.

4.3 Test Limitation

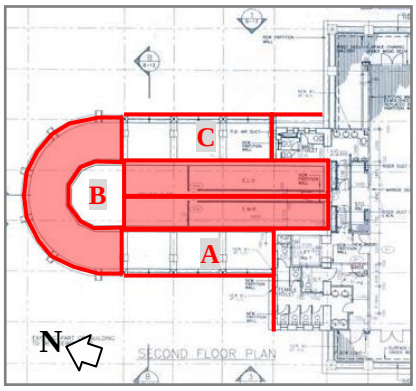
1. Survey should be carried out under sunny weather for external wall investigation.
2. Survey cannot be done at the face where is at the recess area or blocked/screened by any obstacles or their shadows, such as trees or adjacent buildings
3. Survey result will be affected if the survey undertaken in high inclination/ side angles (>40°) due to site constraints or the irregularity of the façade.
4. Survey result accuracy will be affected for those external walls where no direct sunlight can be reached due to the site constraints and the sun orientation or at the narrow area, such as fins areas.

5. POSSIBLE DEFECTS FINDINGS

Table 1: Summary of each IR Image Finding in Appendix B

6. SUMMARY AND CONCLUSION

According to the survey, there were **222** numbers of locations with abnormal temperature obtained under the Infrared Thermography Inspection. Please refer to Appendix A and Appendix B.



Location Plan

The result of the Infrared Thermography Inspection is summarized in the following table:

Elevation		Infra-red Scan No.	Suspected Defects Found					
			Type I	Type II	Type U	Type W	Type V	Total
A	NW	IR1-IR8	47	0	4	7	0	58
B	NW,NE	IR9-IR23	55	0	1	10	0	66
C	NE	IR24-IR34	60	0	2	36	0	98
Number of Overall Possible Defects			**162**	**0**	**7**	**53**	**0**	**222**

It should be noted that the survey cannot be done at the face where is at the recess or blocked/screened. And, the survey accuracy will be affected at where no direct sunlight reached or with high inclination/side angle or narrow/thin features such as A/C rack or window sills/fins/bay or irregularity of the materials due to the technology limitations.

During the Inspection, vegetation is noted all along the surface channel at the pitch roof of the chapel. Moreover, impaired and cracked waterproofing membrane on the

pitch roof are identified (Please refer to Appendix C). It definitely weakens the water proofing integrity of the roof.

Planned maintenance works should be arranged for the defect to restore the condition.

- END -

Appendix A
Summary of Findings

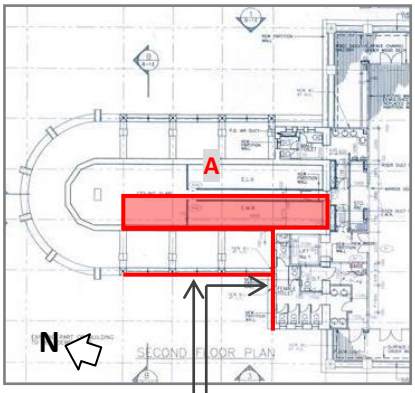
Summary of findings No. 1 (A1)

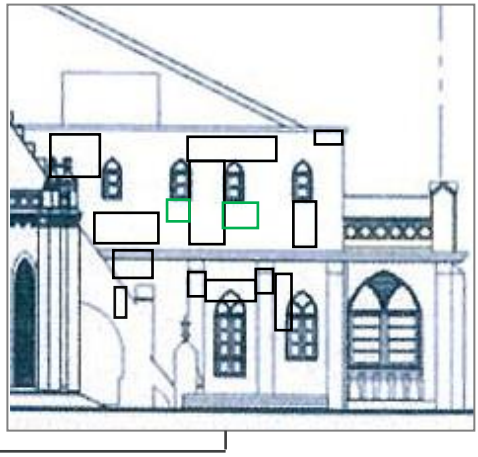
Face A- Northwest Elevation

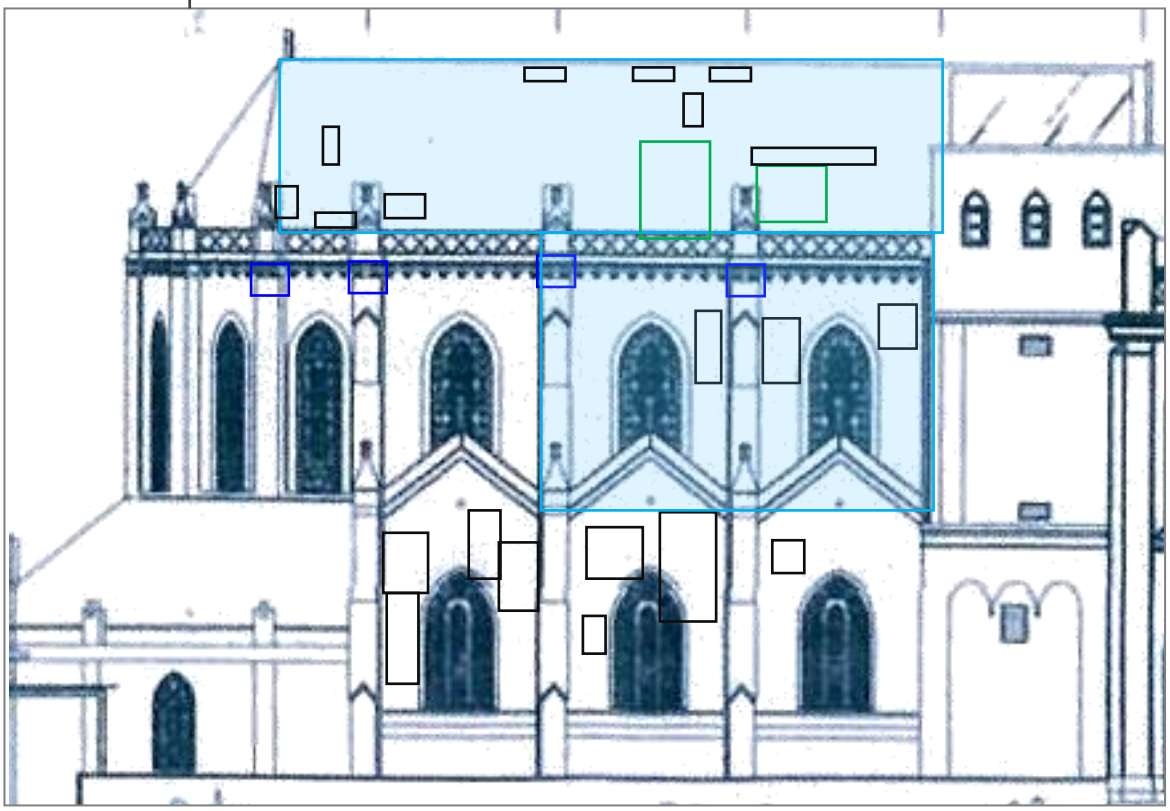
Legend

- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**

Face A- Northwest Elevation					
IR Nos.	**IR1-IR8**				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	47	0	4	7	0
Remarks	- Part of the surfaces is screened/ shadowed - No direct sunlight - Part of the surfaces is under big side/ view angle				







*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**

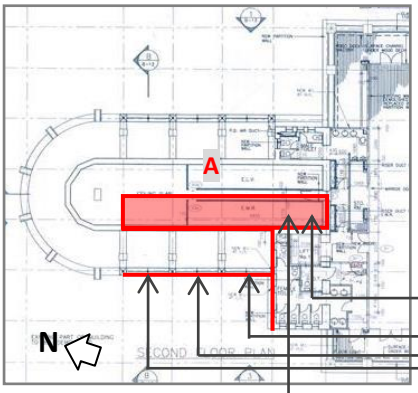
Summary of findings No. 2 (A2)

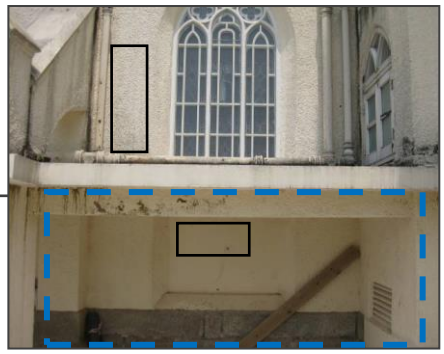
Face A- Northwest Elevation

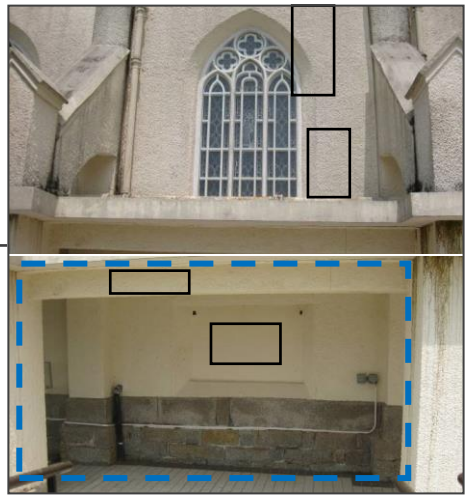
Legend

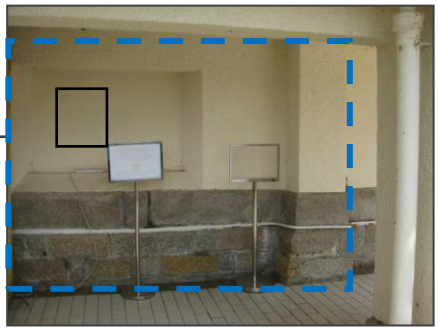
- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**

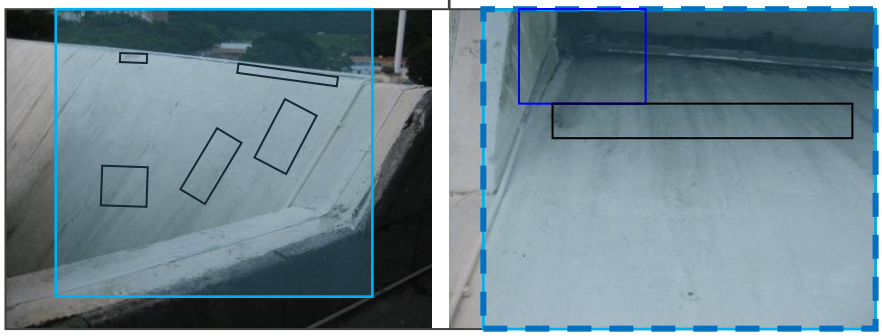
*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**











Summary of findings No. 3 (A3)

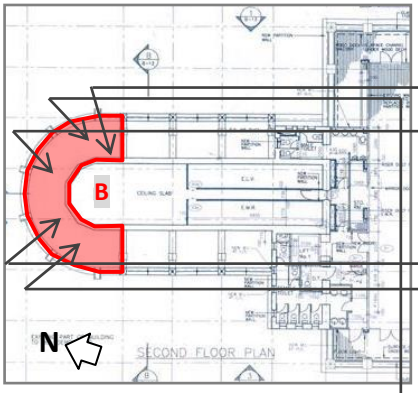
Face B- Northwest, Northeast Elevation

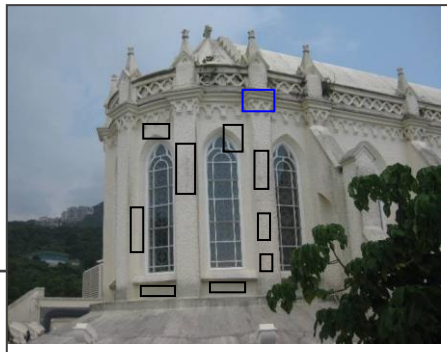
Legend

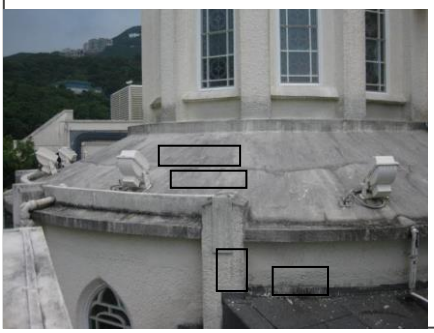
- Defect Type I
- Defect Type II
- Defect Type U
- Defect Type W
- Defect Type V
- Screened area/ cannot surveyed area:
- *No direct sunlight
- *Large inclination/ side angle

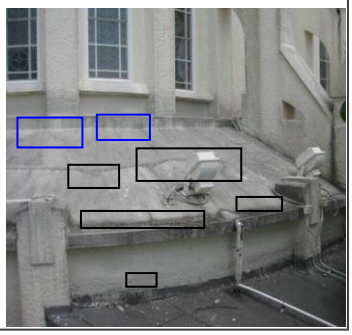
*** No direct sunlight or large inclination angle/ side angle due to the site constraint, the survey accuracy will be affected.**

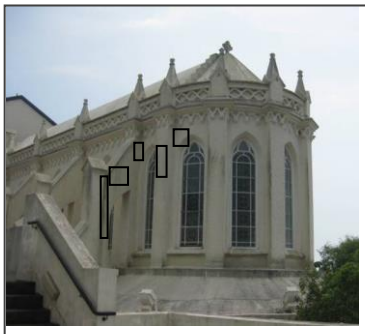
Face B- Northwest, Northeast Elevation					
IR Nos.	IR9-IR23				
Suspected defects found	I	II	U	W	V
	55	0	1	10	0
Remarks	- Part of the surfaces is screened/ shadowed - No direct sunlight				

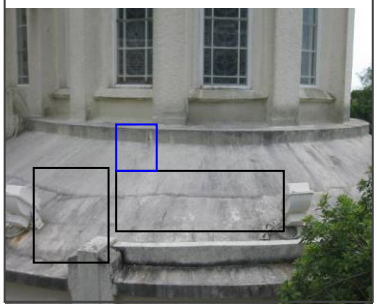


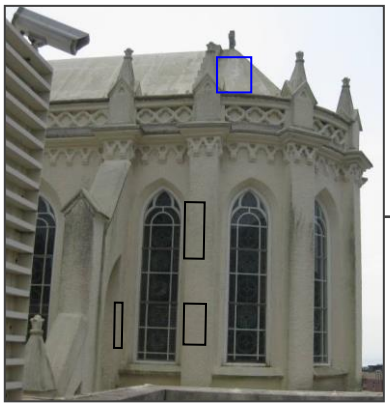


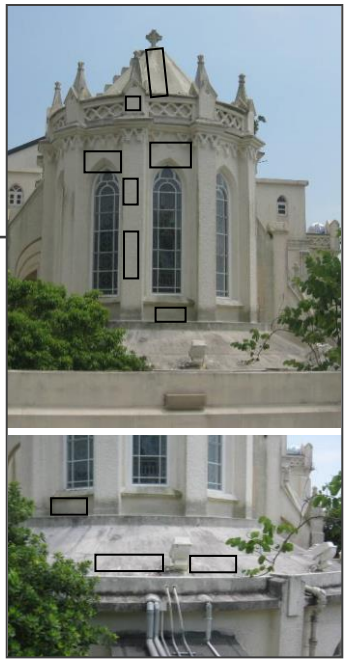


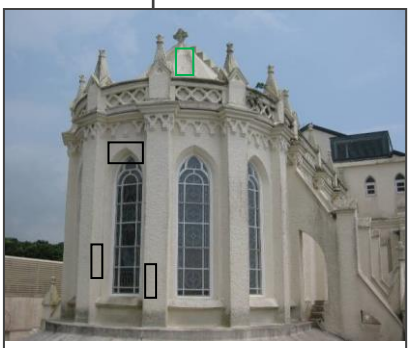


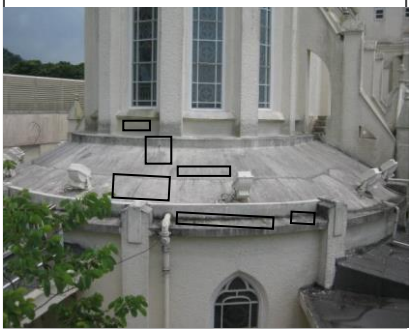










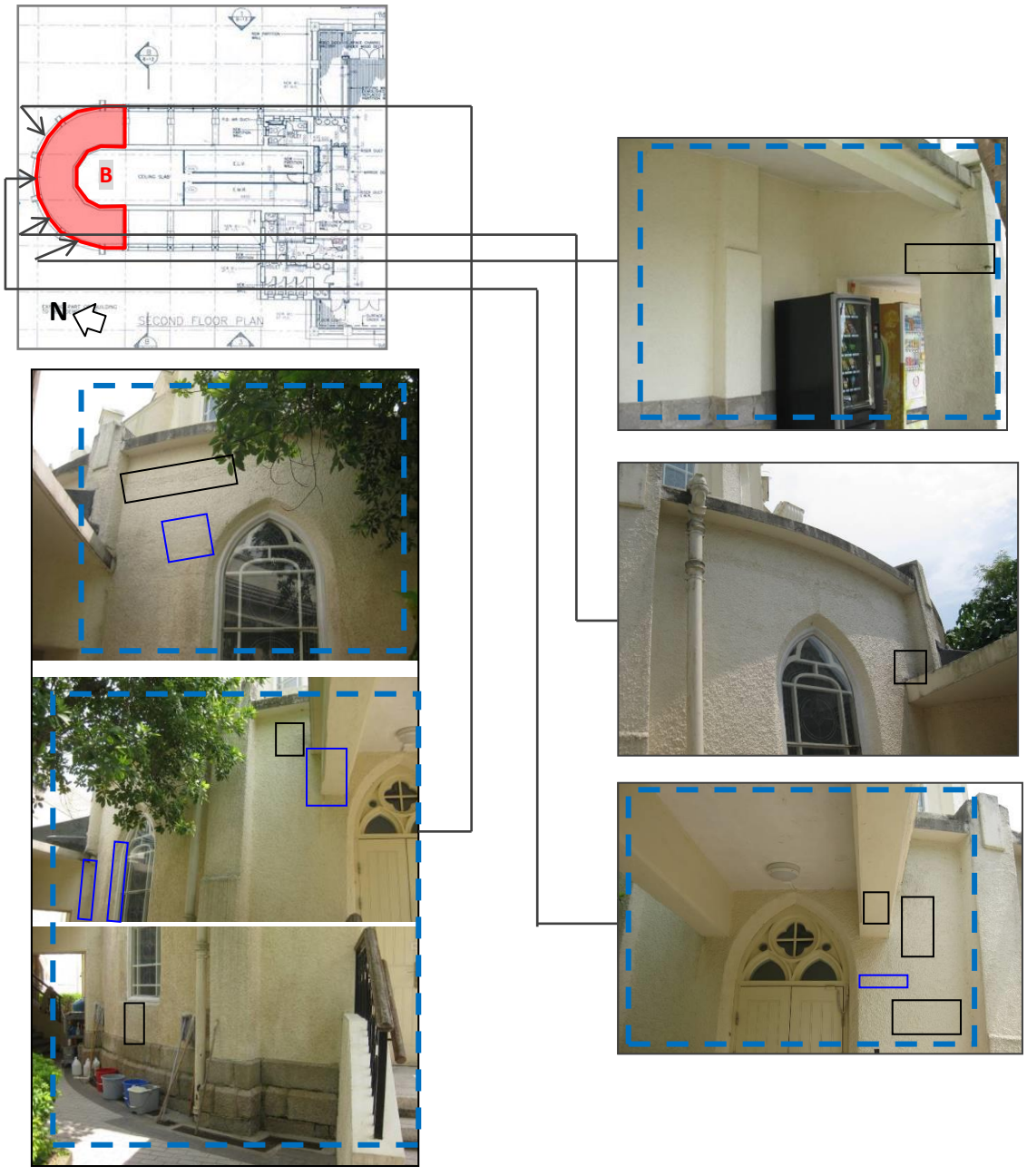


Summary of findings No. 4 (A4)

Face B- Northwest, Northeast Elevation

Legend

- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**



*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**

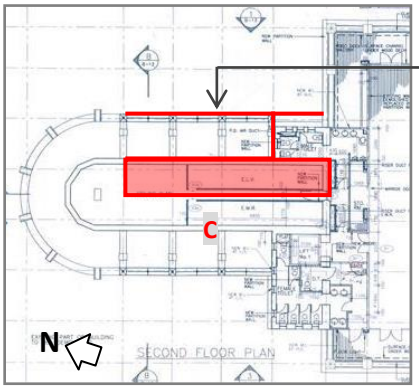
Summary of findings No. 5 (A5)

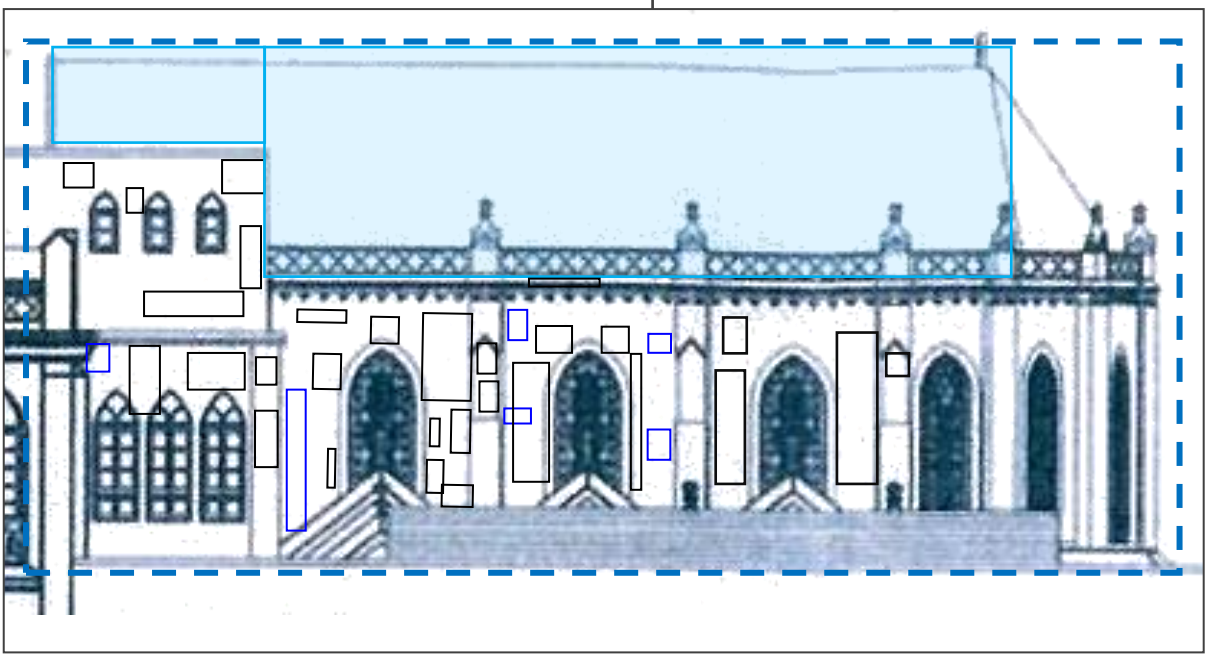
Face C- Northeast Elevation

Legend

- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**

Face C-Northeast Elevation					
IR Nos.	**IR24-IR34**				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	60	0	2	36	0
Remarks	- Part of the surfaces is screened/ shadowed - No direct sunlight - Part of the surfaces is under big side/view angle				





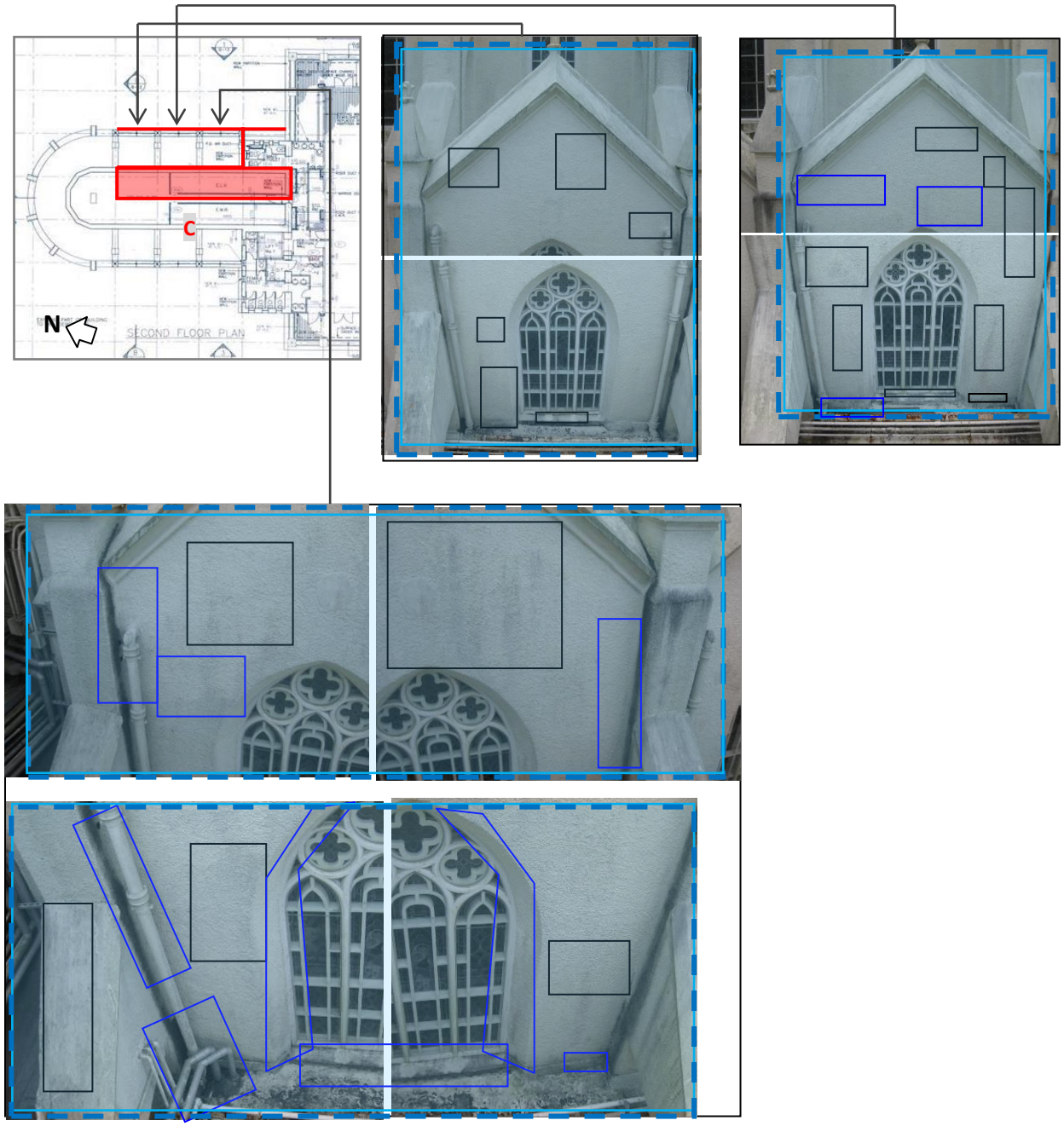
*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**

Summary of findings No. 6 (A6)

Face C- Northeast Elevation

Legend

- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**



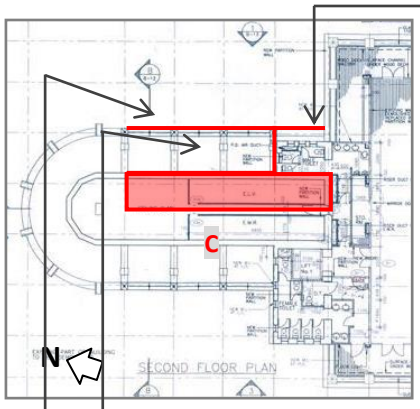
*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**

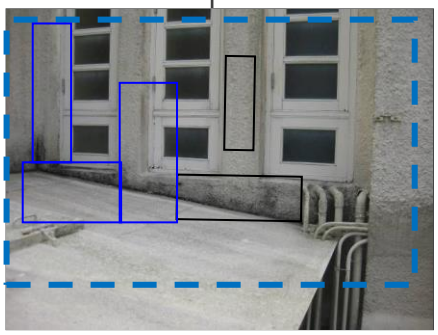
Summary of findings No. 7 (A7)

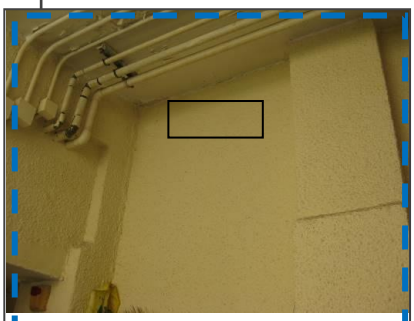
Face C- Northeast Elevation

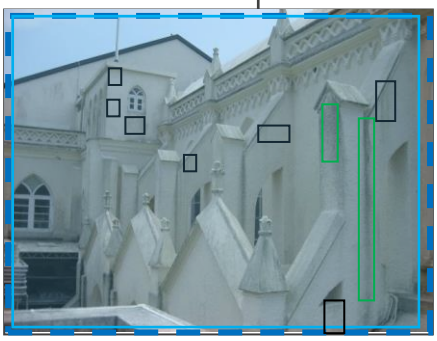
Legend

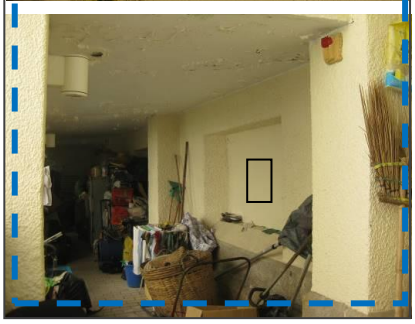
- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**











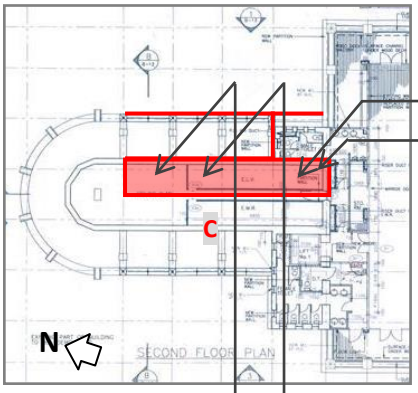
*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**

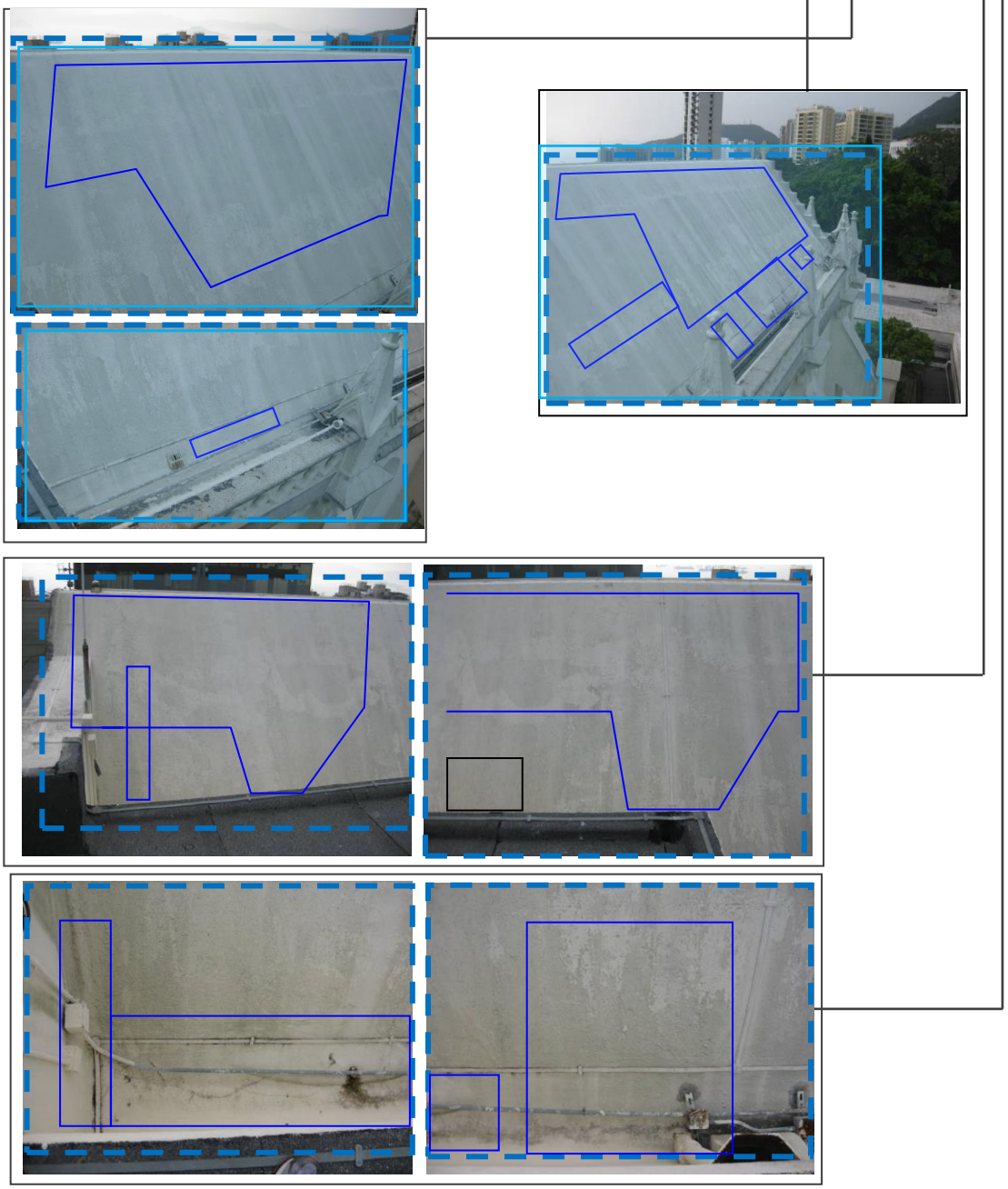
Summary of findings No. 8 (A8)

Face C- Northeast Elevation

Legend

- **Defect Type I**
- **Defect Type II**
- **Defect Type U**
- **Defect Type W**
- **Defect Type V**
- **Screened area/ cannot surveyed area:**
- ***No direct sunlight**
- ***Large inclination/ side angle**





*** Survey accuracy will be affected due to the site constraints such as no direct sunlight or large inclination angle/ side angle.**

Summary of findings No. 9 (A9)

Table 1: Findings

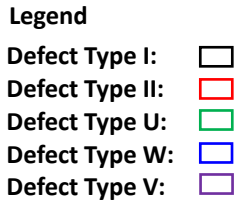
Face	Elevation	IR nos.	Floor	Suspected defects found					Remarks
				I	II	U	W	V	
A	NW	IR1	1/F-2/F	12	0	2	0	0	◆ Part of the surfaces is screened/ shadowed ◆ Part of surfaces is surveyed under big side angle
		IR2	1/F-2/F	9	0	0	4	0	◆ Part of the surfaces is shadowed/ screened
		IR3	G/F	2	0	0	0	0	◆ Part of the surfaces is shadowed/ screened ◆ No direct sunlight
		IR4	G/F	4	0	0	0	0	
		IR5	G/F	3	0	0	0	0	◆ Part of the surfaces is shadowed/ screened
		IR6	Roof	9	0	2	0	0	◆ Part of the surfaces is surveyed under big view angle
		IR7	Roof	2	0	0	2	0	◆ Part of the surfaces is shadowed/ screened ◆ No direct sunlight
		IR8	Roof	6	0	0	1	0	◆ Surfaces is surveyed under big view angle ◆ Surface water and vegetation noted on site
Sub-total nos. of defects at Face A				47	0	4	7	0	
					58				
Face	**Elevation**	**IR nos.**	**Floor**	**Suspected defects found**					**Remarks**
				I	**II**	**U**	**W**	**V**	
B	NW,NE	IR9	1/F-2/F	9	0	0	1	0	◆ -
		IR10	1/F	5	0	0	2	0	◆ Part of the surfaces is shadowed/ screened
		IR11	1/F	4	0	0	0	0	◆
		IR12	1/F-2/F	3	0	1	0	0	◆
		IR13	1/F	6	0	0	0	0	◆ Part of the surfaces is shadowed/ screened
		IR14	1/F-2/F	7	0	0	0	0	
		IR15	1/F	3	0	0	0	0	
		IR16	1/F-2/F	7	0	0	1	0	
		IR17	1/F-2/F	3	0	0	1	0	
		IR18	G/F	1	0	0	0	0	◆ Part of the surfaces is shadowed/ screened ◆ No direct sunlight
		IR19	G/F	1	0	0	0	0	
		IR20	G/F	3	0	0	1	0	
		IR21	G/F	2	0	0	3	0	
		IR22	G/F	1	0	0	1	0	
		IR23	G/F	0	0	0	0	0	
Sub-total nos. of defects at Face B				55	0	1	10	0	
					66				

Summary of findings No. 10 (A10)

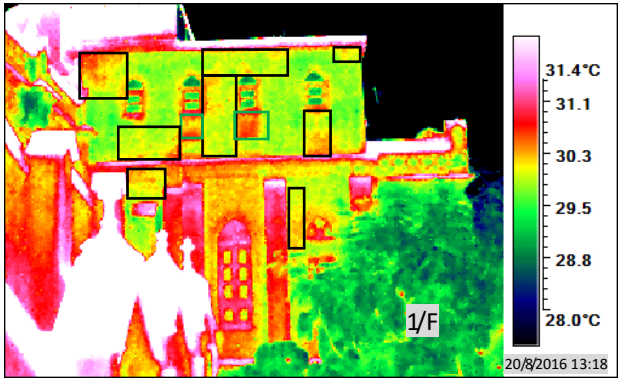
Face	Elevation	IR nos.	Floor	Suspected defects found					Remarks
				I	II	U	W	V	
C	NE	IR24	1/F-2/F	10	0	0	0	0	◆ No direct sunlight ◆ -Big view angle
		IR25	1/F-2/F	13	0	0	7	0	
		IR26	2/F	11	0	0	1	0	◆ No direct sunlight
		IR27	1/F	2	0	0	3	0	
		IR28	1/F	3	0	0	6	0	◆ No direct sunlight ◆ -Big view angle
		IR29	1/F-2/F	11	0	0	5	0	
		IR30	1/F-2/F	7	0	2	0	0	
		IR31	G/F	2	0	0	0	0	
		IR32	Roof	0	0	0	7	0	
		IR33	Roof	1	0	0	3	0	◆ No direct sunlight
		IR34	Roof	0	0	0	4	0	
Sub-total nos. of defects at Face C				60	0	2	36	0	◆
				98					
Total nos. of defects(A,B,C)				**162**	**0**	**7**	**53**	**0**	
				222					

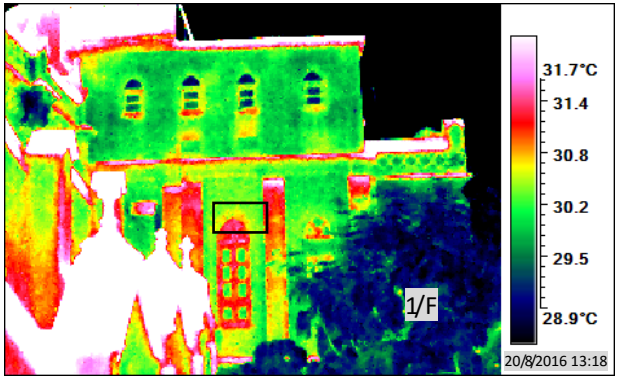
Appendix B

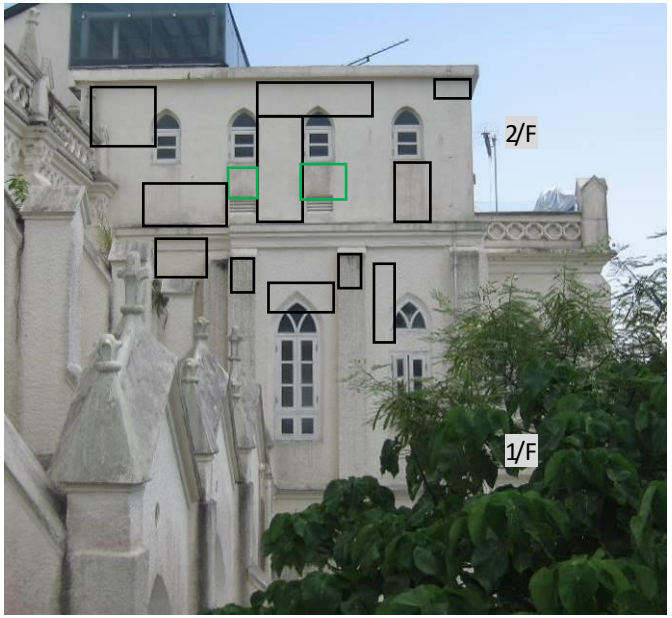
IR Images Findings

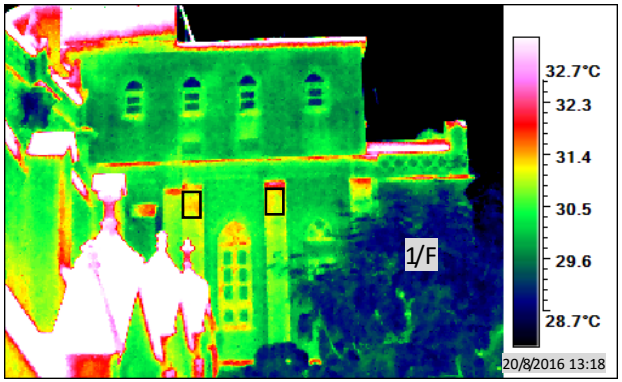


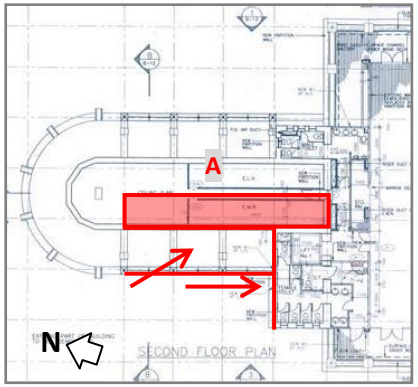
Infrared Image No. 1 (IR1)

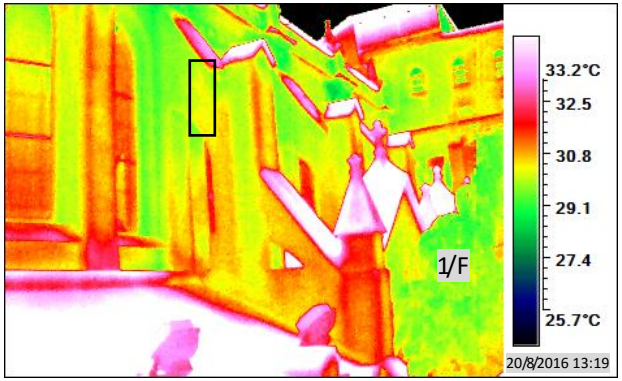






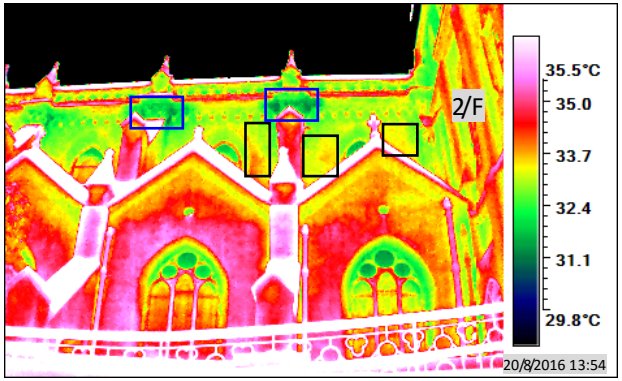


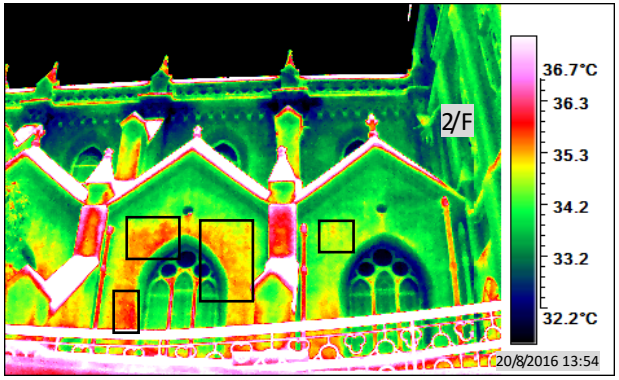


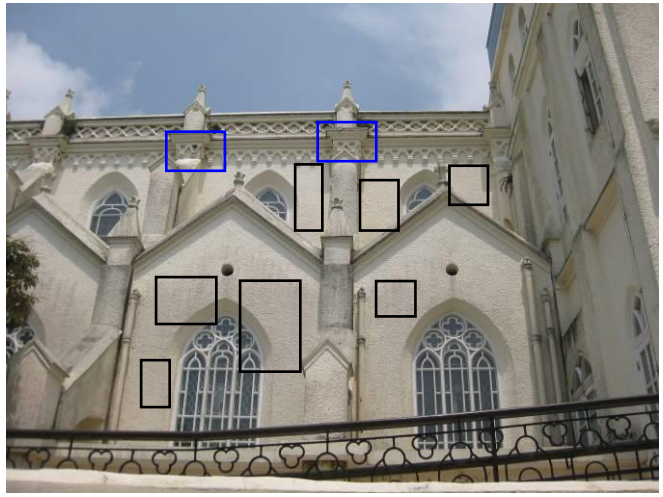


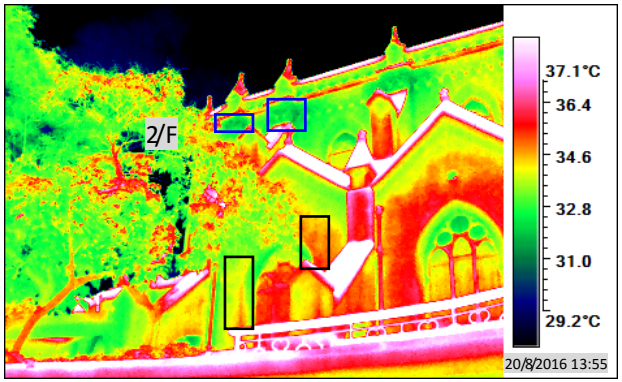
Face A-Norththwest Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	12	0	2	0	0
Remarks	- Part of the surfaces is screened/ shadowed - Part of surfaces is surveyed under big side angle				

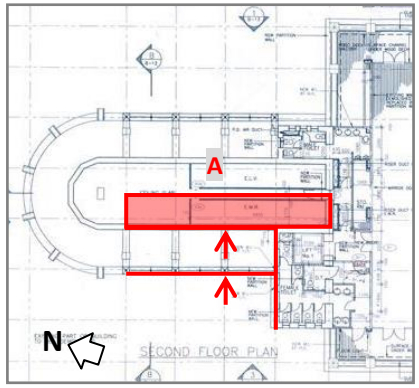
Infrared Image No. 2 (IR2)





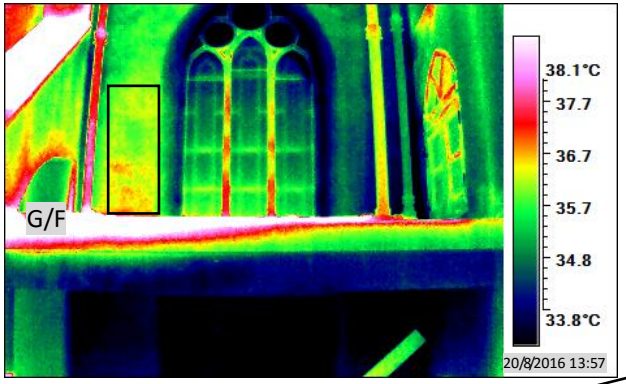


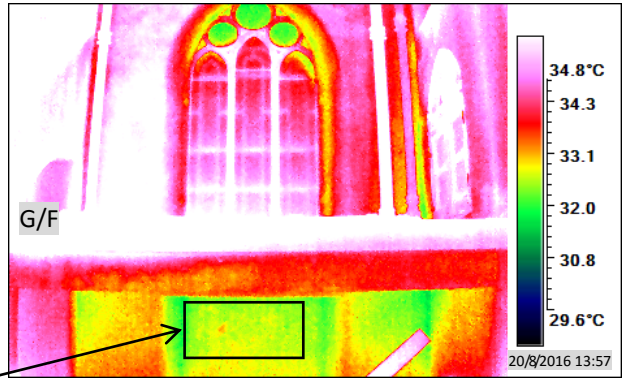


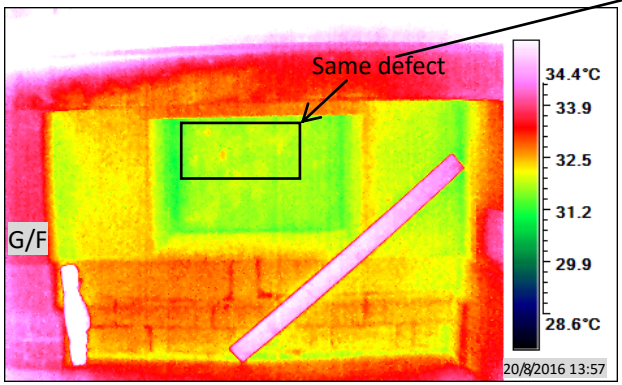


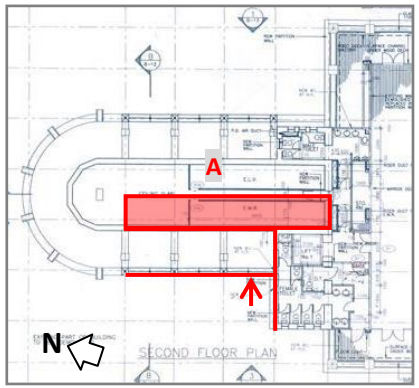
Face A-Norththwest Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	9	0	0	4	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 3 (IR3)



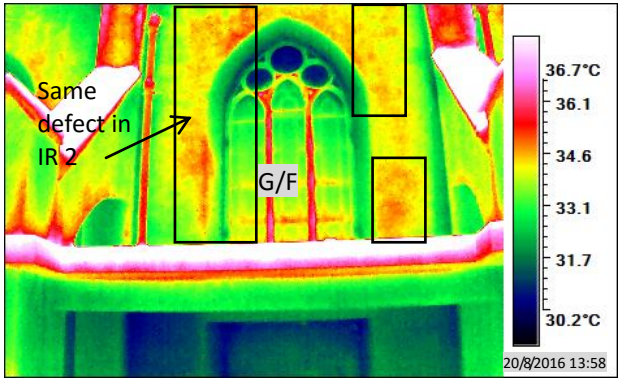


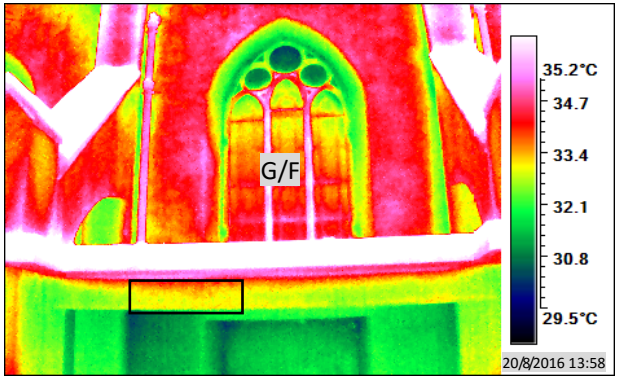


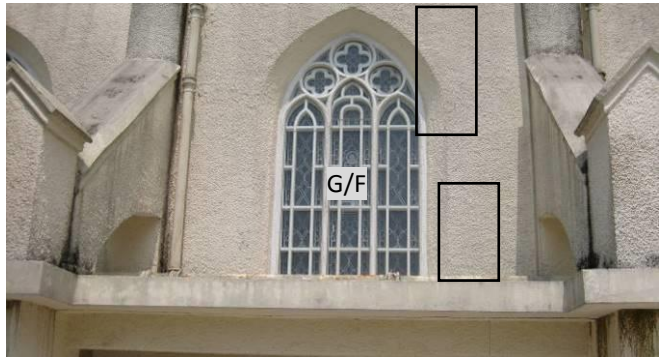


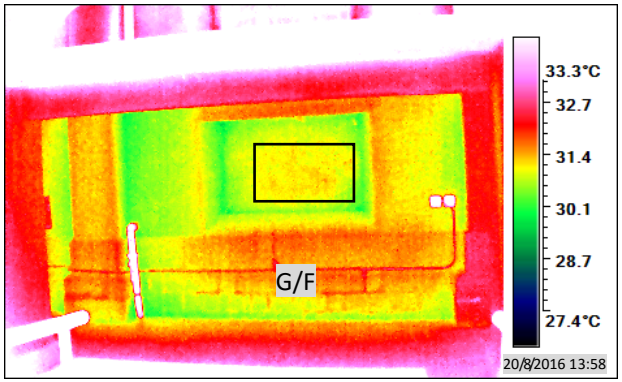
Face A-Norththwest Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	2	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed - No direct sunlight				

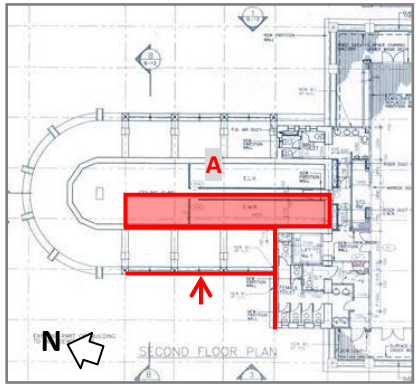
Infrared Image No. 4 (IR4)

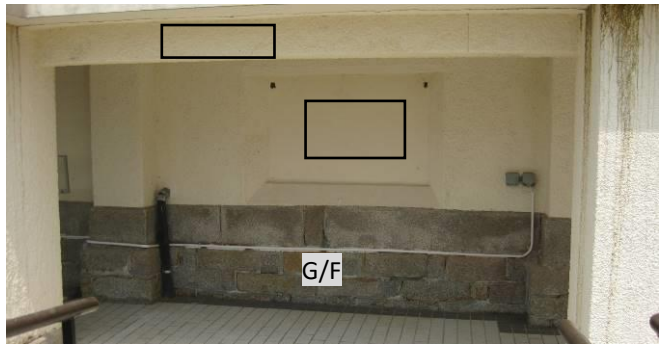






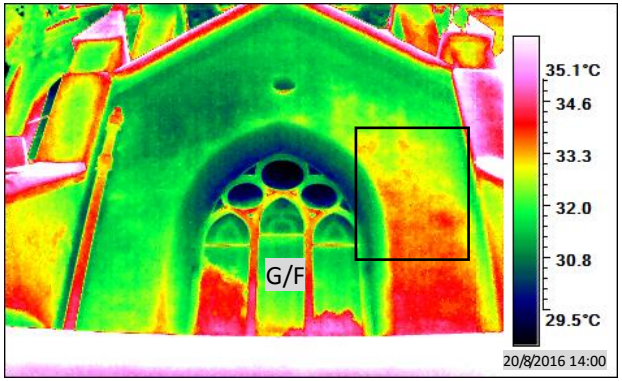


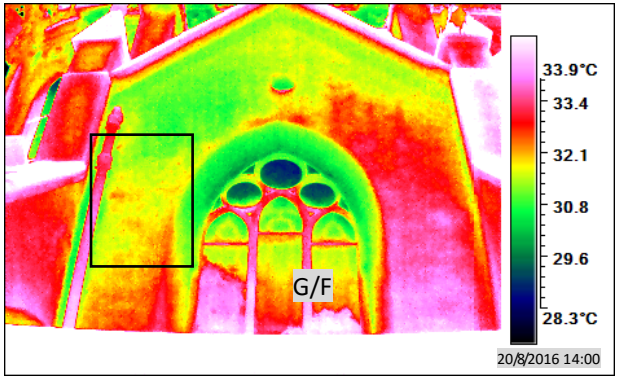


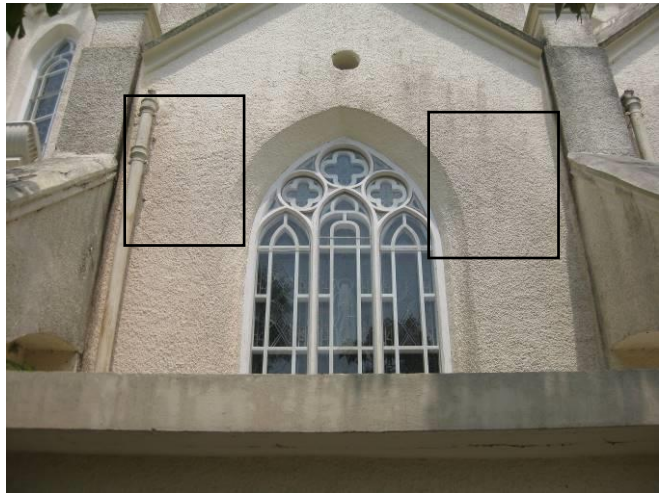


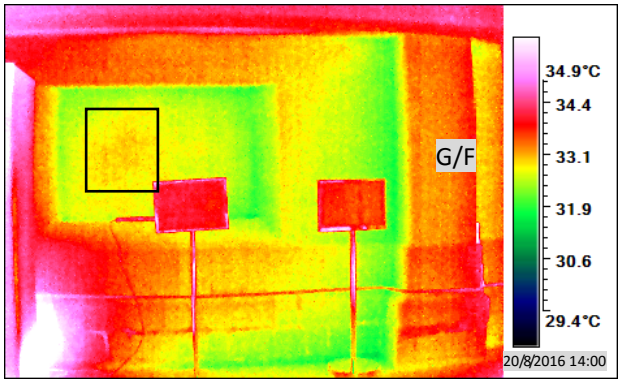
Face A-Norththwest Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	4	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed - No direct sunlight				

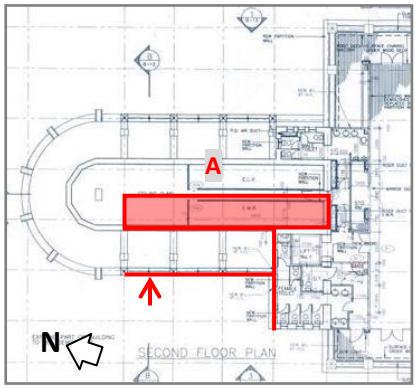
Infrared Image No. 5 (IR5)





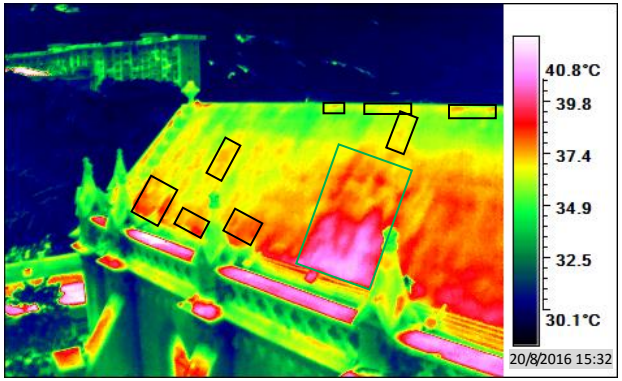


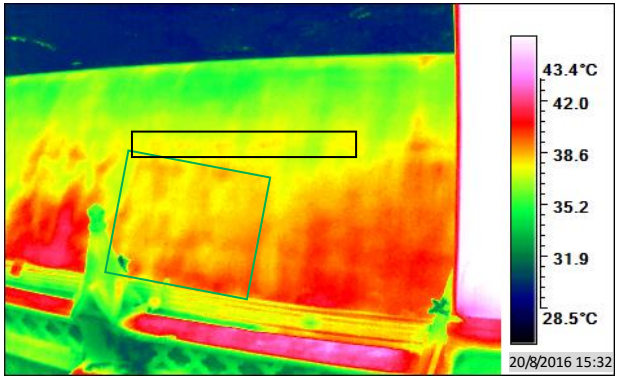


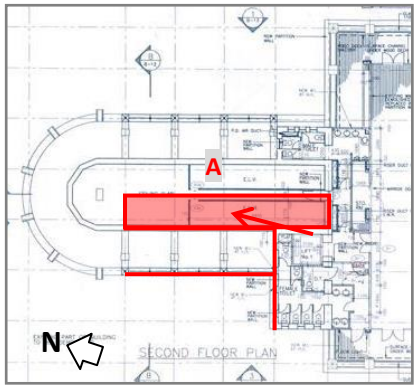


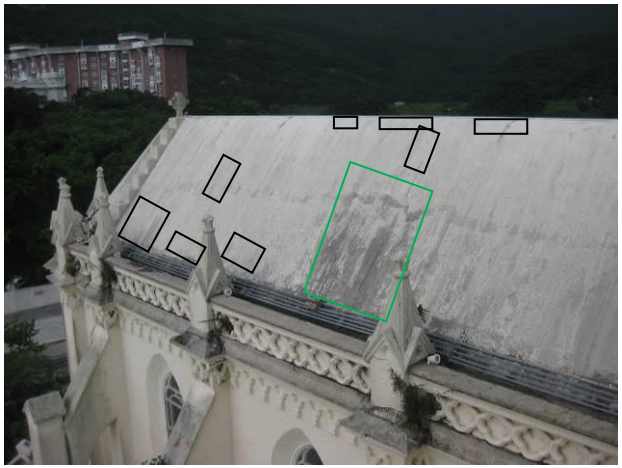
Face A-Norththwest Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	3	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 6 (IR6)



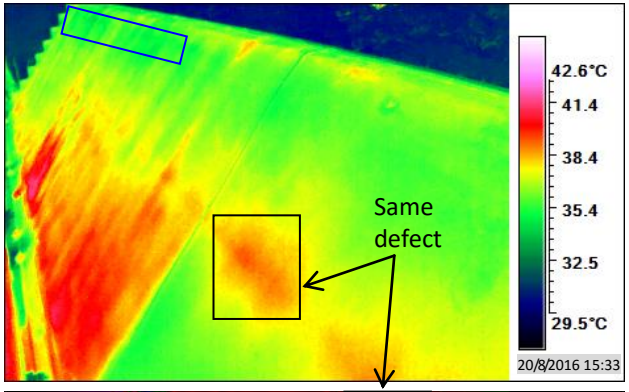


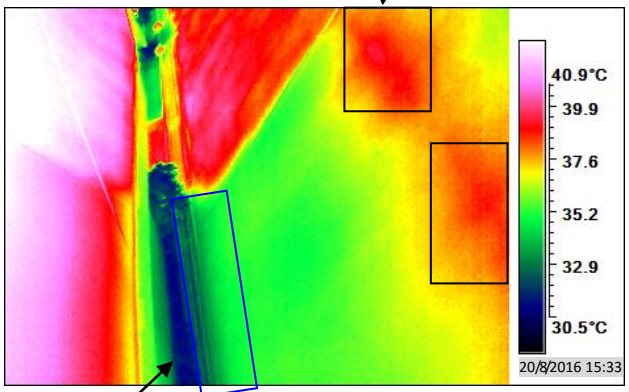




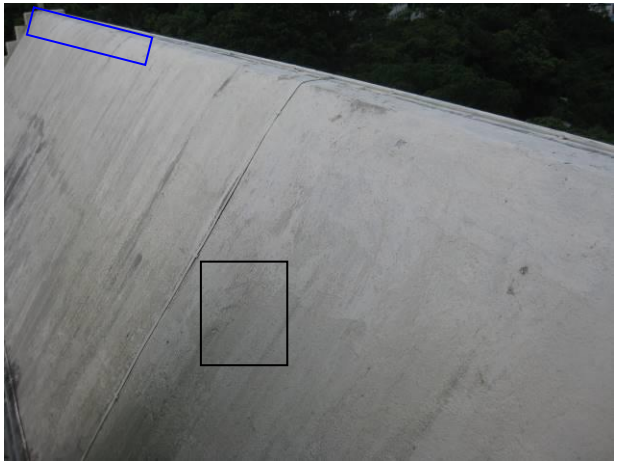
Face C-Norththeast Elevation					
Floor	R/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	9	0	2	0	0
Remarks	- Part of the surfaces is surveyed under big view angle				

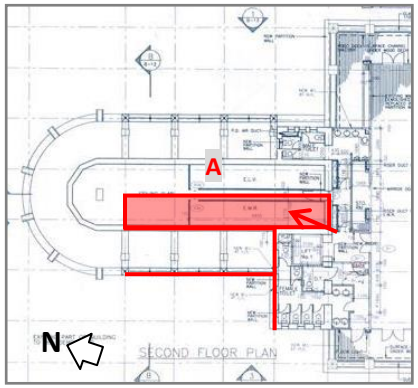
Infrared Image No. 7 (IR7)





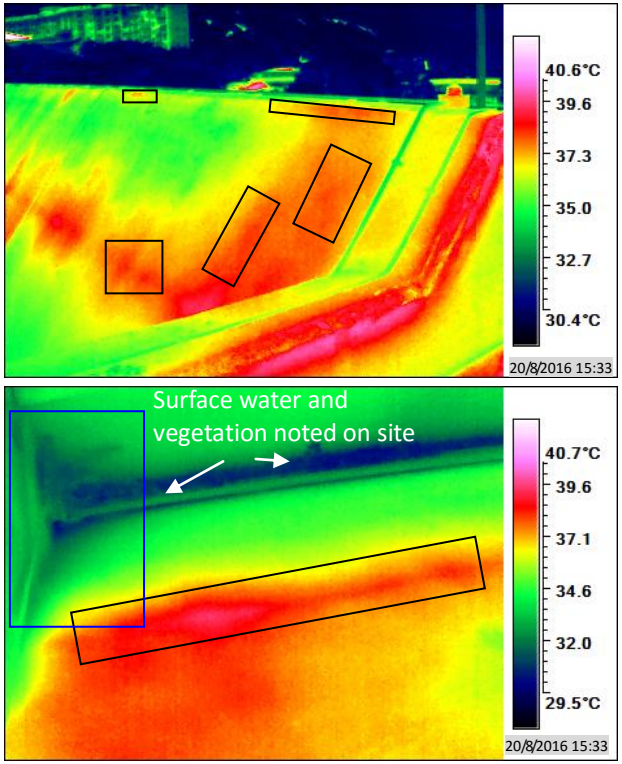
Surface water and vegetation noted on site

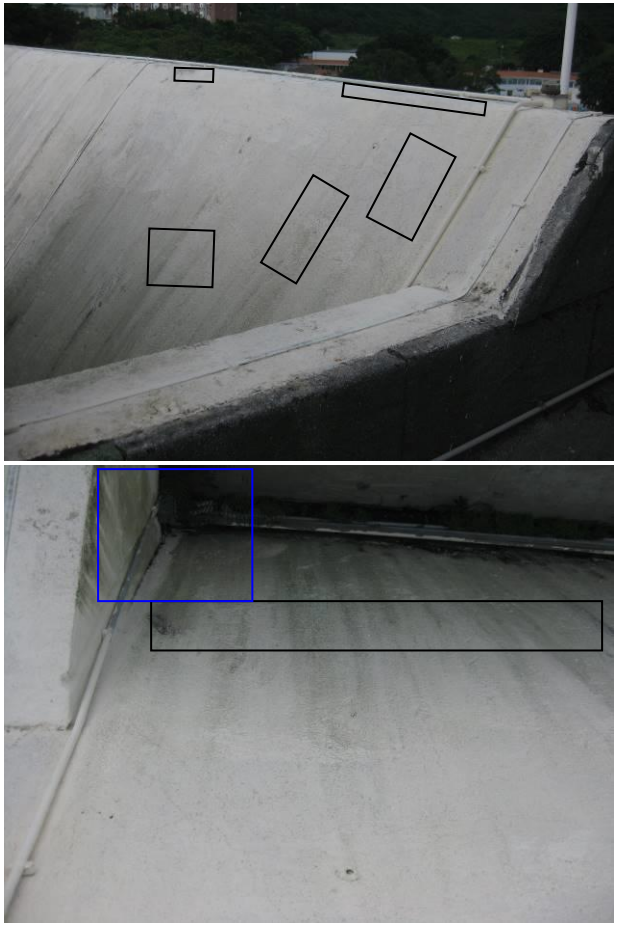


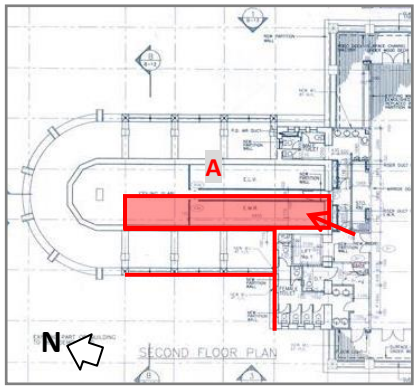


Face C-Norththeast Elevation					
Floor	R/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	2	0	0	2	0
Remarks	- Surfaces is surveyed under big view angle				

Infrared Image No. 8 (IR8)

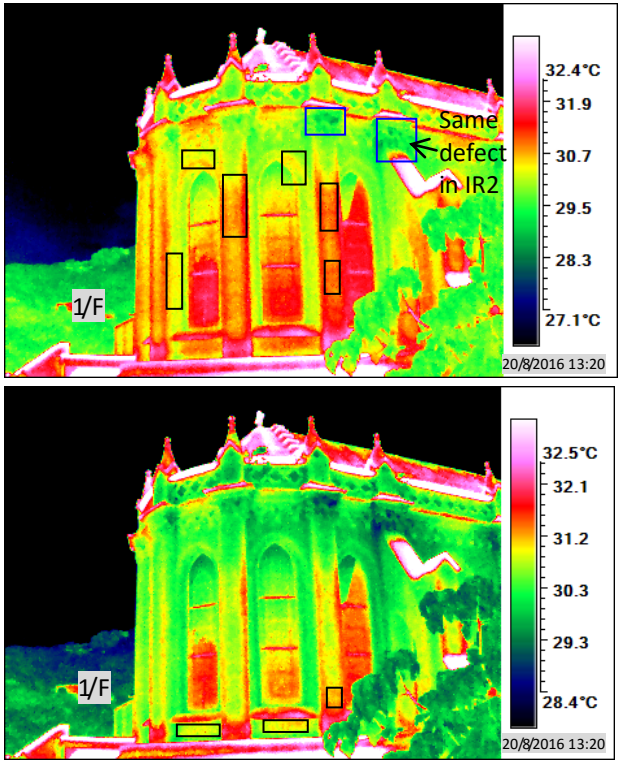


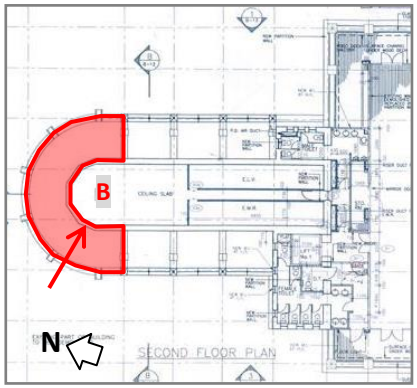




Face C-Norththeast Elevation					
Floor	R/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	6	0	0	1	0
Remarks	- Surfaces is surveyed under big view angle - Surface water and vegetation noted on site				

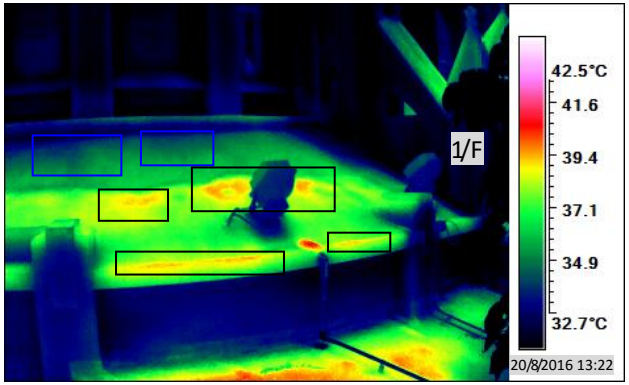
Infrared Image No. 9 (IR9)

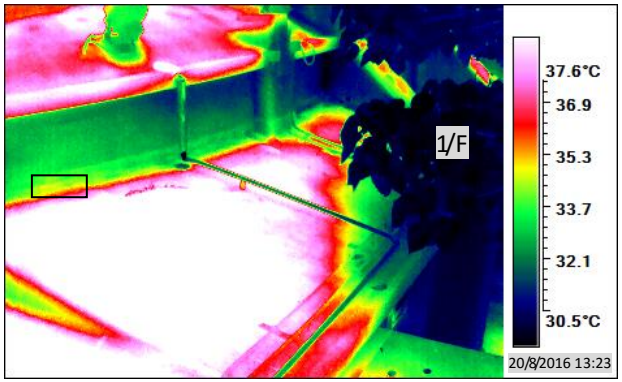


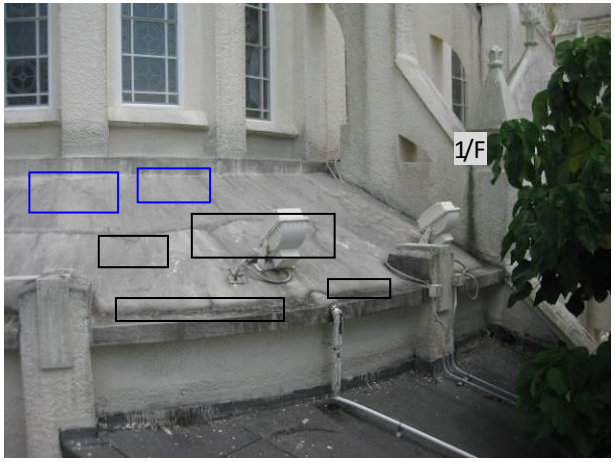


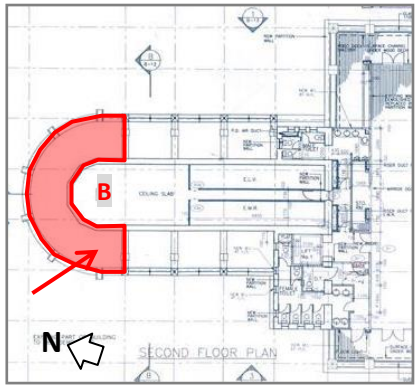
Face B-Norththwest,Northeast Elevation					
Floor	1-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	9	0	0	1	0
Remarks					

Infrared Image No. 10 (IR10)



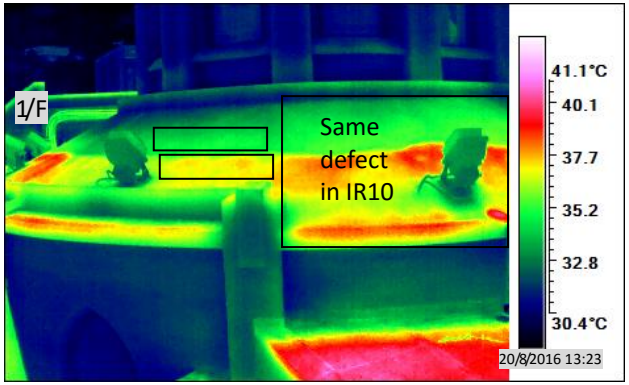


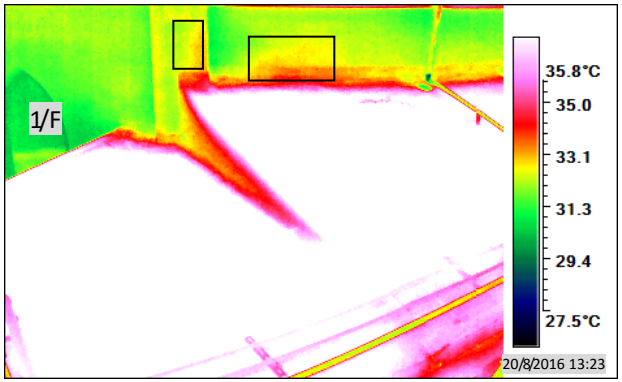


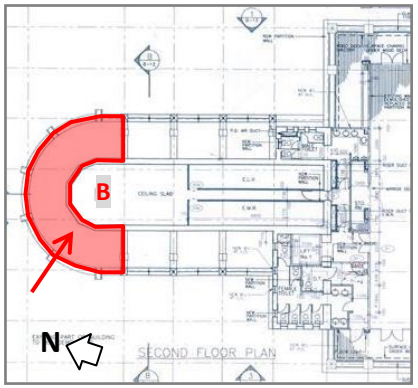


Face B-Norththwest,Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	5	0	0	2	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 11 (IR11)

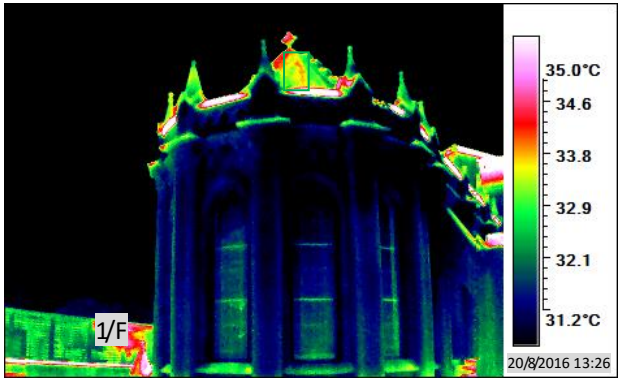


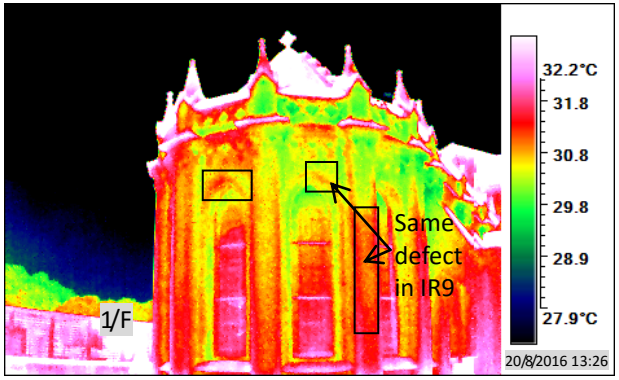


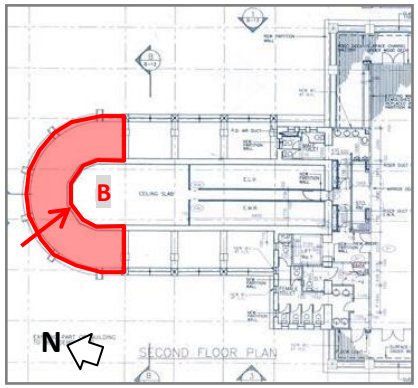


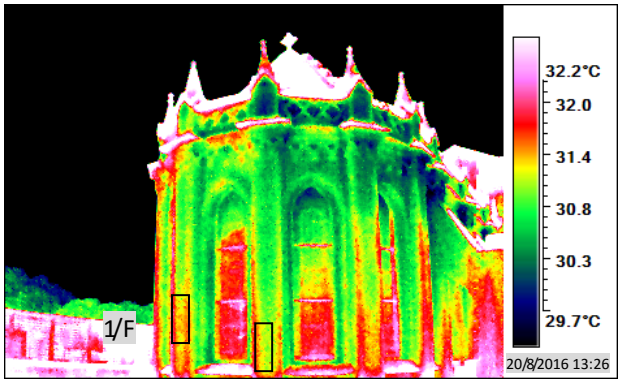
Face B-Norththwest,Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	4	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 12 (IR12)



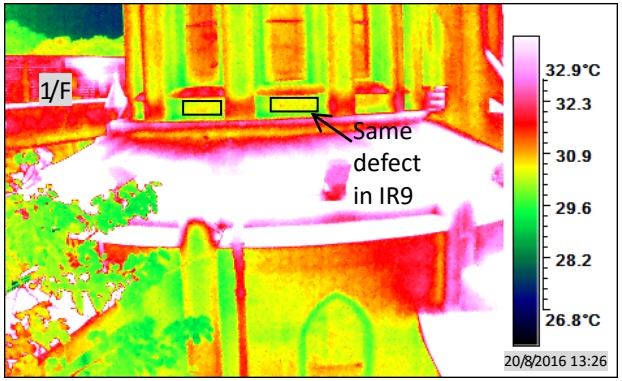


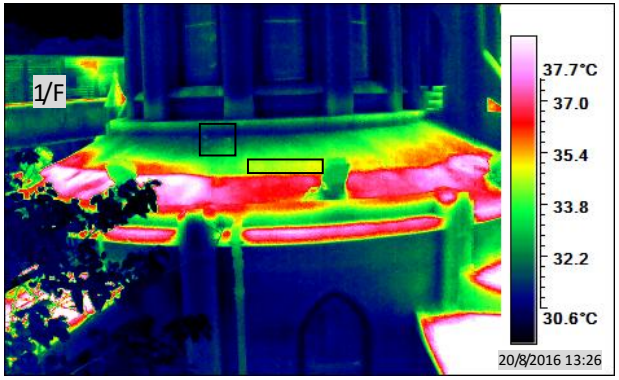


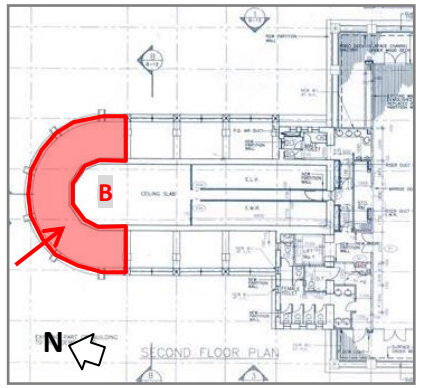


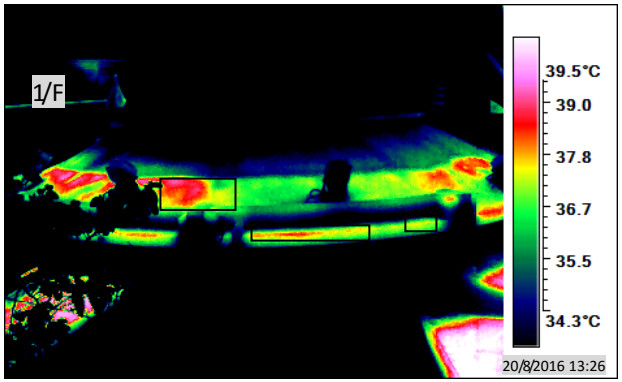
Face B-Norththwest,Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	3	0	1	0	0
Remarks					

Infrared Image No. 13 (IR13)



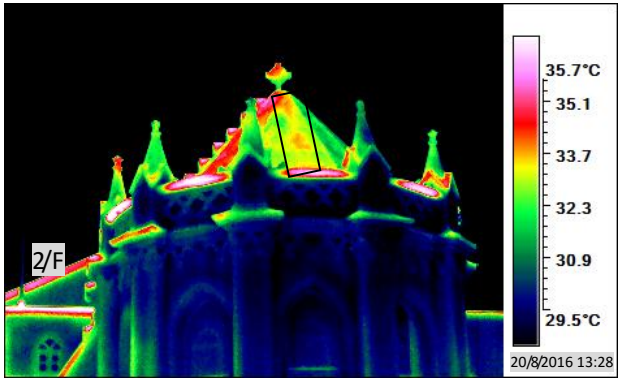


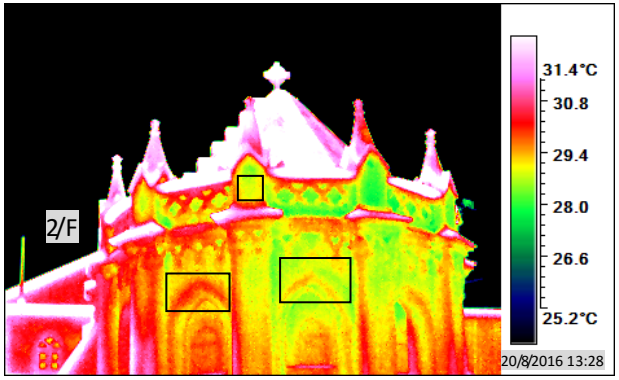


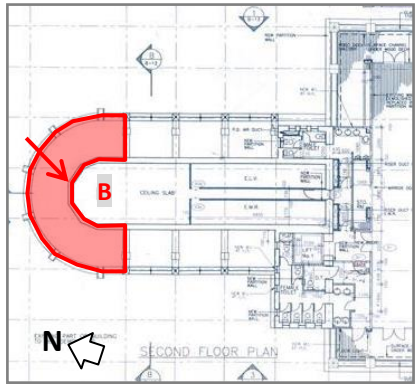


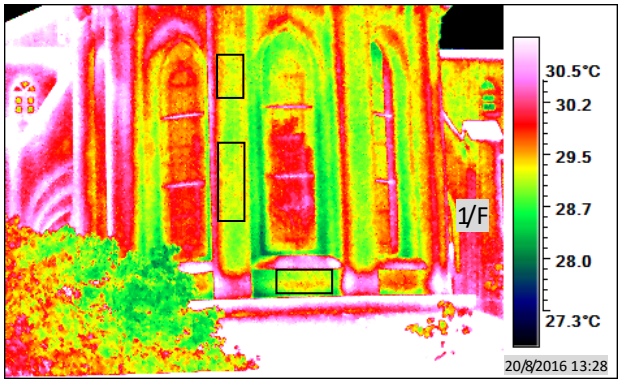
Face B-Norththwest,Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	6	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 14 (IR14)



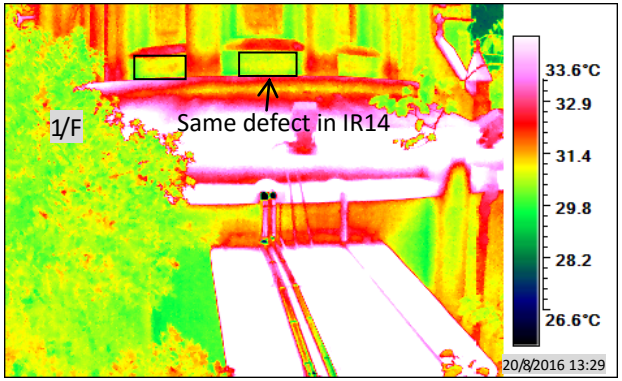


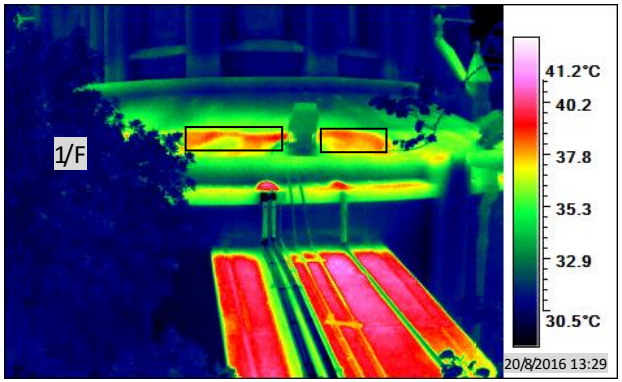


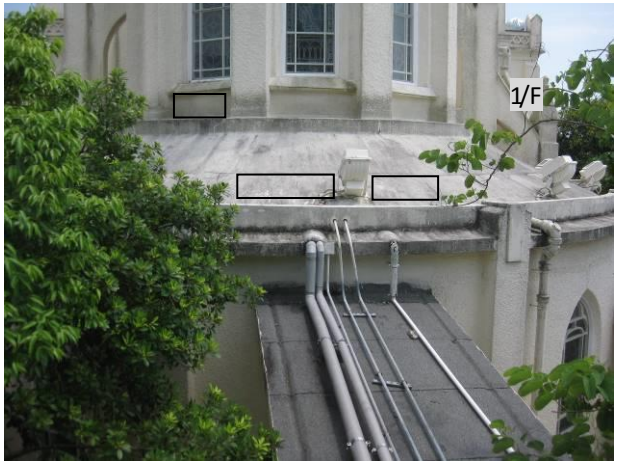


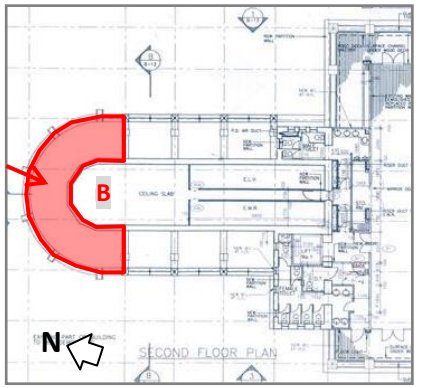
Face B-Norththwest,Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	7	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 15 (IR15)



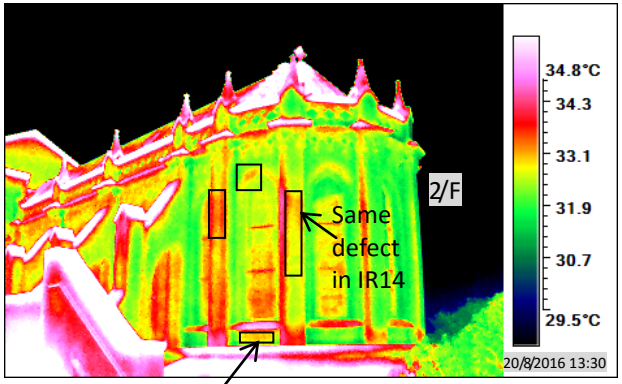


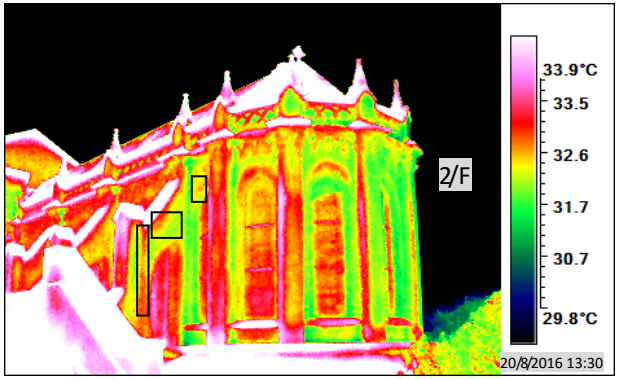


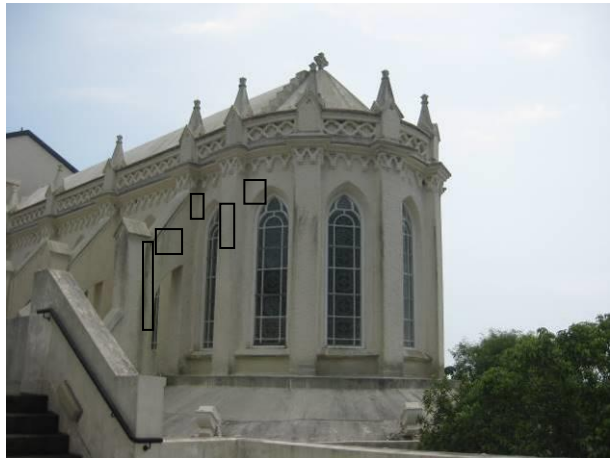


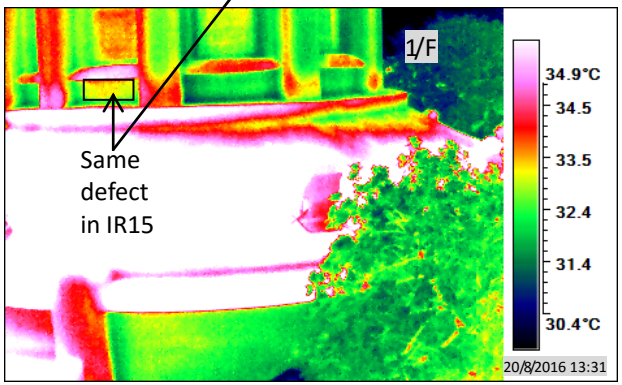
Face B-Norththwest,Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	3	0	0	0	0
Remarks	- Part of the surfaces is screened/ shadowed				

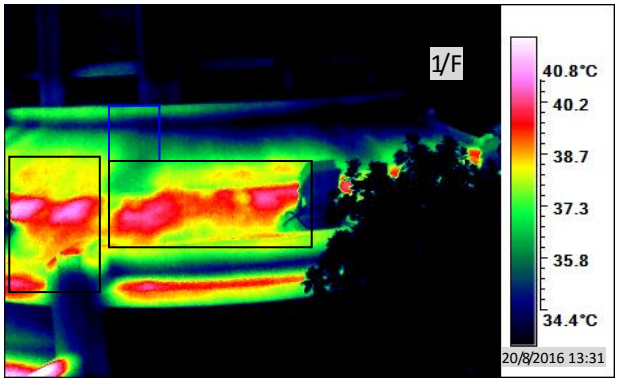
Infrared Image No. 16 (IR16)

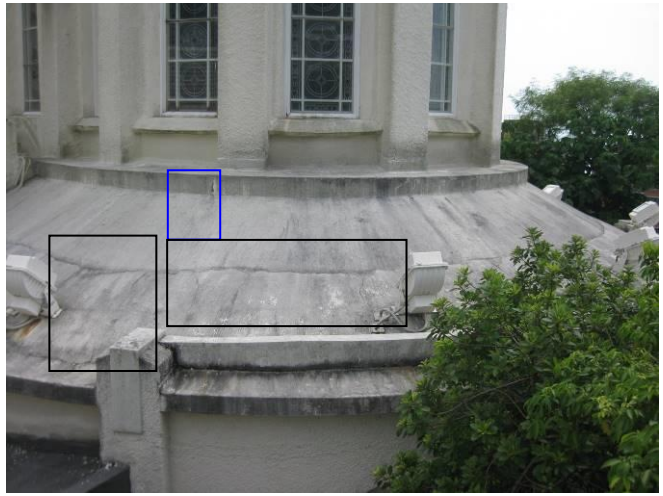


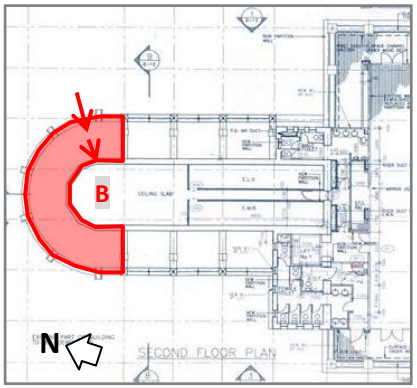






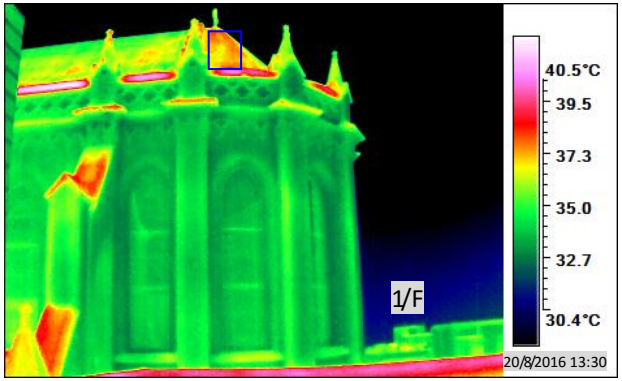


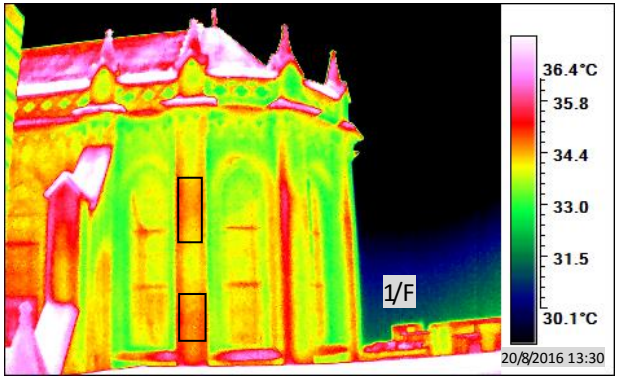


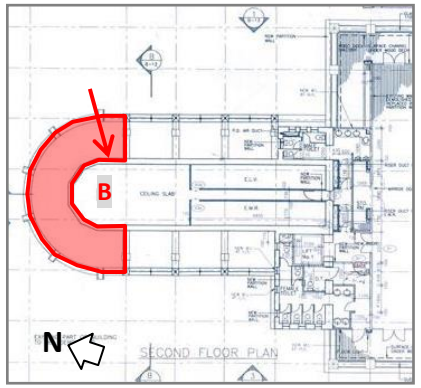


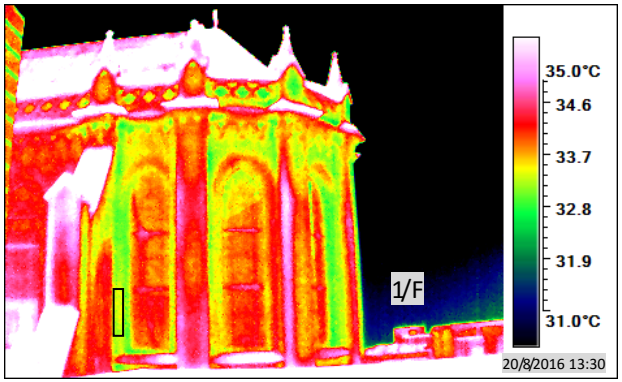
Face B-Norththwest,Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	7	0	0	1	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 17 (IR17)



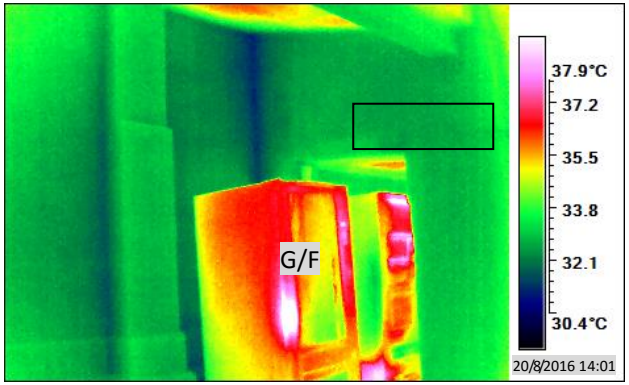


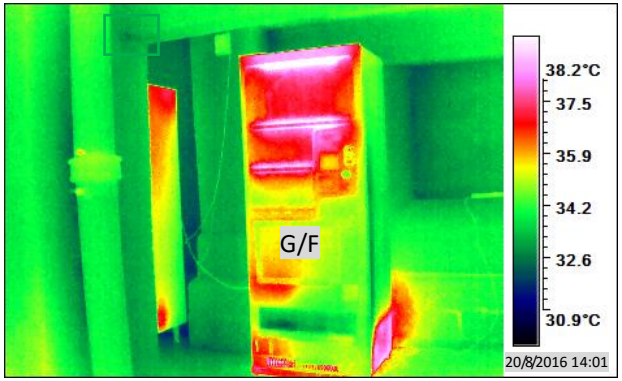


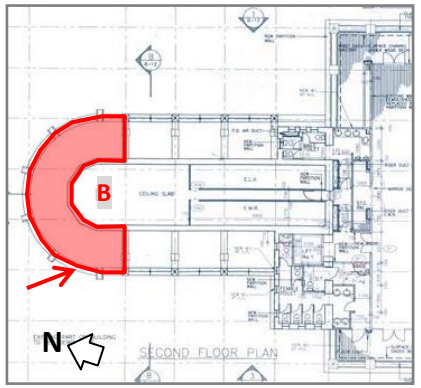


Face B-Norththwest,Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	3	0	0	1	0
Remarks	- Part of the surfaces is screened/ shadowed				

Infrared Image No. 18 (IR18)

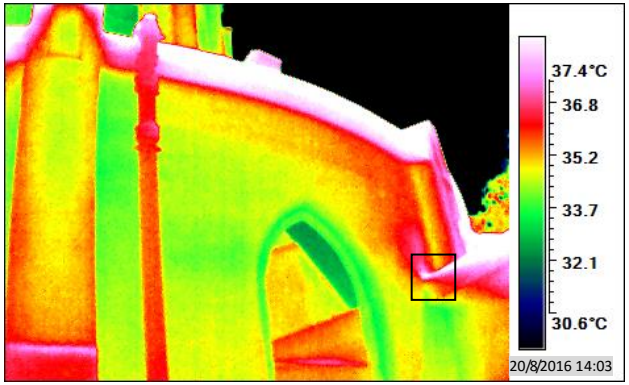


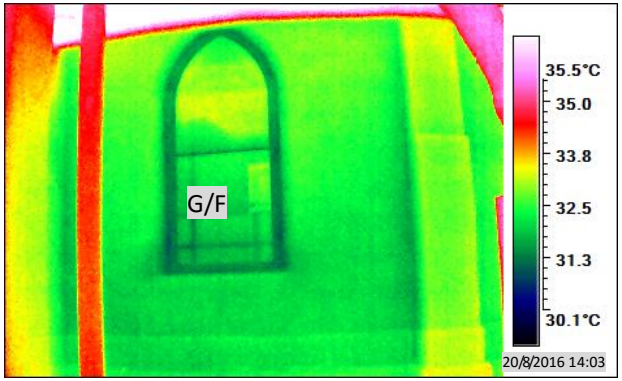


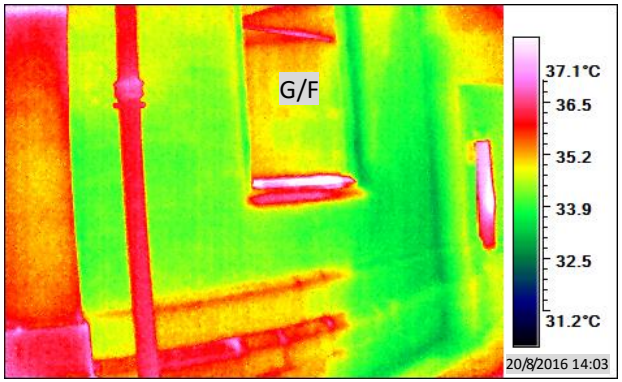


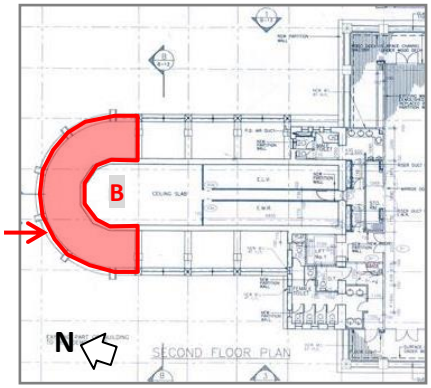
Face B-Norththwest,Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	1	0	0	0	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

Infrared Image No. 19 (IR19)



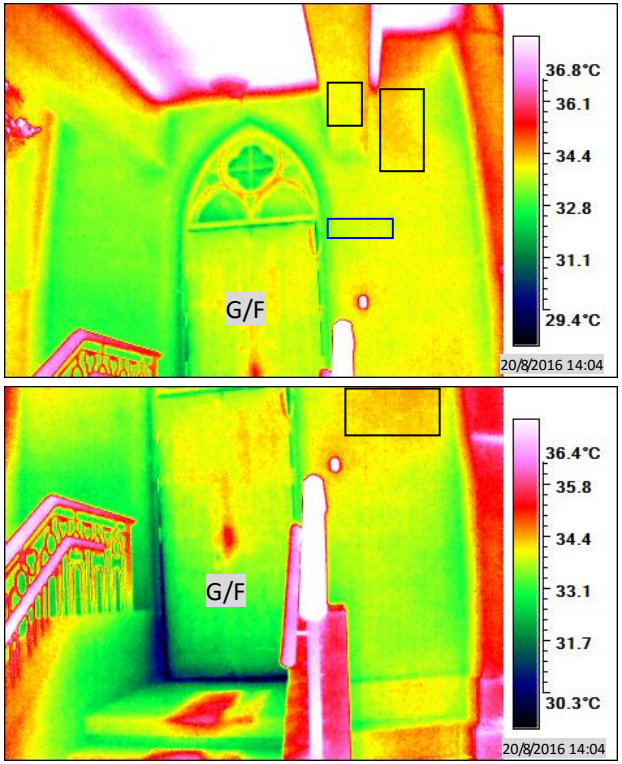


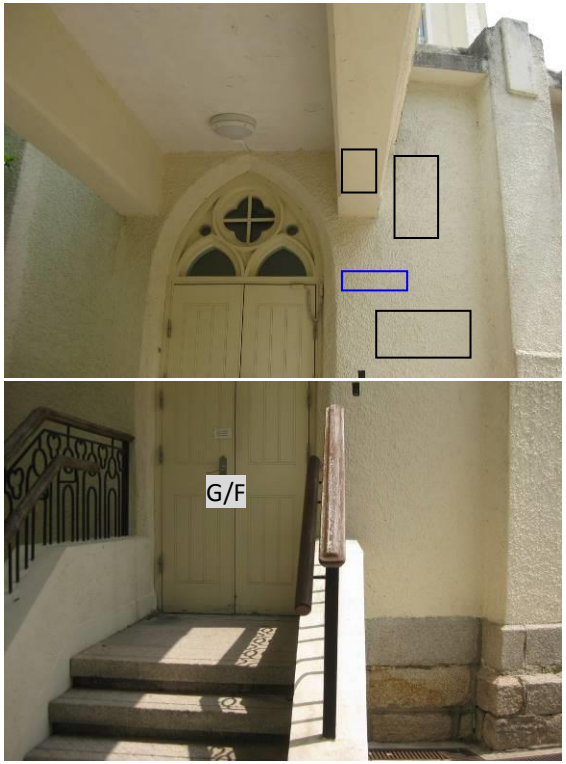


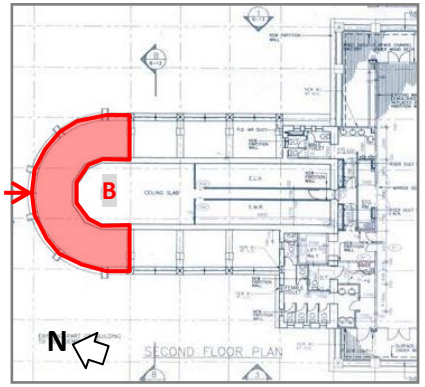


Face B-Norththwest,Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	1	0	0	0	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

Infrared Image No. 20 (IR20)

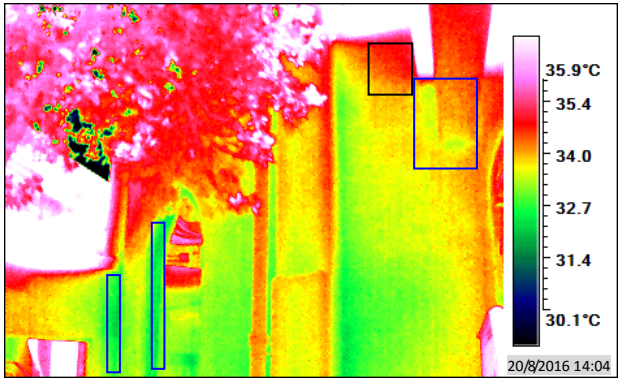


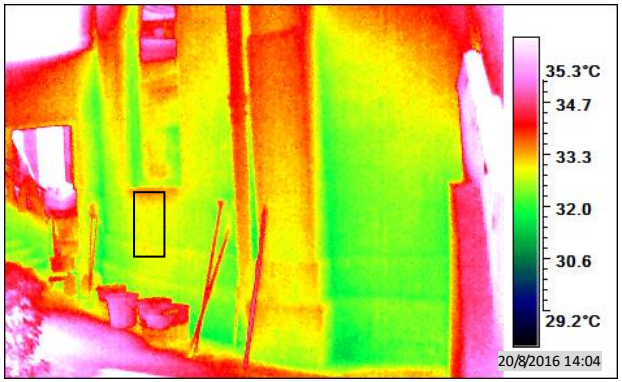


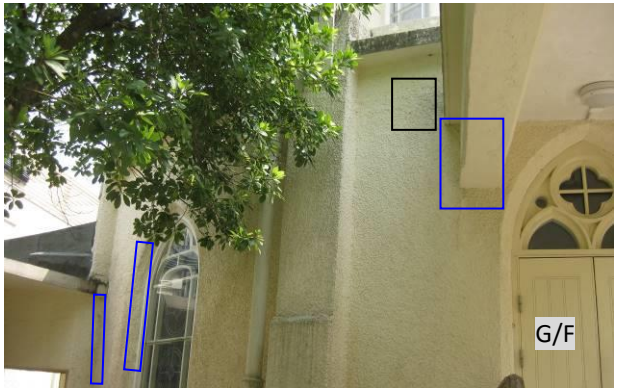


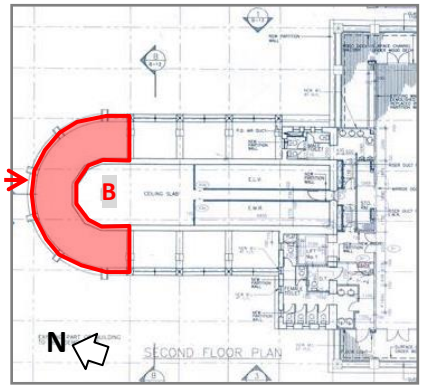
Face B-Norththwest,Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	3	0	0	1	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

Infrared Image No. 21 (IR21)



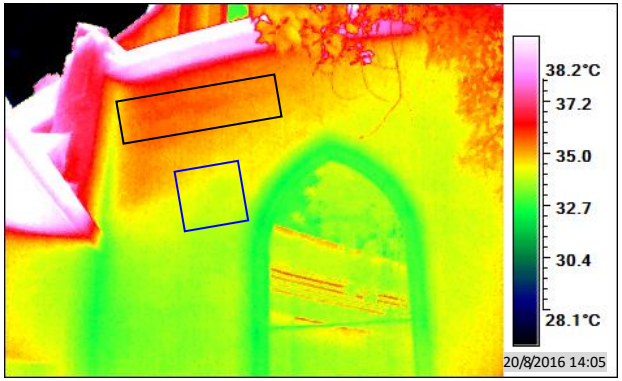


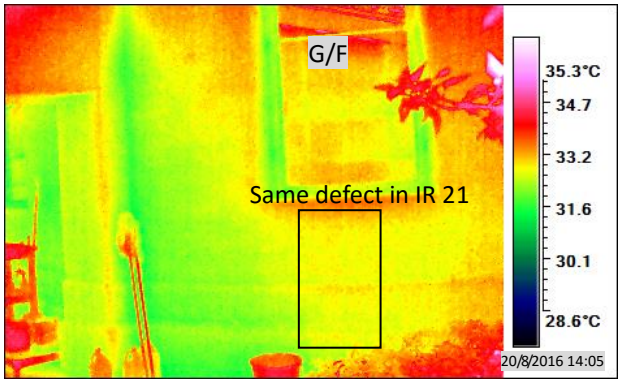


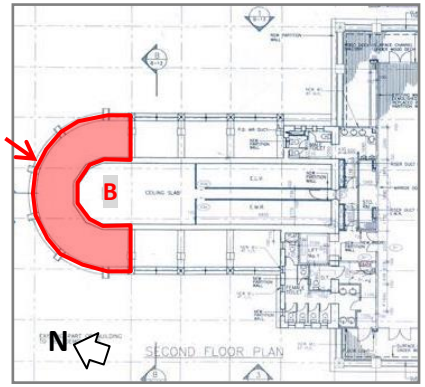


Face B-Norththwest,Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	2	0	0	3	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

Infrared Image No. 22 (IR22)

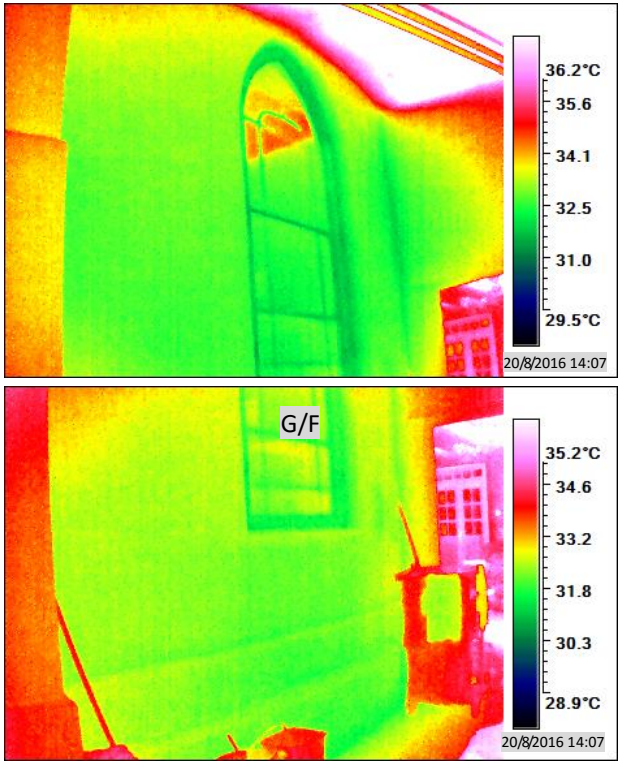


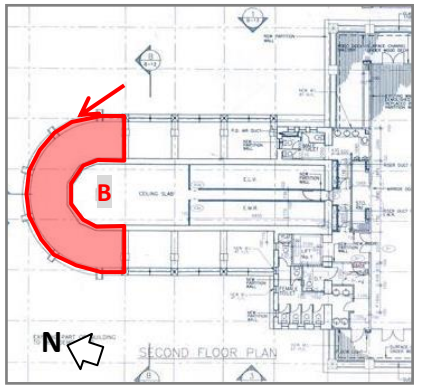




Face B-Norththwest,Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	1	0	0	1	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

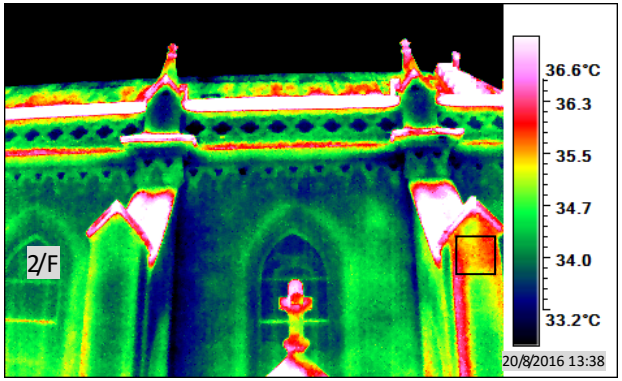
Infrared Image No. 23 (IR23)

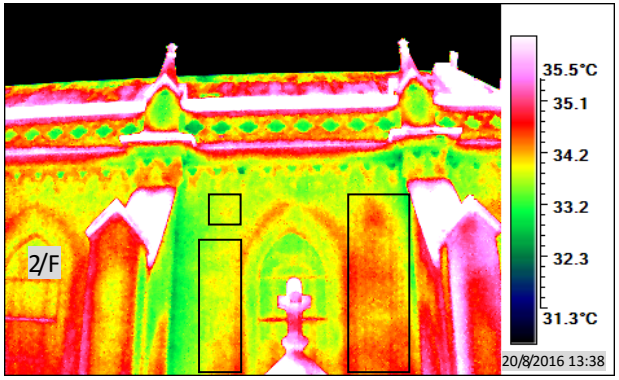


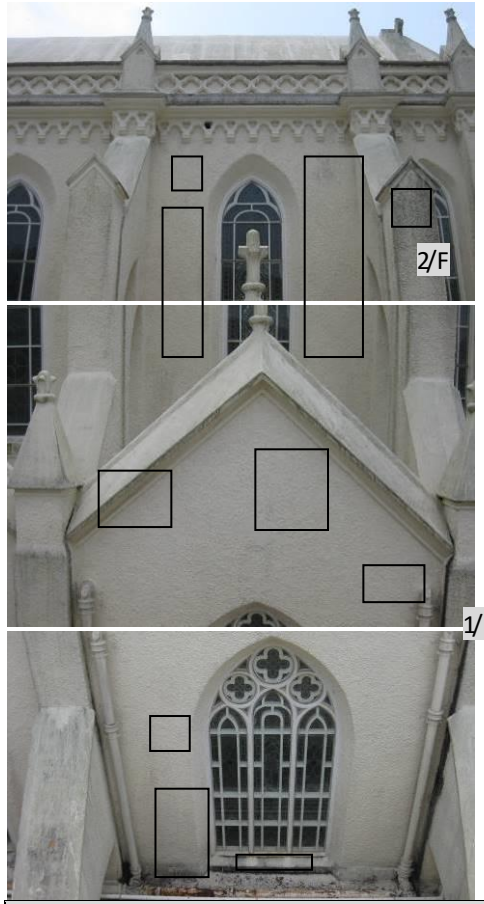


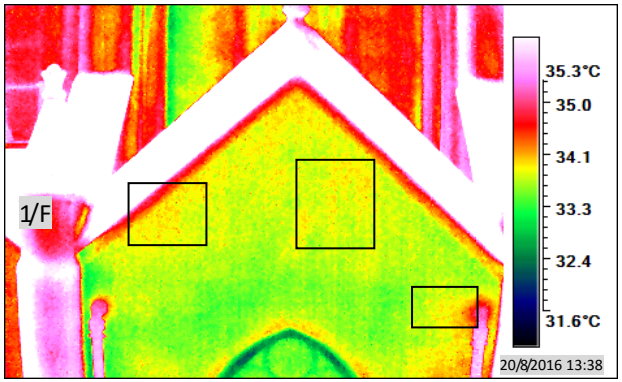
Face B-Norththwest,Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	0	0	0	0	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

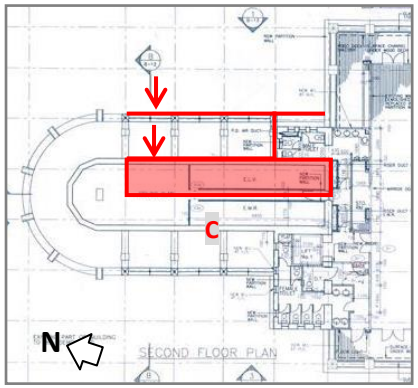
Infrared Image No. 24 (IR24)

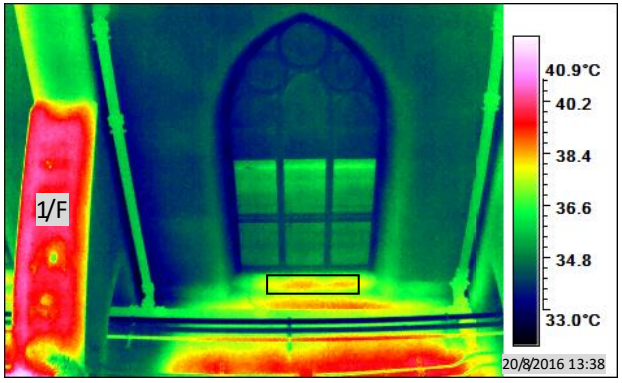


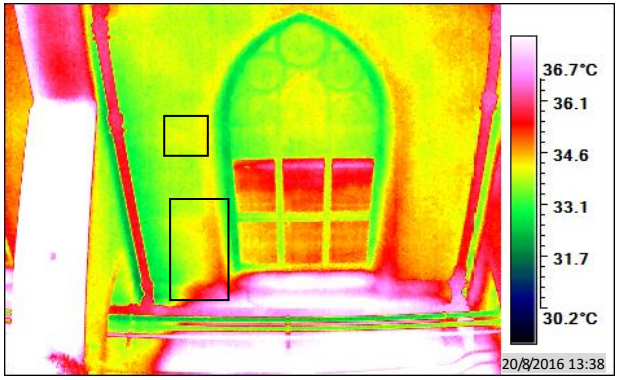






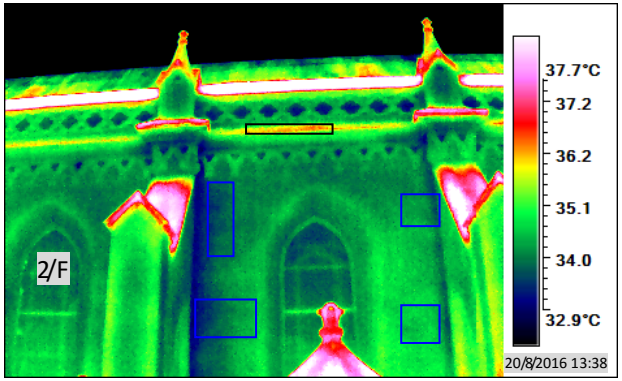


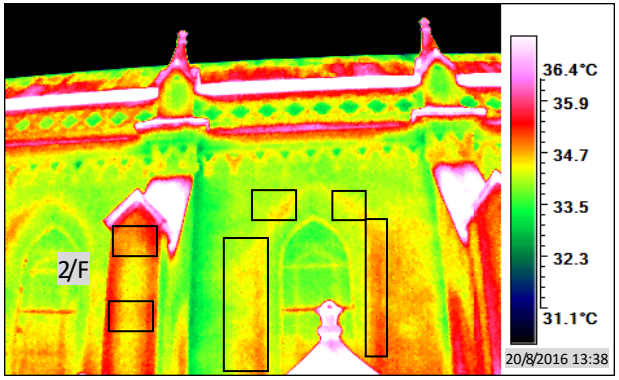


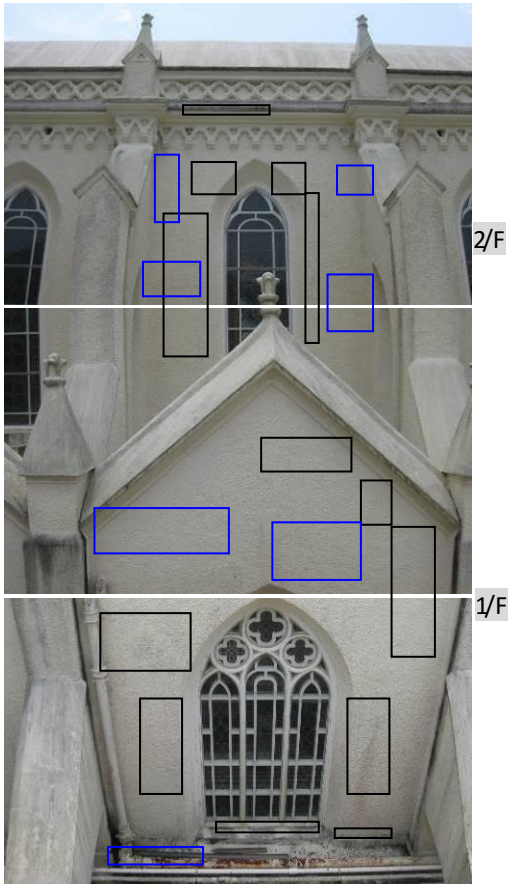


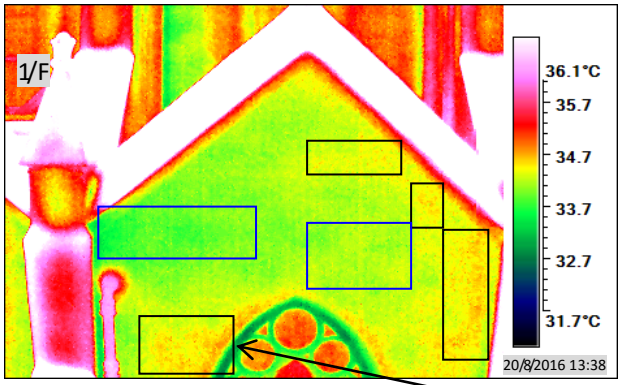
Face C- Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	10	0	0	0	0
Remarks	- No direct sunlight - Part of surfaces is surveyed under big view angle				

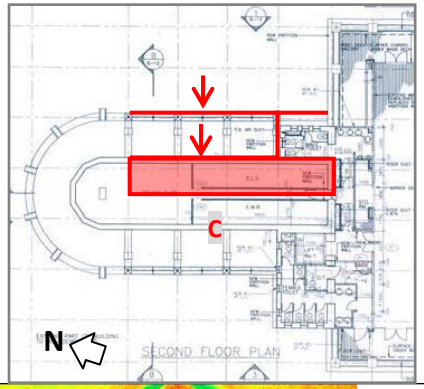
Infrared Image No. 25 (IR25)

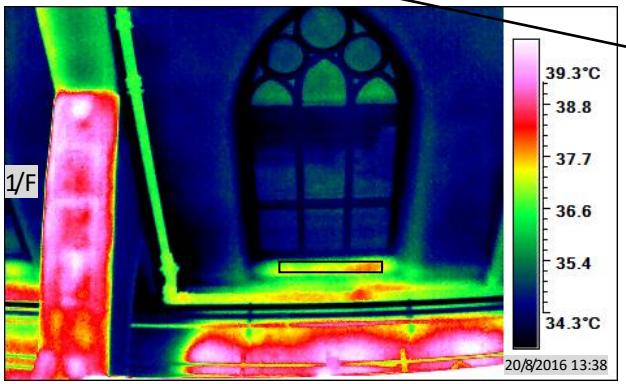


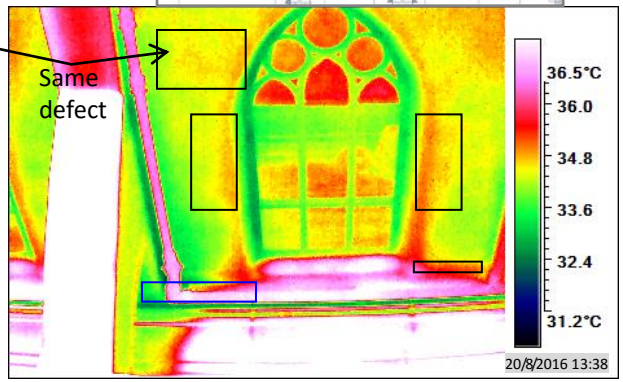






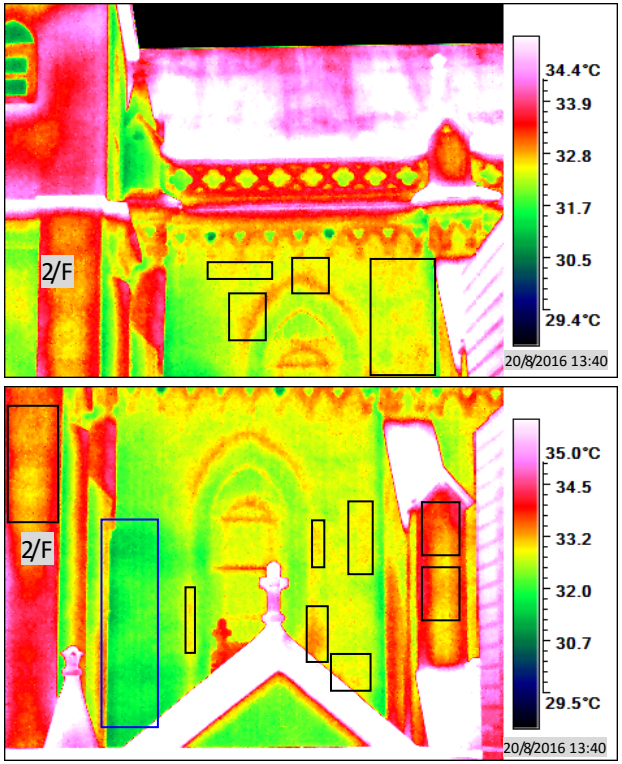


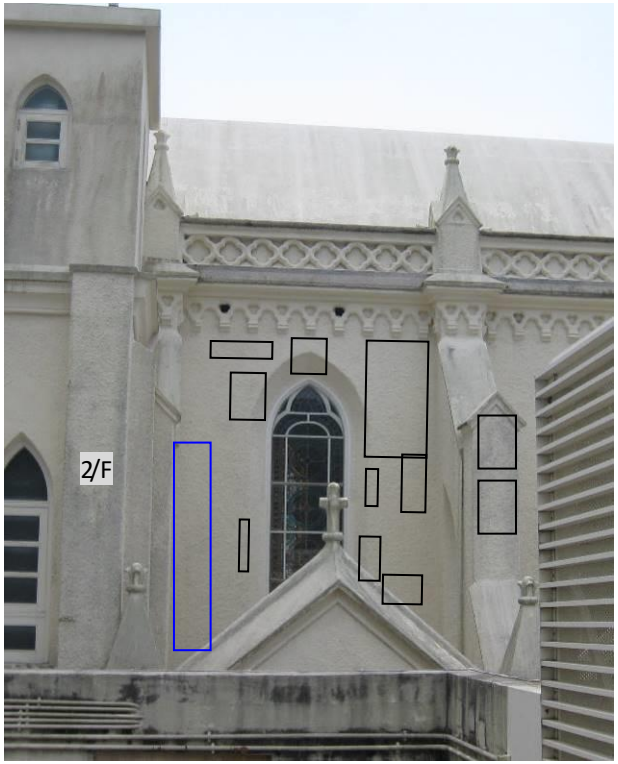


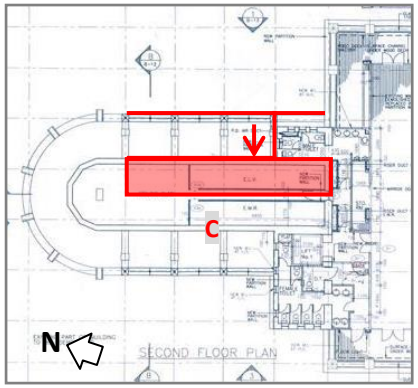


Face C- Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	13	0	0	7	0
Remarks	- No direct sunlight - Part of surfaces is surveyed under big view angle				

Infrared Image No. 26 (IR26)

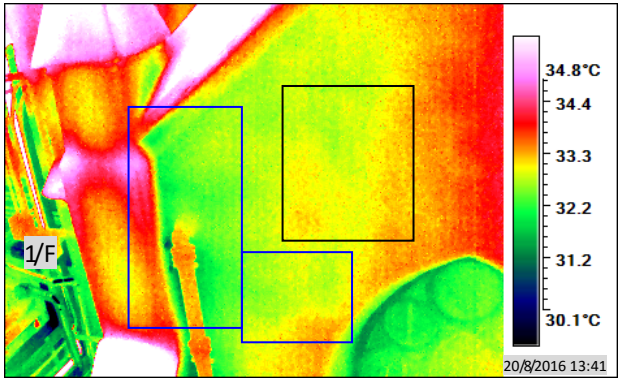


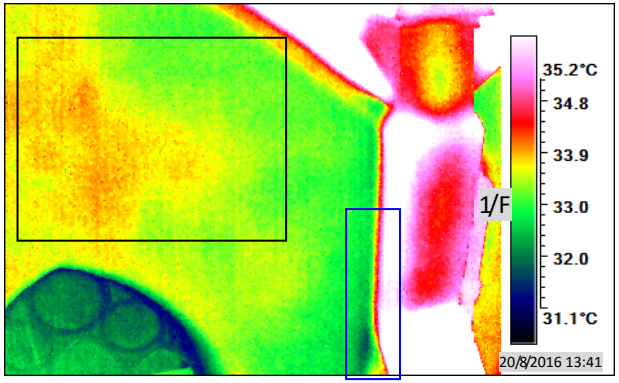


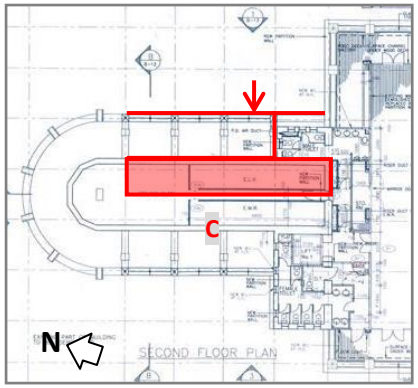


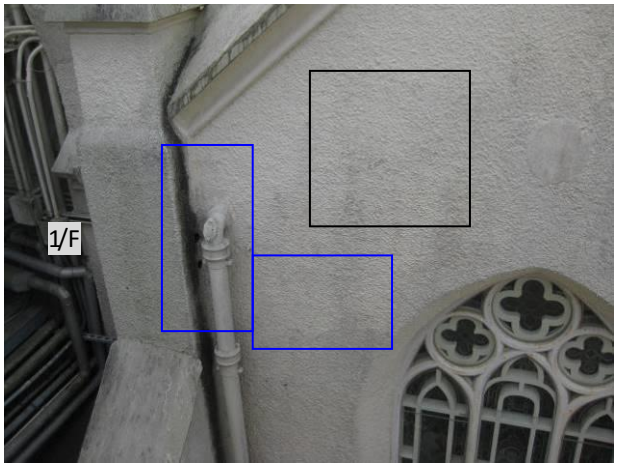
Face C- Northeast Elevation					
Floor	2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	11	0	0	1	0
Remarks	- No direct sunlight - Part of surfaces is surveyed under big view angle				

Infrared Image No. 27 (IR27)



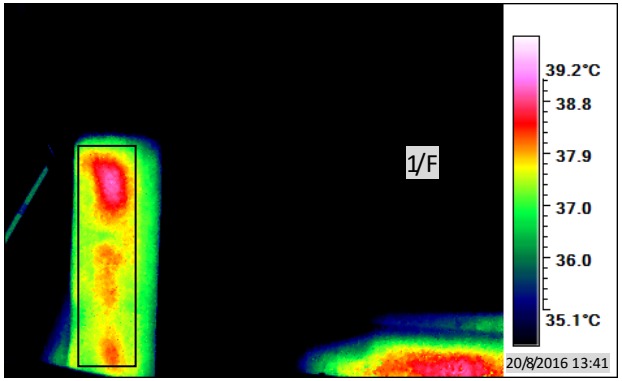


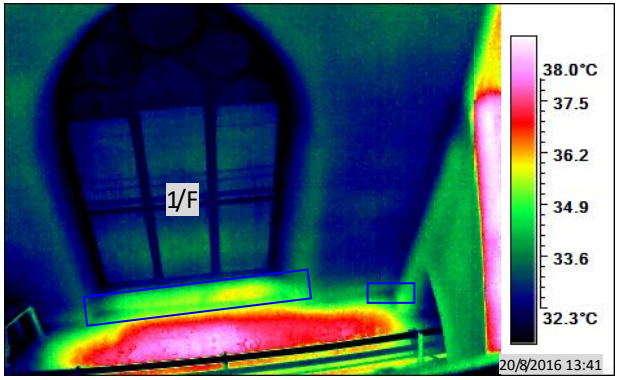


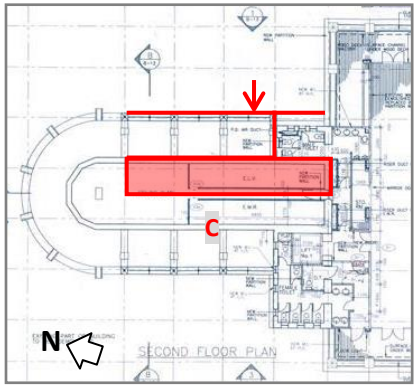


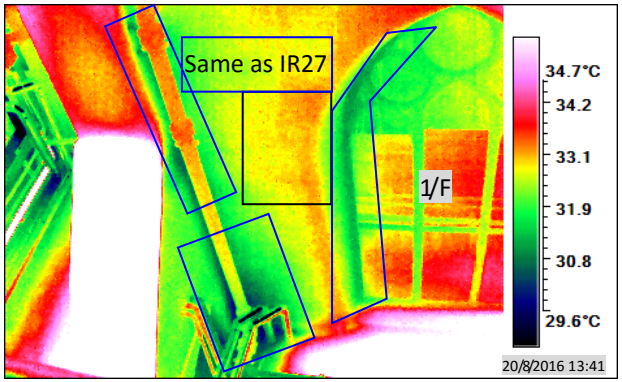
Face C- Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	2	0	0	3	0
Remarks	- No direct sunlight				

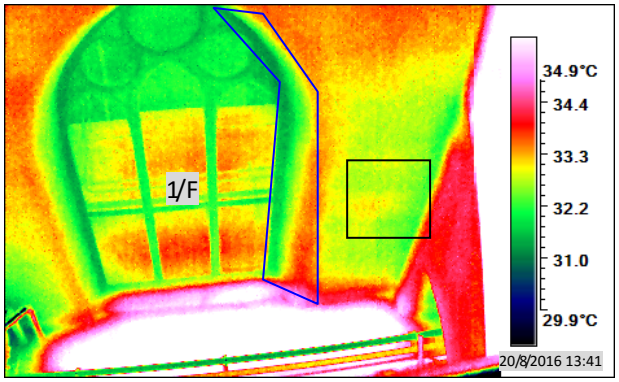
Infrared Image No. 28 (IR28)

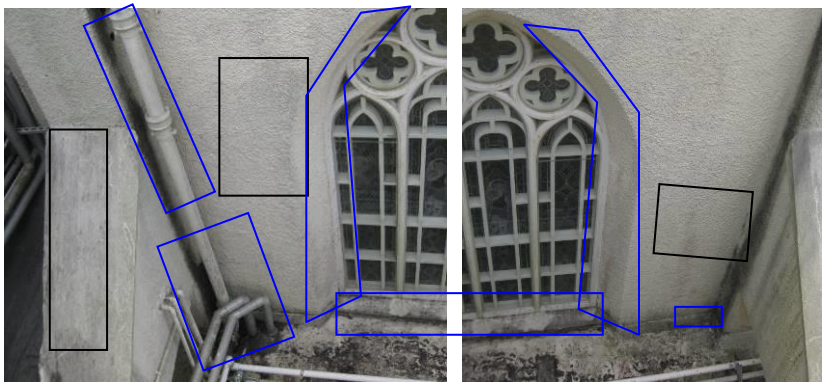






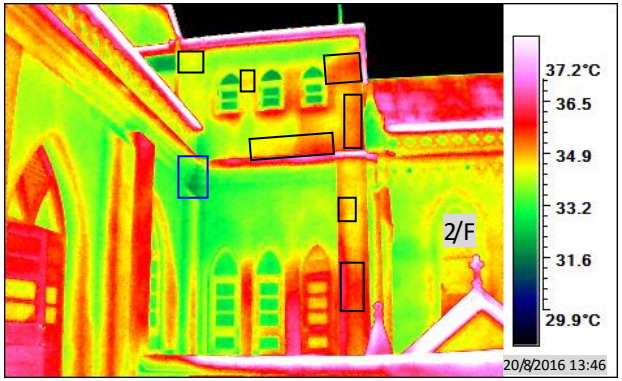


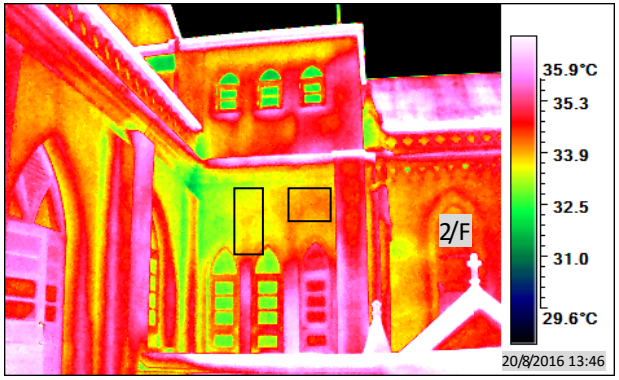


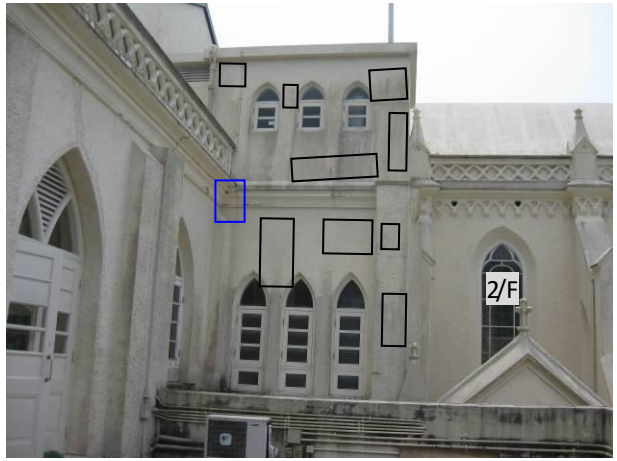


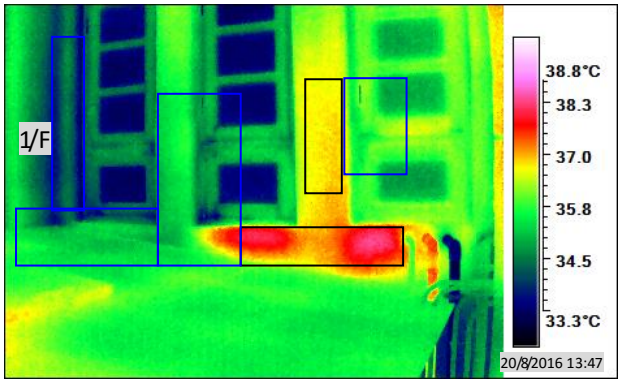
Face C- Northeast Elevation					
Floor	1/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	3	0	0	6	0
Remarks	- No direct sunlight - Part of surfaces is surveyed under big view angle				

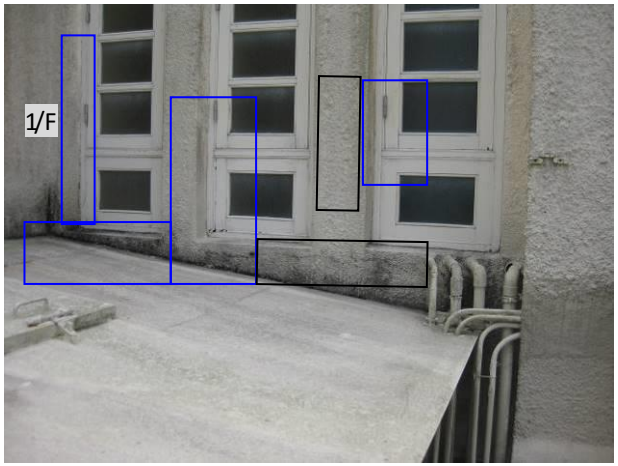
Infrared Image No. 29 (IR29)

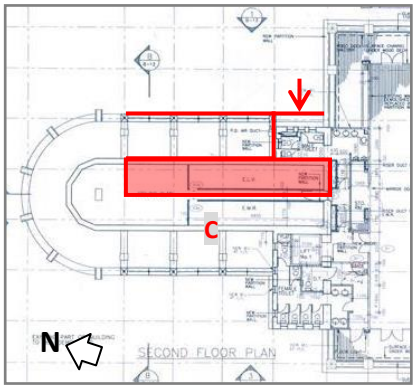






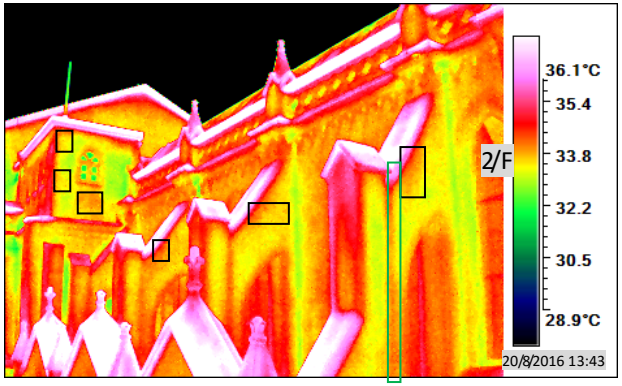


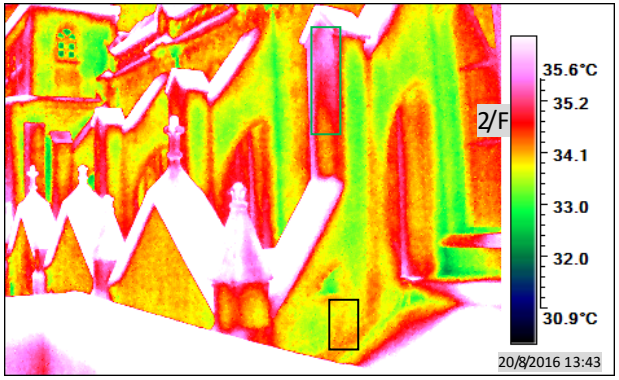


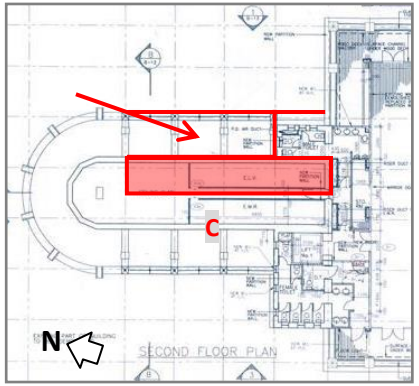


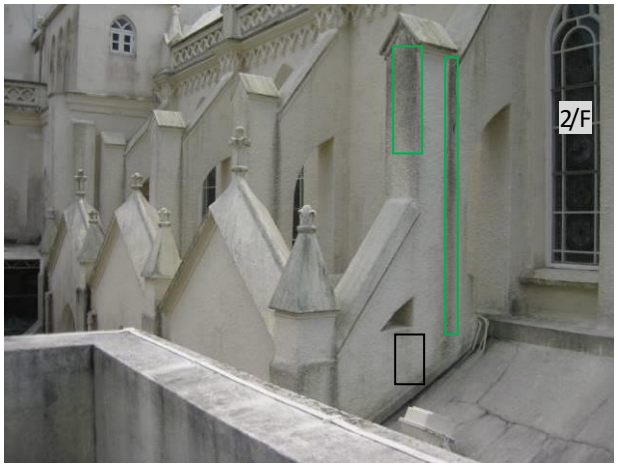
Face C- Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	11	0	0	5	0
Remarks	- No direct sunlight				

Infrared Image No. 30 (IR30)



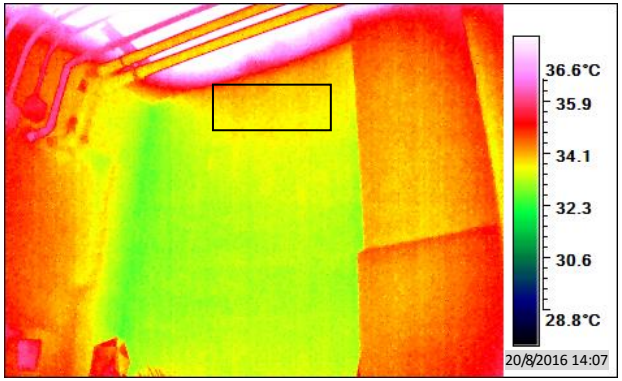


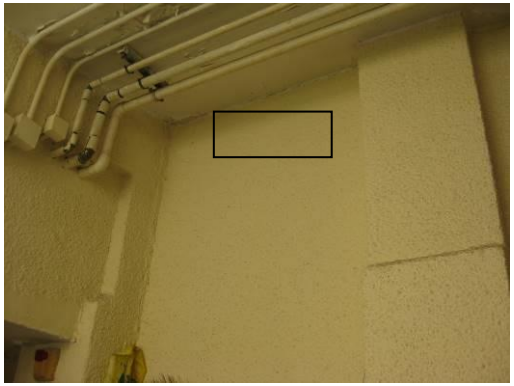


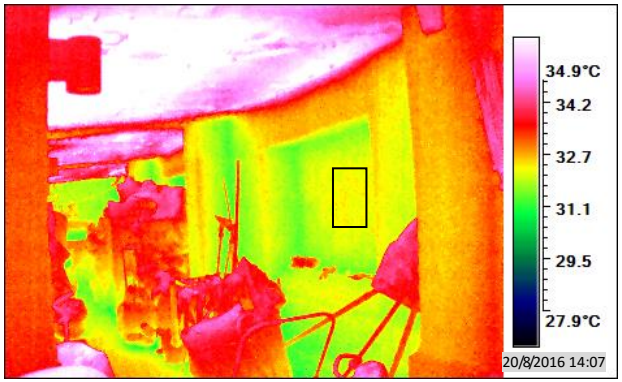


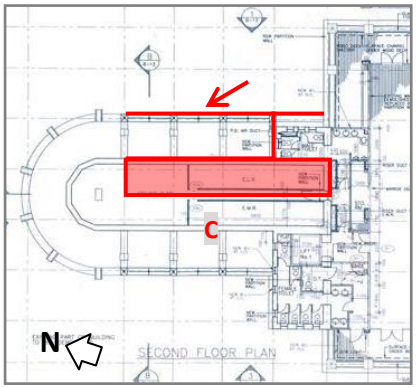
Face C- Northeast Elevation					
Floor	1/F-2/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	7	0	2	0	0
Remarks	- No direct sunlight - Part of surfaces is surveyed under big view angle				

Infrared Image No. 31 (IR31)



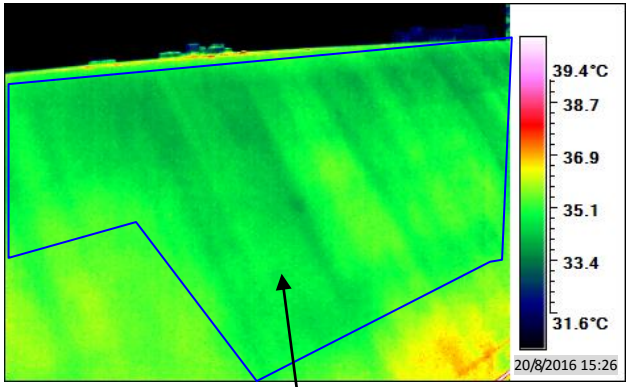


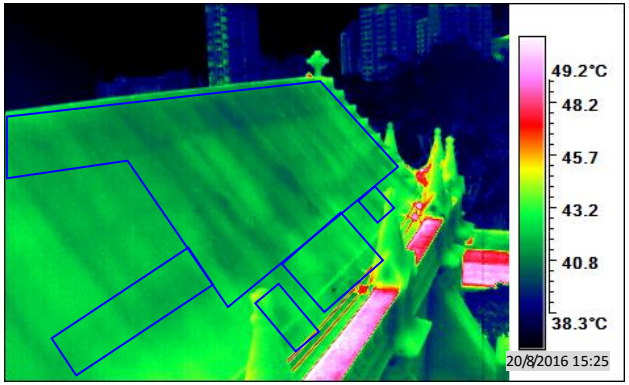


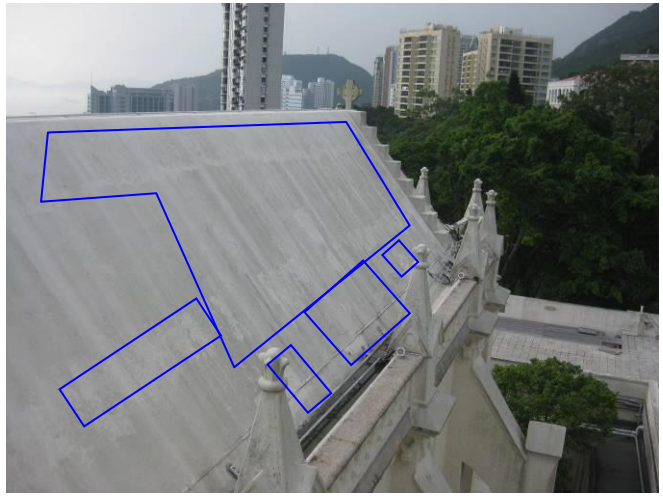


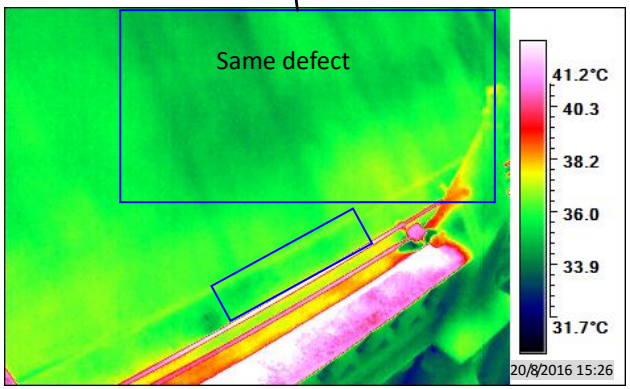
Face C- Northeast Elevation					
Floor	G/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	2	0	0	0	0
Remarks	- No direct sunlight -Part of the surfaces is screened/ shadowed				

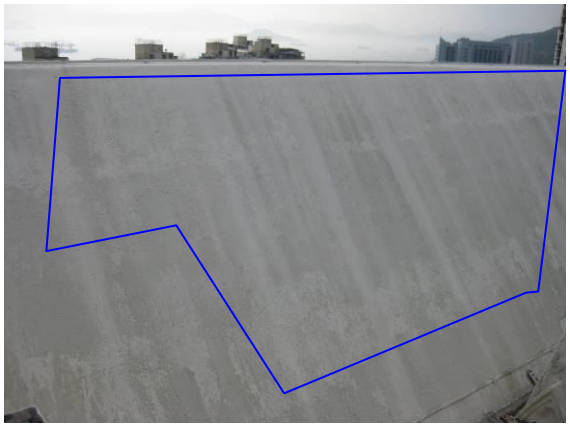
Infrared Image No. 32 (IR32)

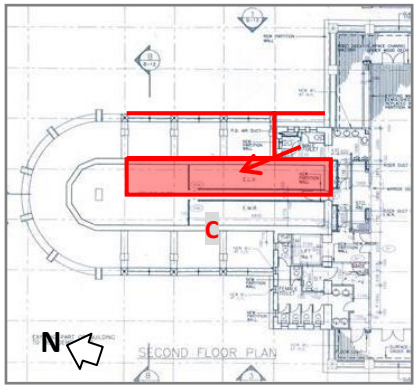






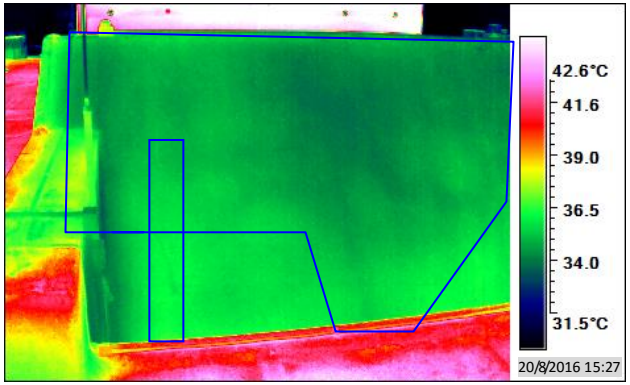


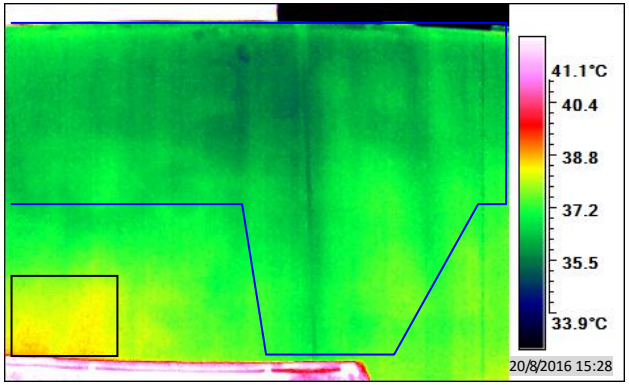


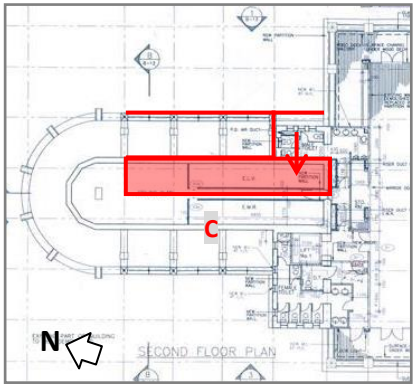


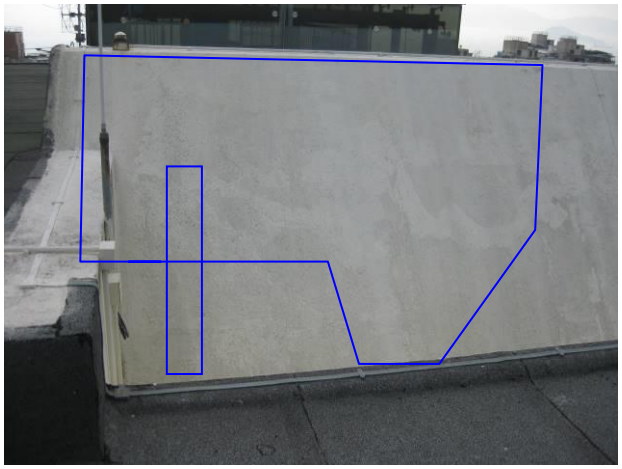
Face C- Northeast Elevation					
Floor	R/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	0	0	0	7	0
Remarks	- No direct sunlight - Part of surfaces is surveyed under big view angle				

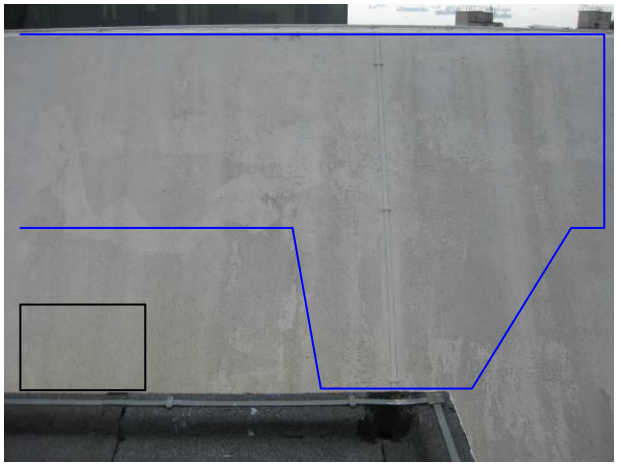
Infrared Image No. 33 (IR33)





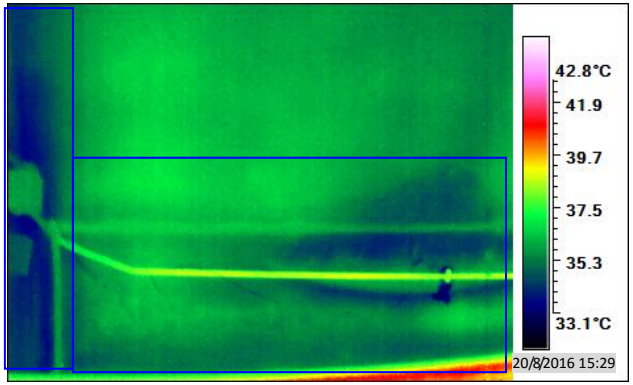


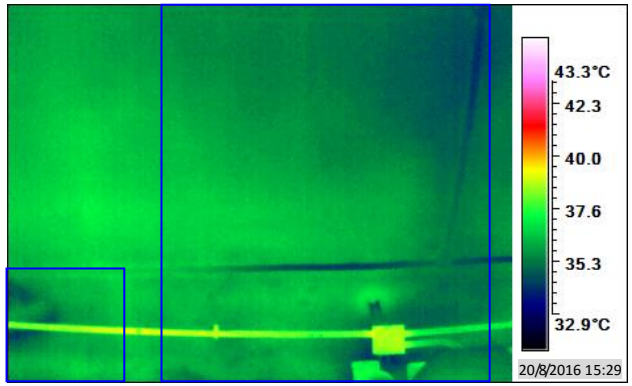


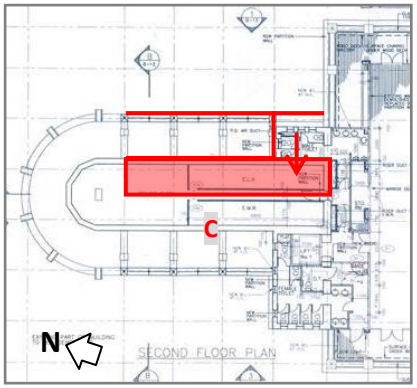


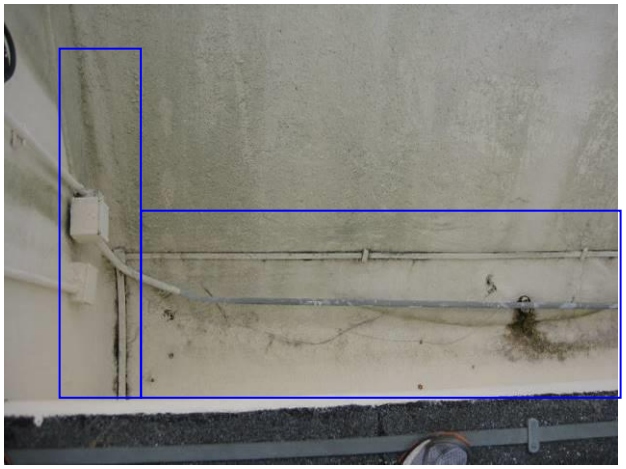
Face C- Northeast Elevation					
Floor	R/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	1	0	0	3	0
Remarks	- No direct sunlight				

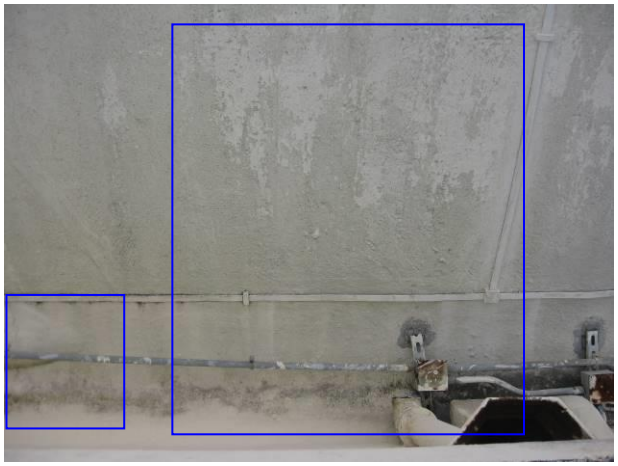
Infrared Image No. 34 (IR34)











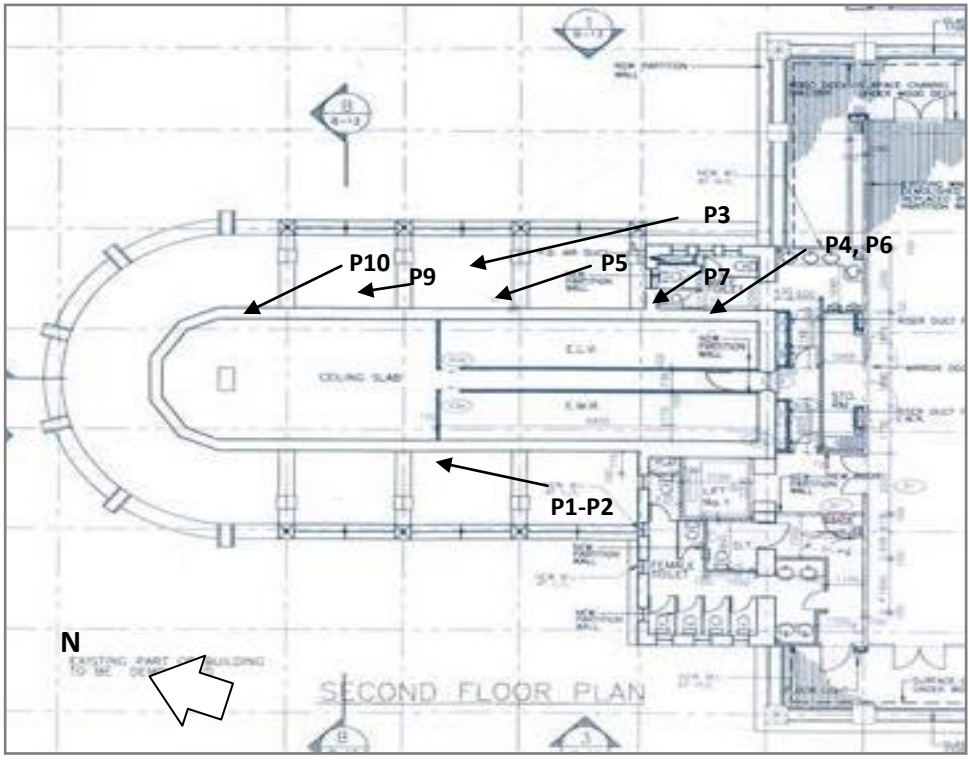
Face C- Northeast Elevation					
Floor	R/F				
Suspected defects found	**I**	**II**	**U**	**W**	**V**
	0	0	0	4	0
Remarks	- No direct sunlight				

Appendix C

Site Photos

Pitch Roof

Photography Record at Pitch Roof



P10 ← **Photographing direction and Photo Number**

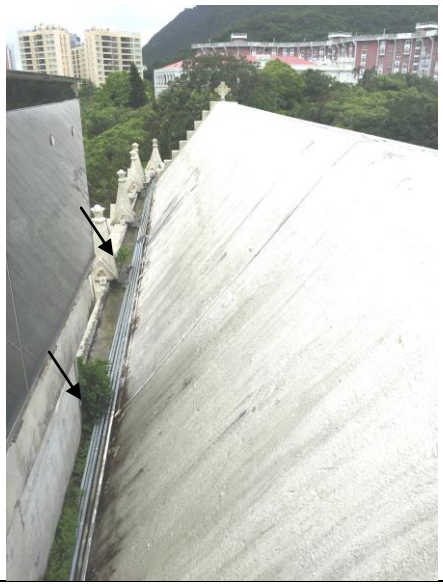


Photo P1 – Vegetation along the surface channel at the roof of the Bethanie observed

Photo P2 – Impaired and deteriorated water proofing membrane noted at the roof

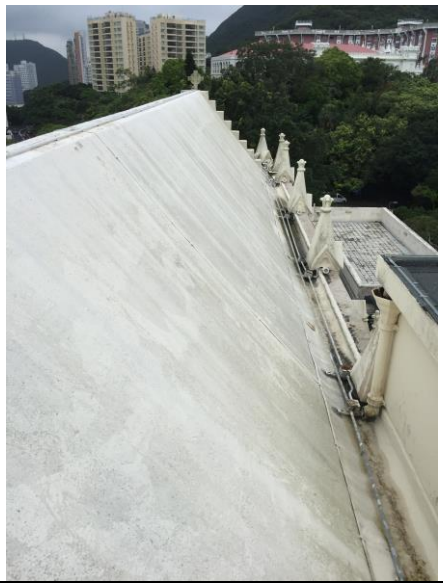


Photo P3 – Cracked and aging of the waterproofing membrane at the roof noted

Photo P4 – Pack of water trapped under the roof waterproofing membrane

Photo P5 – Drain outlet is higher than the surface channel

Photo P6 – Conduit anchor punched through the water proofing membrane and water flowing from inside

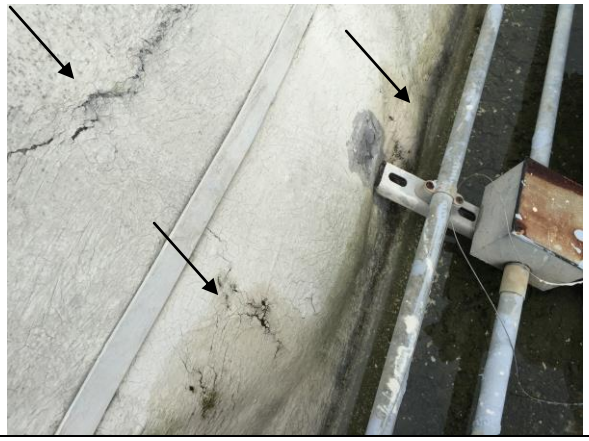


Photo P7 – bluged and cracked water proofing membrane is observed

Photo P8 – Water ponding at the surface channel of the pitch roof due to the inappropriate floor level and level of the drain

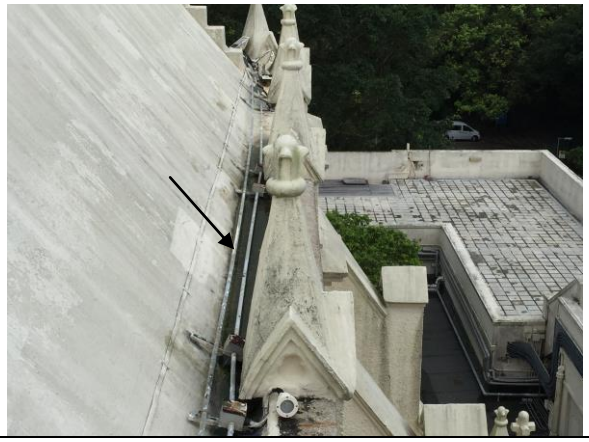


Photo P9 – Water ponding at the surface channel of the pitch roof due to the inappropriate floor level and level of the drain

Photo P10 - Cracked water proofing membrane is observed

領峰工程顧問有限公司
Reachable Engineering Consultants Ltd.
Room 2305, 23/F., Marina House, No. 68 Hing Man Street, Shaukeiwan, H.K.
Tel: 21173 481 Fax.: 3007 0203 Email: reach_service@yahoo.com.hk / info@reachable.com.hk

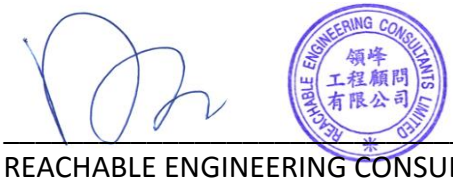
REPORT OF

WATER SEEPAGE INVESTIGATION AT THE INTERNAL WALL OF

BETHANIE
NO. 139 POK FU LAM ROAD, HONG KONG

Location	:	**Bethanie** **No. 139 Pok Fu Lam Road, Hong Kong**
Survey Date	:	**14th July & 22nd August 2016**
Report Date	:	**12th September, 2016**
Our Contract No.	:	**I16-038A**
Client	:	**Substance Lab Limited**

REPORT PREPARED BY



REACHABLE ENGINEERING CONSULTANTS LTD.
CERTIFIED INFRARED THERMOGRAPHER LEVEL II
NO.2011MY29N010
(INFRARED TRAINING CENTRE – SWEDEN)

TABLE OF CONTENT

1. INTRODUCTION 2

2. SURVEY INFORMATION 2

3. SURVEY METHODOLOGY 2-3

4. RESULT 3

5. CAVEAT 3

Appendix A Survey findings

Appendix B Infra-red images and photo record

Appendix C Protimeter Moisture Test

1. INTRODUCTION

We are instructed to carry out Infrared Thermography Inspection for the water leakage investigation at the internal wall of Bethanie, No. 139 Pok Fu Lam road, Hong Kong.

Purpose of this investigation is to inspect the water leakage condition of the exposed internal wall at the Chapel specified by the client.

2. SURVEY INFORMATION

Survey Date:	14th July & 22nd August 2016
Operation Team:	Ms. Antonia Tsoi & Mr. Chung Sheung Chi
Equipment Used:	Thermography System: TP8s Series (8-14μm wavelength, 0.08°C at 30°C Sensitivity) Wind Speed Measuring Device: Lutron AM-4202 Humidity Measuring Device: Chino HN-CHNR Temperature Measuring Device: UNI_T UT325 Digital Camera GE Protimeter - Protimeter Surveymaster
Survey Location:	Exposed surface instructed by the client
Supplementary Method:	Visual Inspection/ Hand Touching

3. SURVEY METHODOLOGY

Every object above absolute zero emits Infra-red energy. Thermograph is a process by which differences in the heat can be converted into a thermal image by application of the use of specialized scanning cameras.

Under certain ambient condition, buildings with surface defects in the form of debonding render, mosaic tile or delaminating concrete emit differing amounts of infra-red radiation. When the surface is heating up by the sun or

environment, areas that are defective will show up as a result of their differential transmittance of infra-red radiation, it indicates that there anomalies inside behind the surface finishes. Further attention is recommended.

Interim Technical Guidelines on The Inspection, Assessment and Repair or Buildings for the Building Safety Inspection Scheme (BSIS), published by Buildings Department was used as our guidelines, where applicable.

Visual observation, Protimeter Moisture Test and simple hand touching was also used to verify any water trapped or other flaw existed if accessible.

4. RESULT

Sign of suspected water leakage is found during the survey.

(Details, refer to Appendix A)

5. CAVEAT

a. Contents of the report should not be disclosed to other non-relevant parties without consent.

b. This report was only addressed to the areas accessible during the investigation date. In addition, no destructive testing to the roofing system and no opening-up inspection had been carried out.

- END -

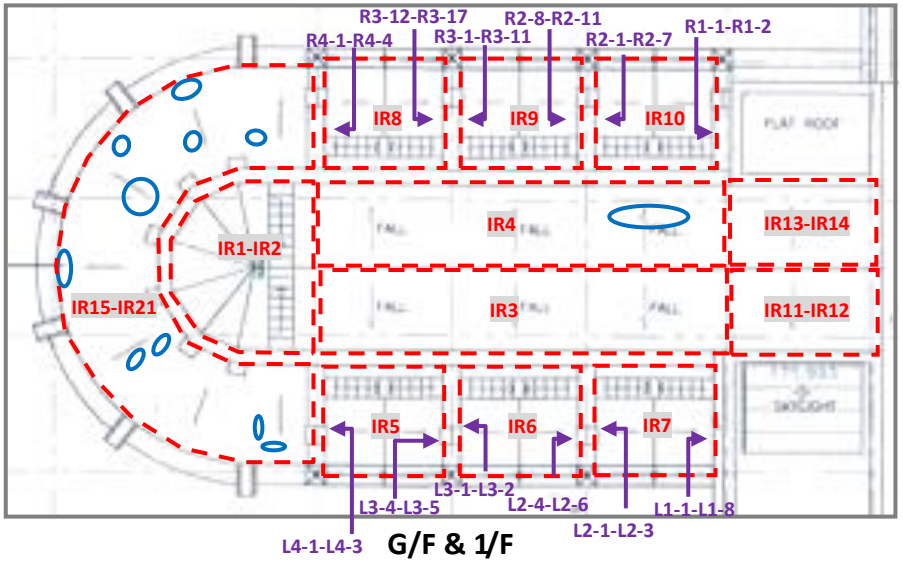
Appendix A

Summary of Findings

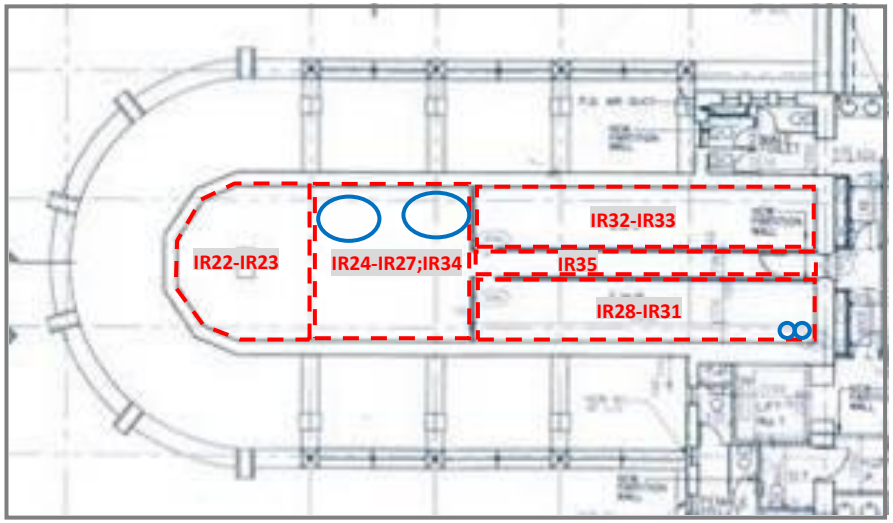
Summary of findings No. 1 (A1)

Legend

- Survey area & IR Numbers
- Moisture Measurement Numbers
- Suspected water leakage under Infrared Thermography Inspection (can refer to Appendix B)
- Relative High Moisture Reading found under Protimeter Moisture Test (can refer to Appendix C)



G/F & 1/F

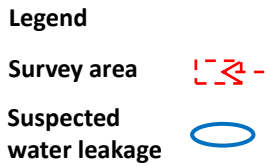


2/F

Comment:
Sign of suspected water leakage was noted after raining

Appendix B

IR Images Findings



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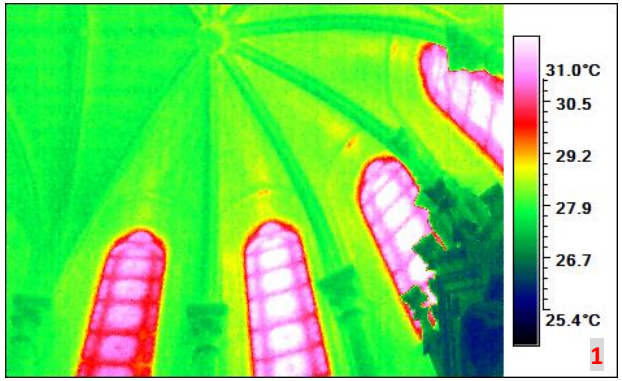

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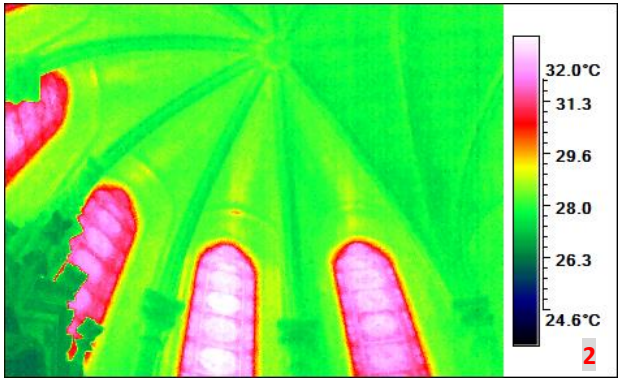

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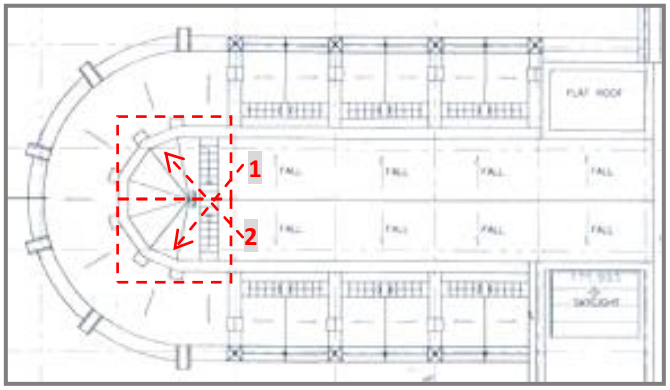
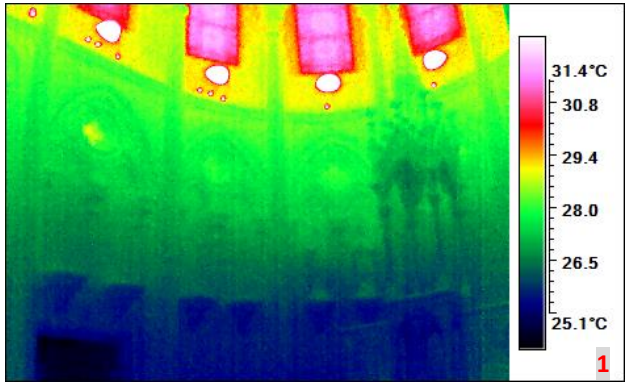
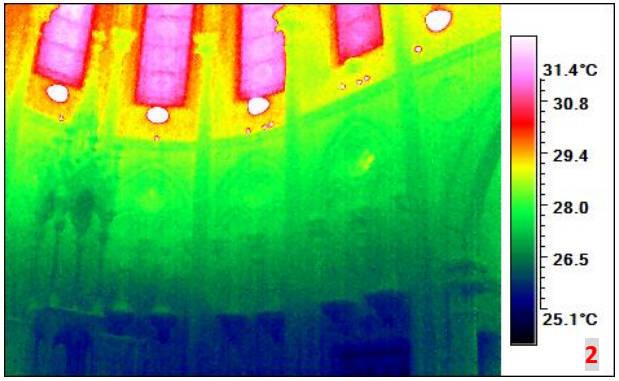
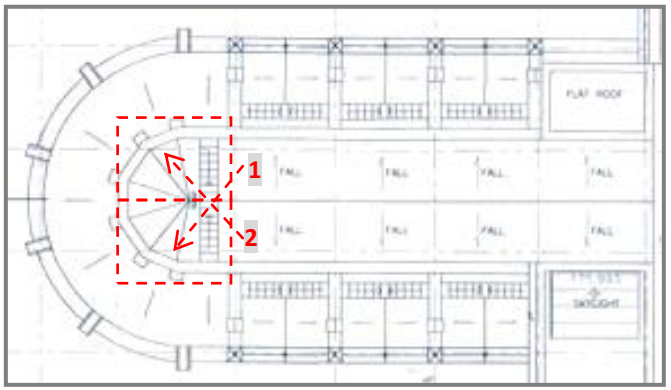


Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

Infrared Image No. 2 (IR2)







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2016/07/14 10:18

Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

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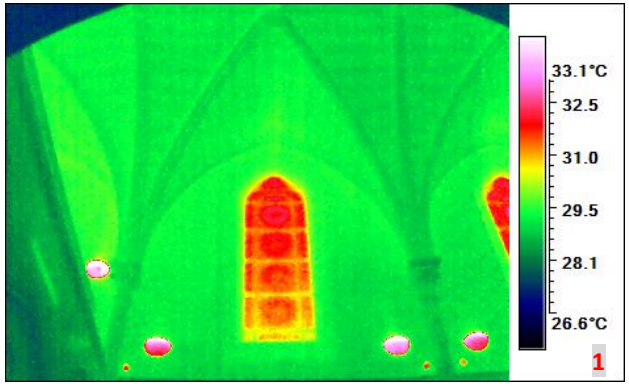

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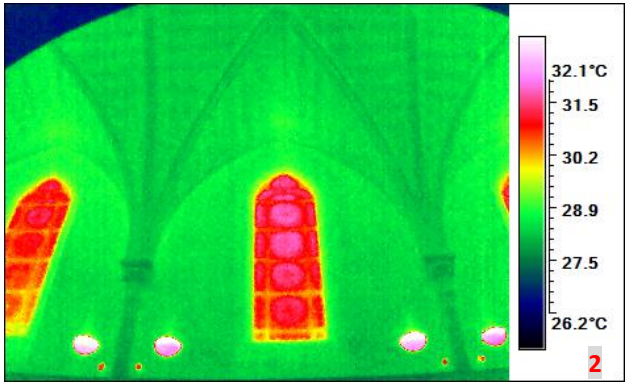

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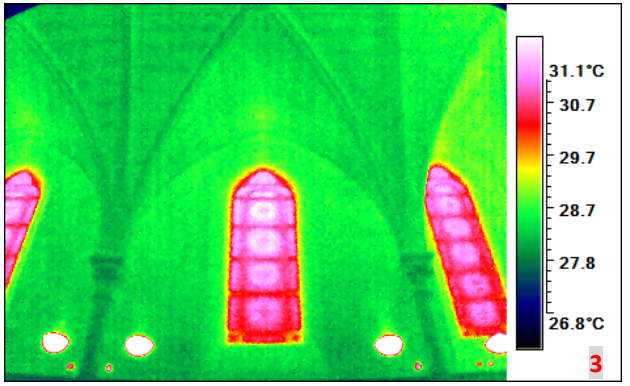

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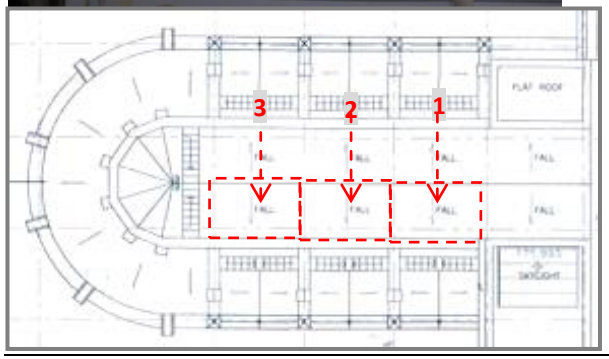

Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

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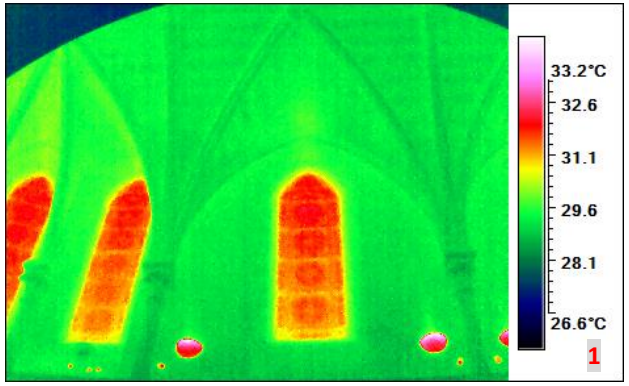

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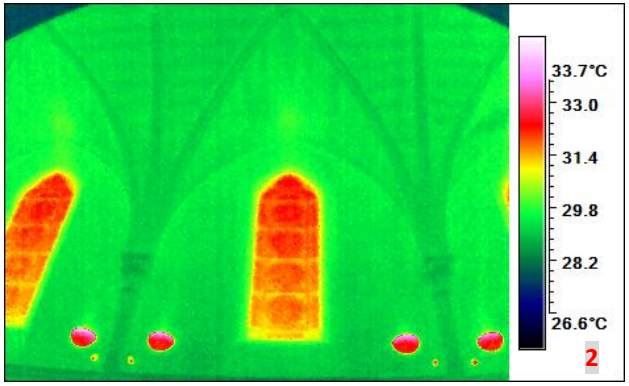

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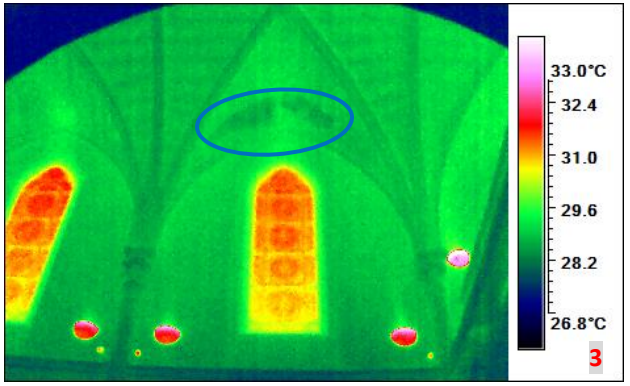

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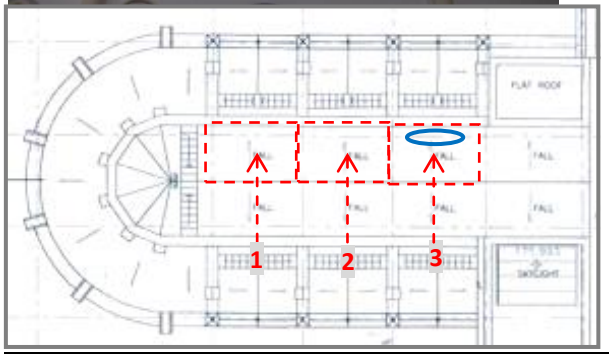

Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

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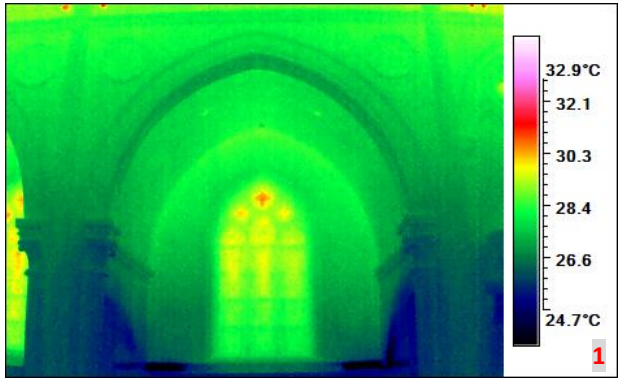

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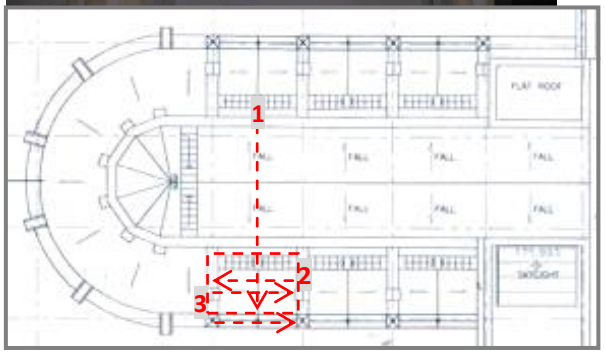

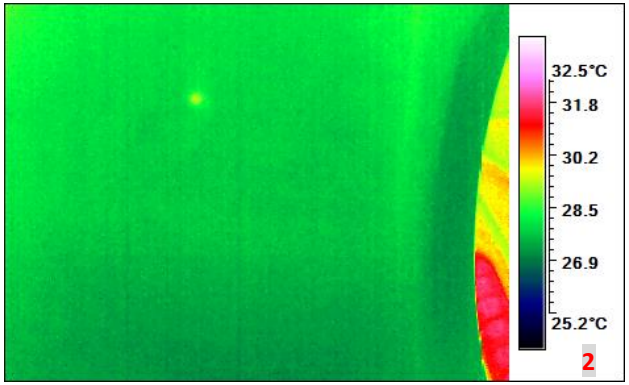

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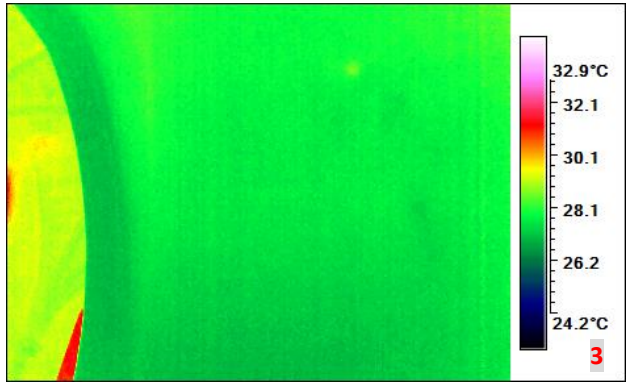

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Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

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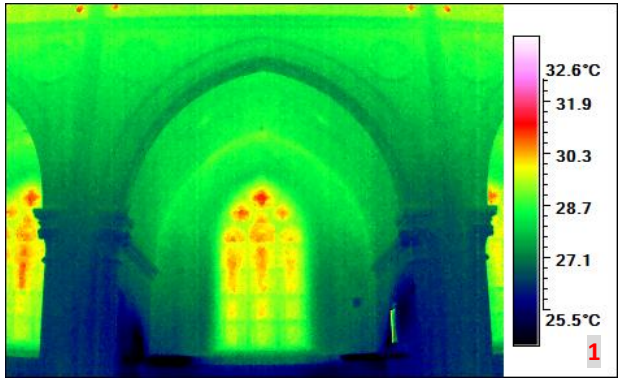

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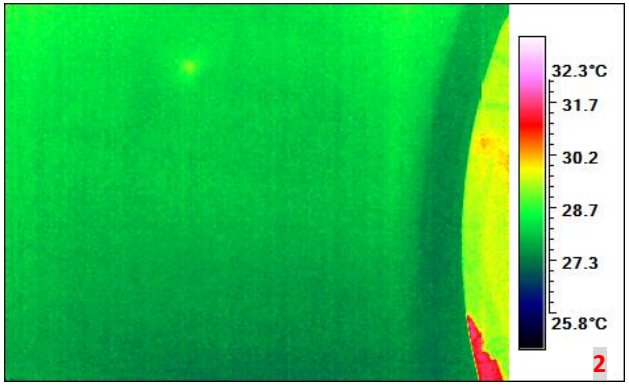

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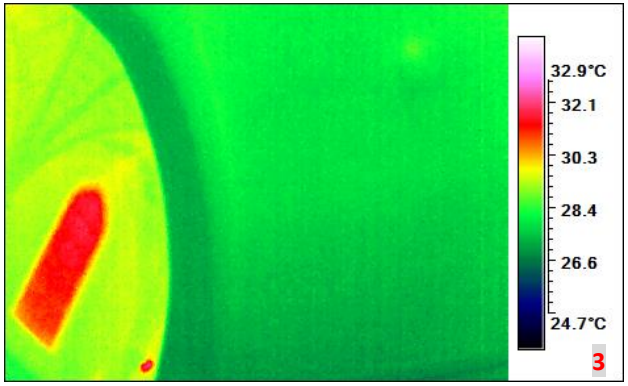

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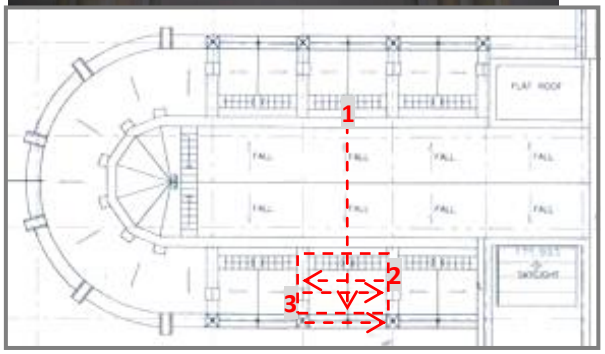

Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

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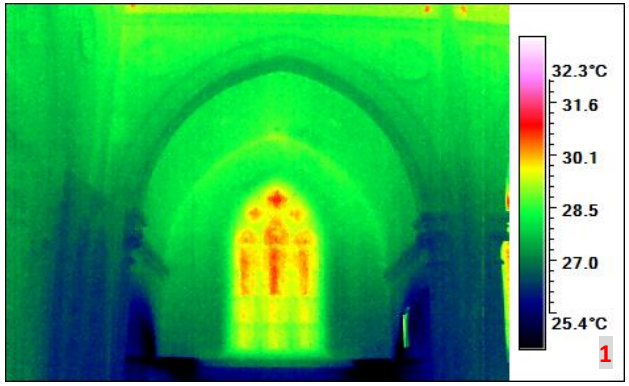

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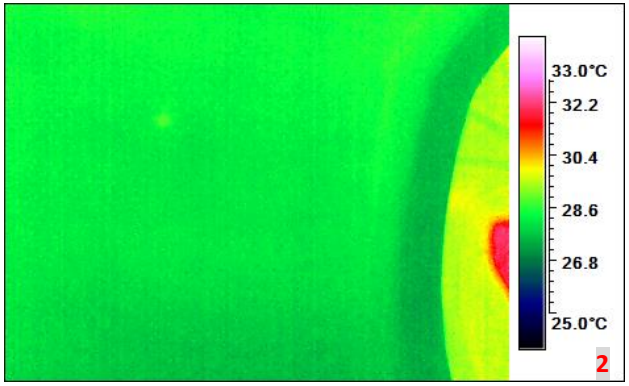

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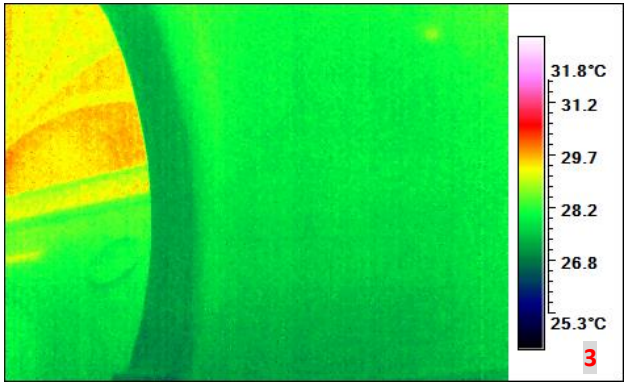

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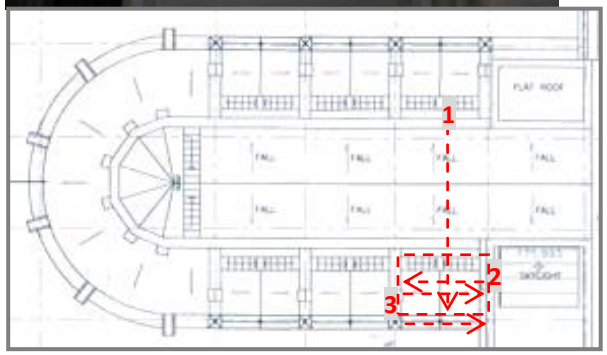

Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

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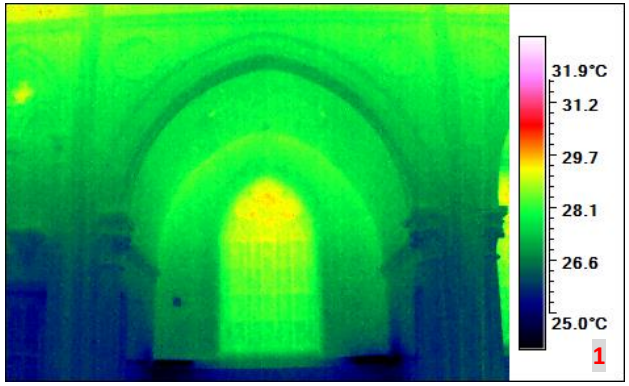

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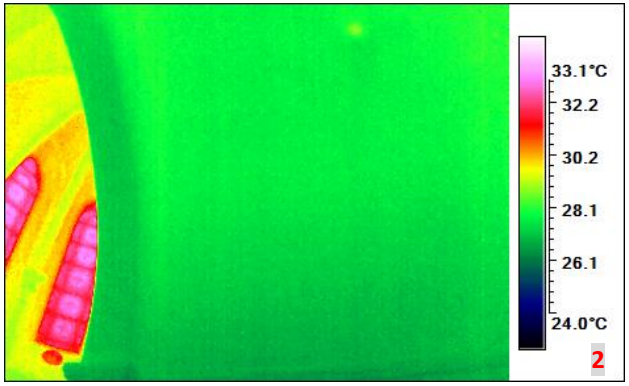

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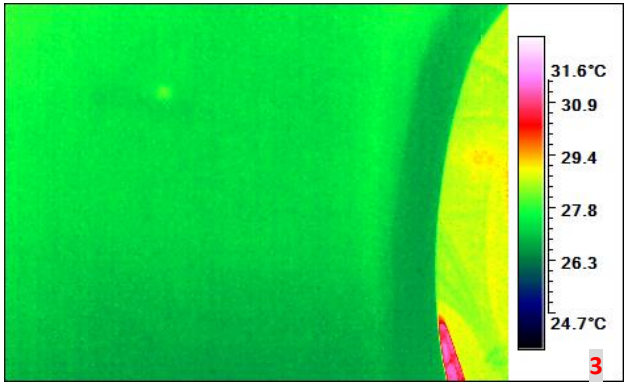

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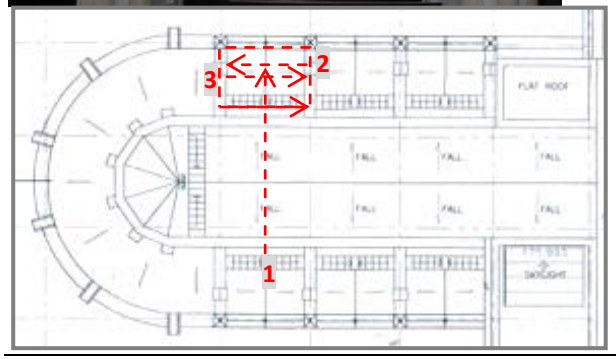
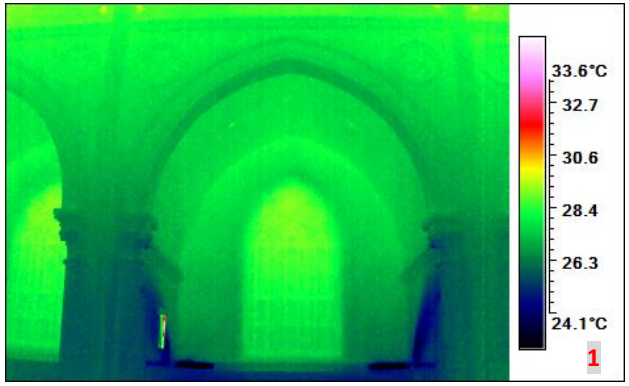
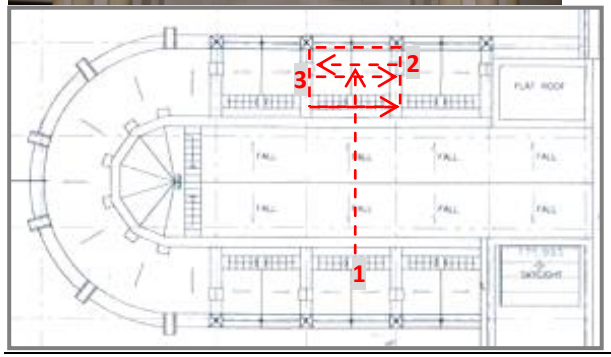


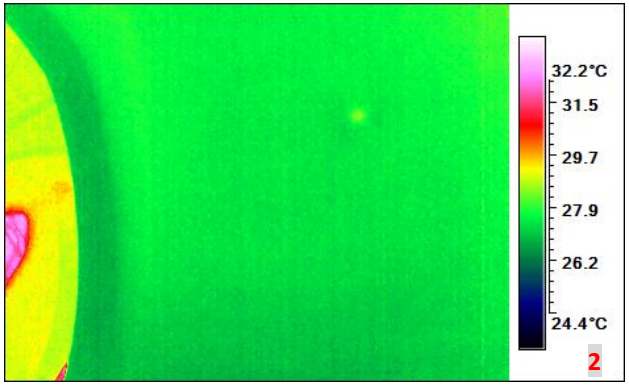
Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

Infrared Image No. 9 (IR9)



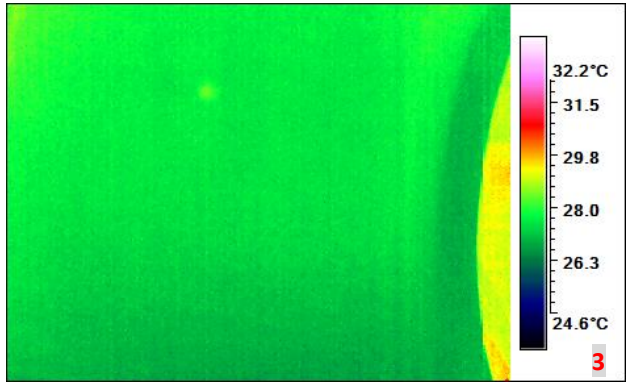
2016/07/14 10:38





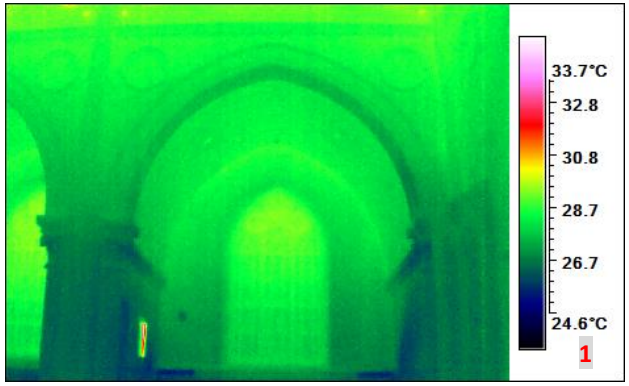
2016/07/14 10:39

Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

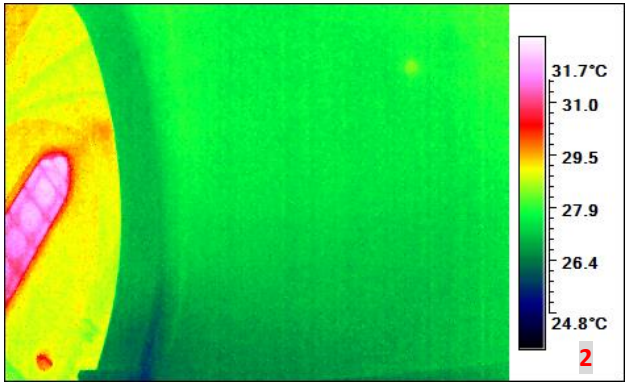


2016/07/14 10:39

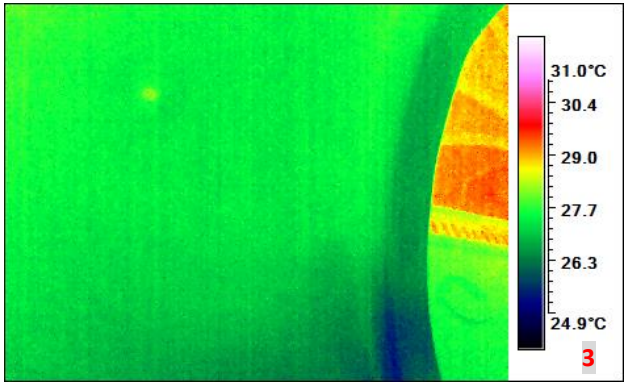
Infrared Image No. 10 (IR10)



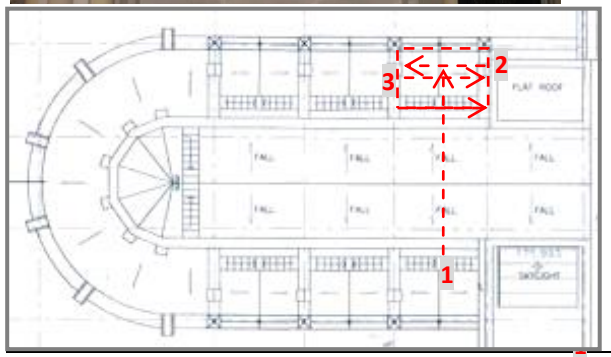
2016/07/14 10:43



2016/07/14 10:44

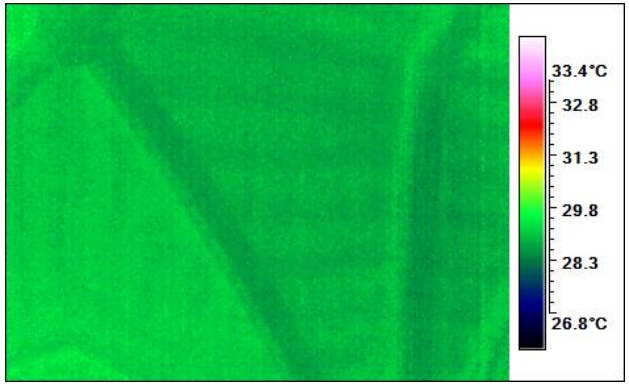


2016/07/14 10:45

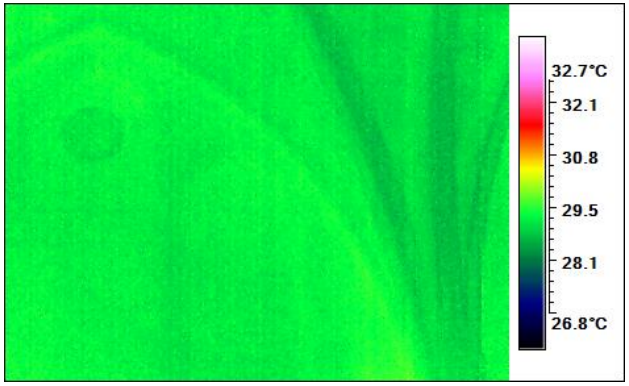


Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

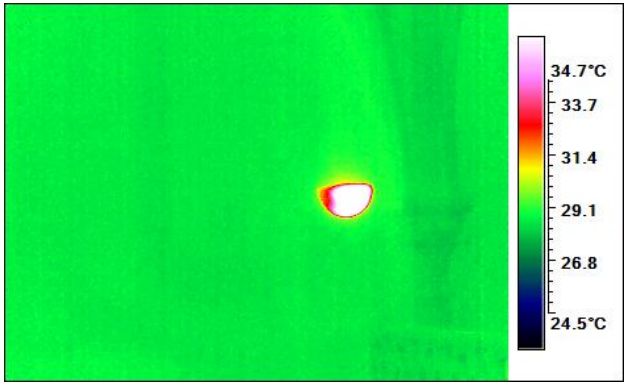
Infrared Image No. 11 (IR11)



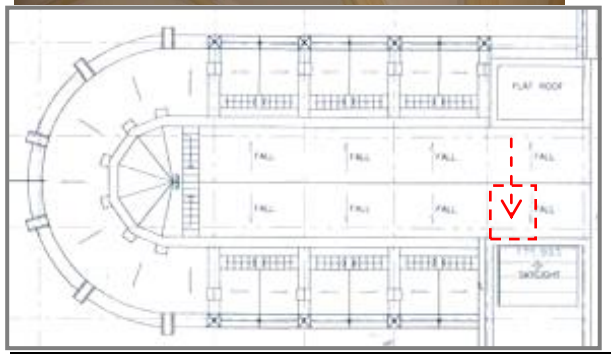
2016/07/14 10:48



2016/07/14 10:48

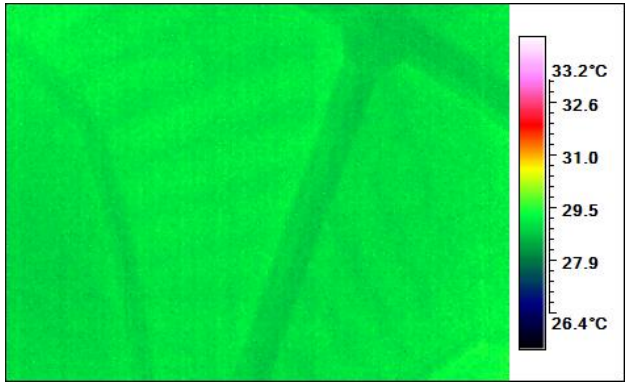


2016/07/14 10:48

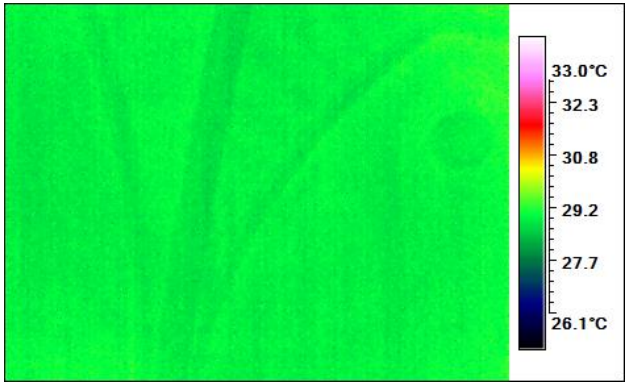


Bethanie Chapel	
Location	1/F
Remarks	No sign of water/moisture was noted after raining

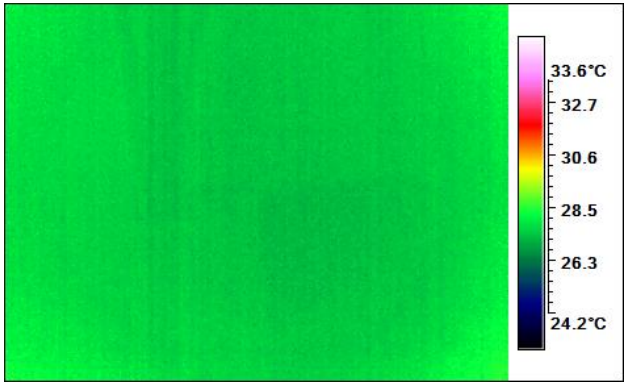
Infrared Image No. 12 (IR12)



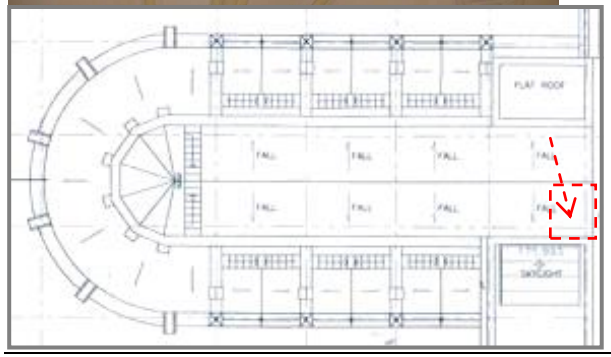
2016/07/14 10:51



2016/07/14 10:51

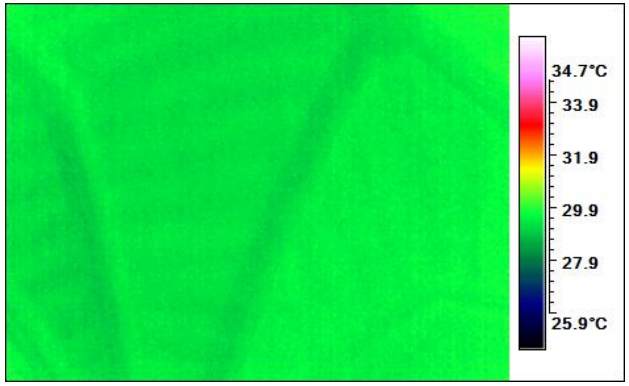


2016/07/14 10:51

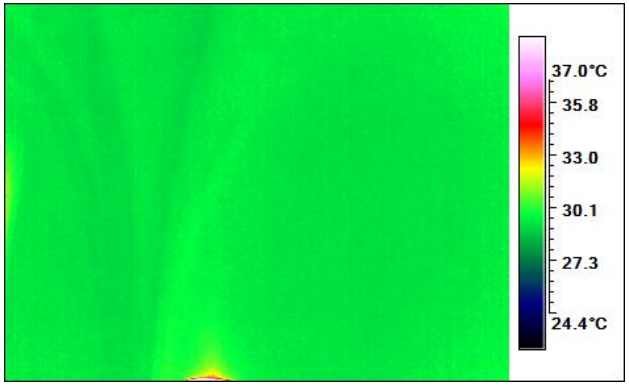


Bethanie Chapel	
Location	1/F
Remarks	No sign of water/moisture was noted after raining

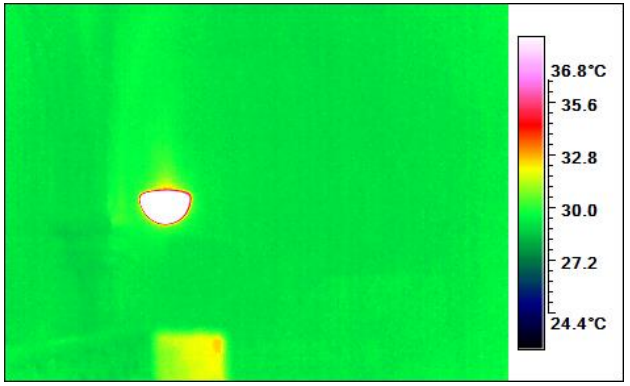
Infrared Image No. 13 (IR13)



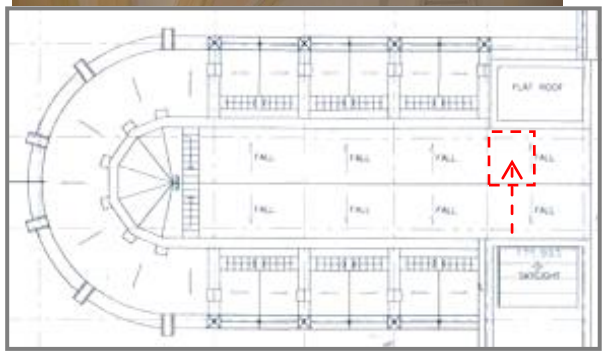
2016/07/14 10:52



2016/07/14 10:52

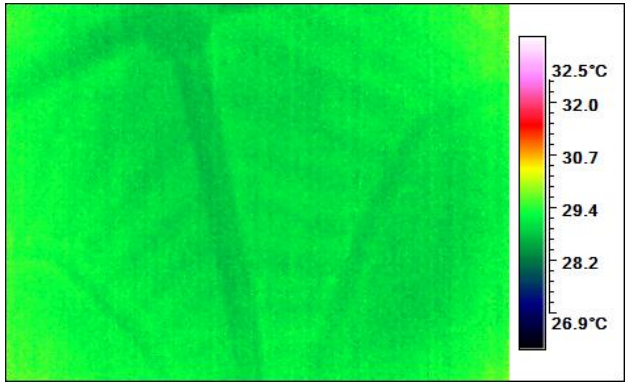


2016/07/14 10:52

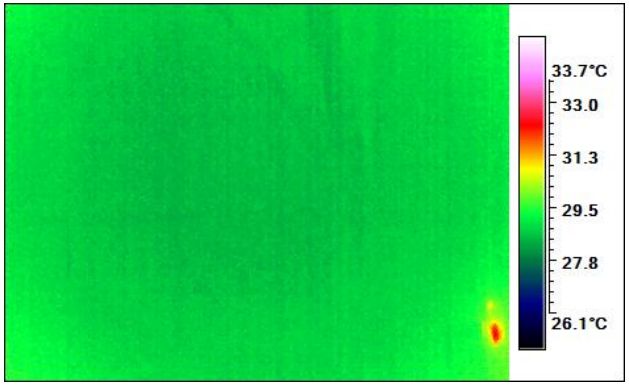


Bethanie Chapel	
Location	1/F
Remarks	No sign of water/moisture was noted after raining

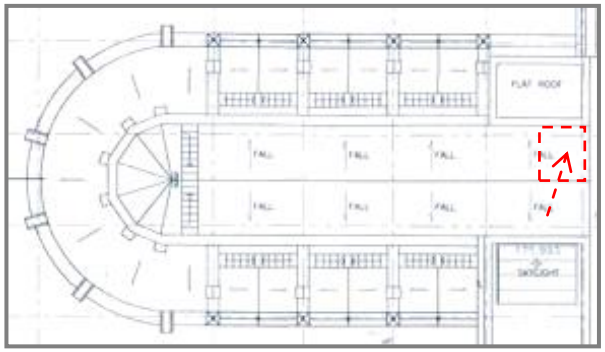
Infrared Image No. 14 (IR14)



2016/07/14 10:53

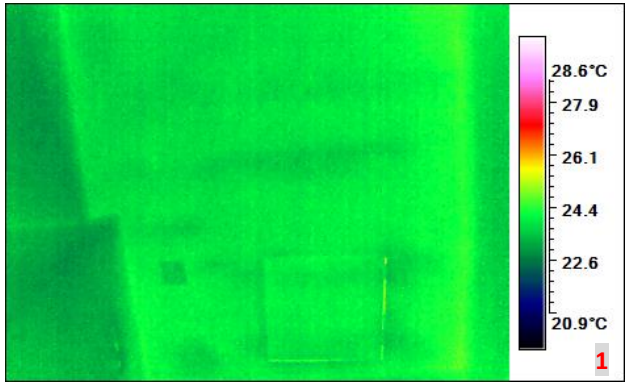


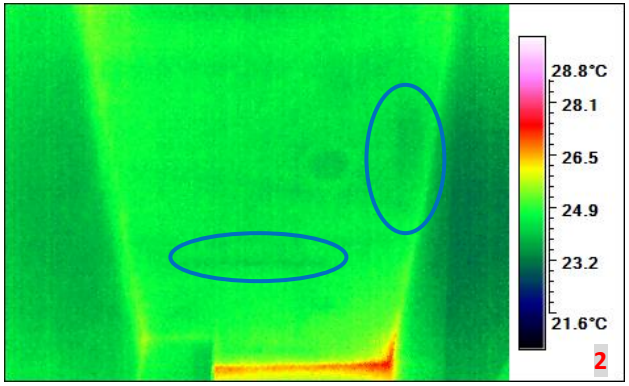
2016/07/14 10:53

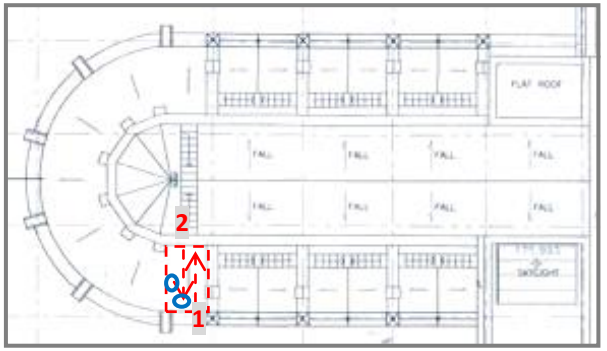


Bethanie Chapel	
Location	1/F
Remarks	No sign of water/moisture was noted after raining

Infrared Image No. 15 (IR15)





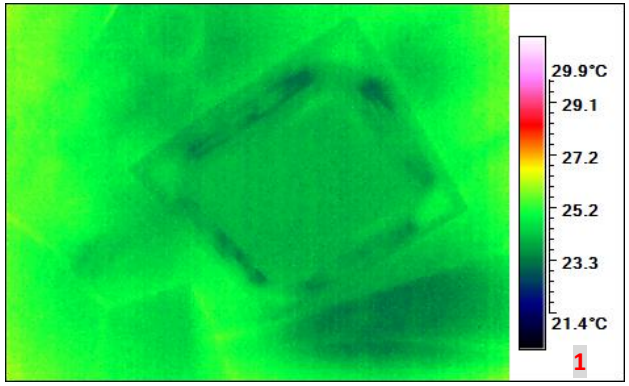


2016/08/22 10:11

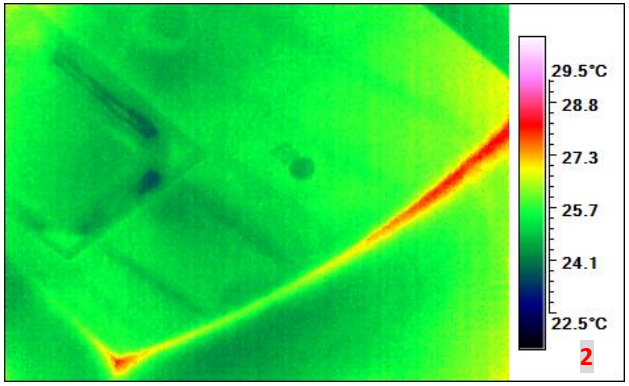
2016/08/22 10:12

Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

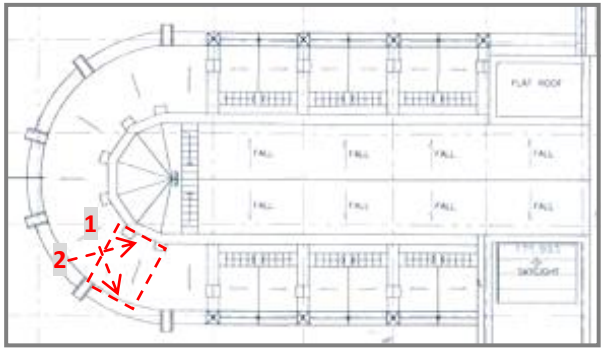
Infrared Image No. 16 (IR16)



2016/08/22 10:12

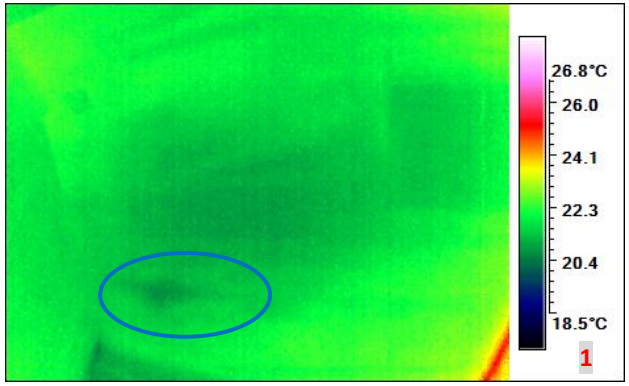


2016/08/22 10:13

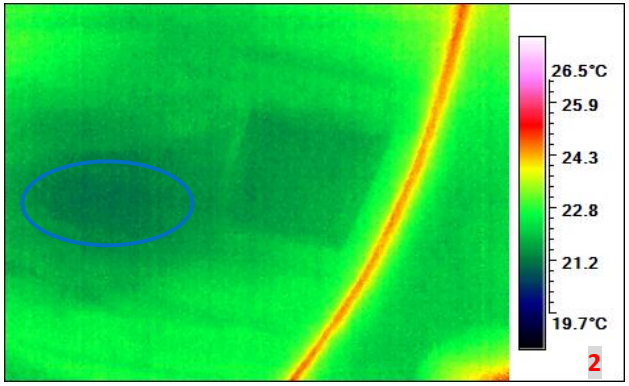


Bethanie Chapel	
Location	G/F
Remarks	No sign of water/moisture was noted after raining

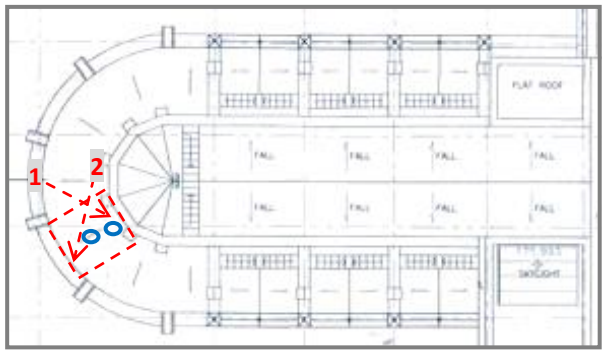
Infrared Image No. 17 (IR17)



2016/08/22 10:13

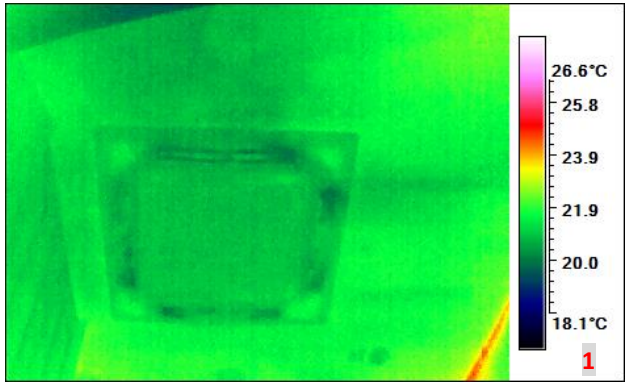


2016/08/22 10:14

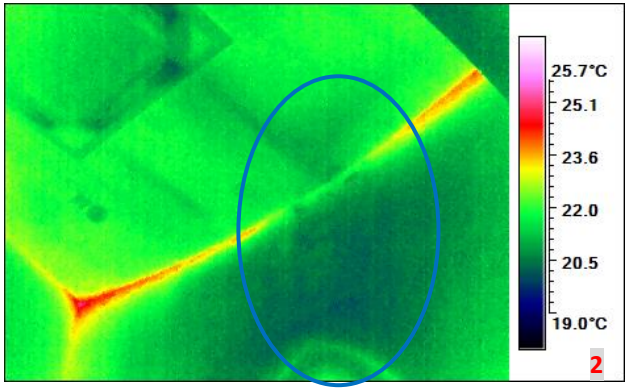


Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

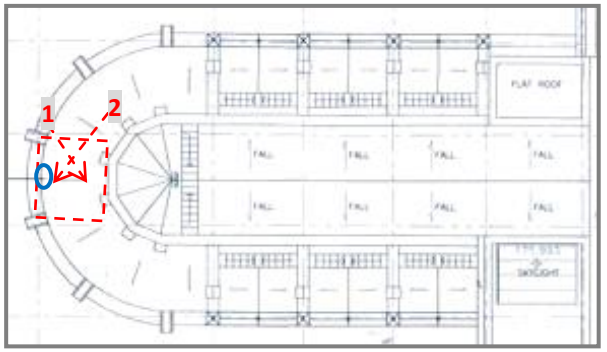
Infrared Image No. 18 (IR18)



2016/08/22 10:14

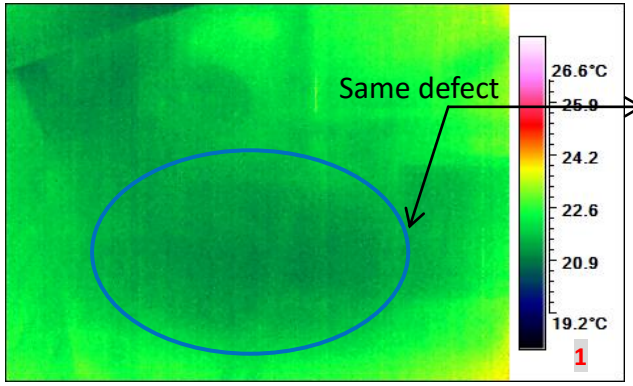


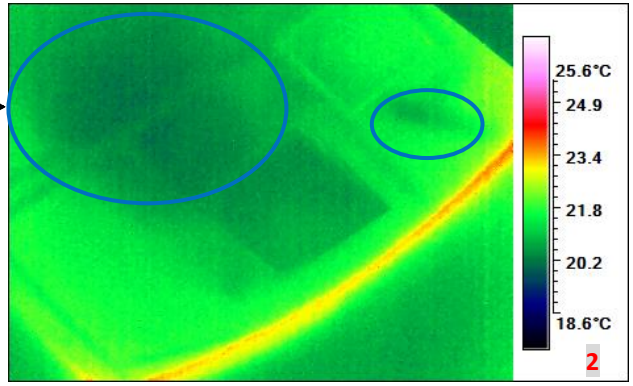
2016/08/22 10:14

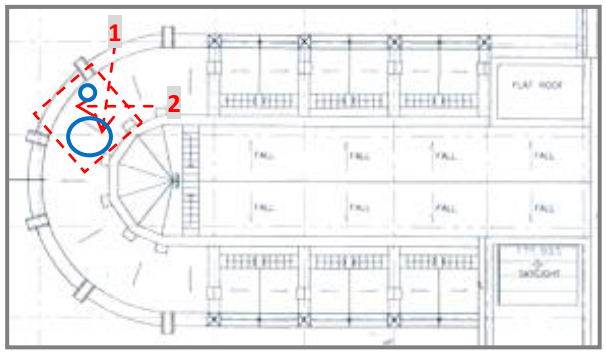


Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

Infrared Image No. 19 (IR19)

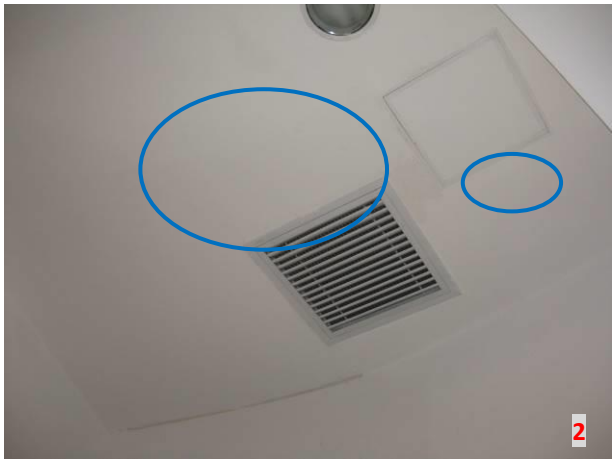






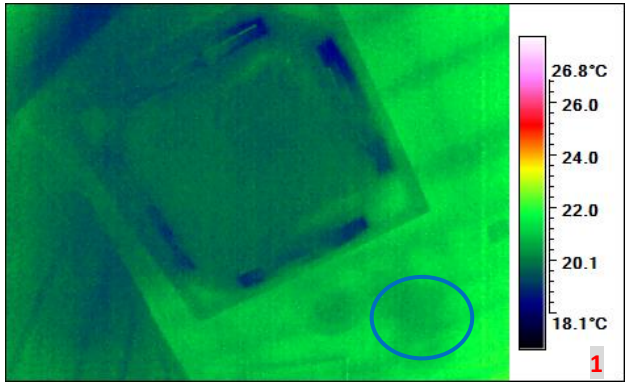
2016/08/22 10:15

2016/08/22 10:15

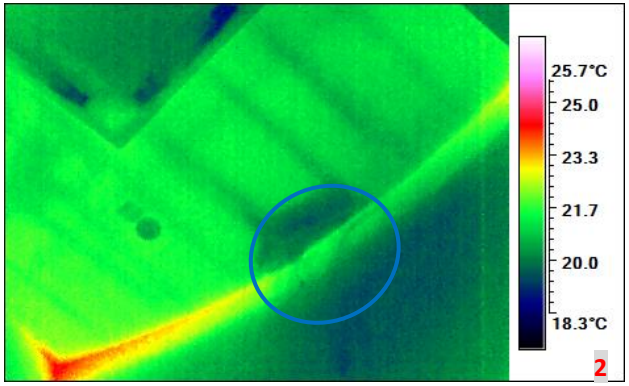


Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

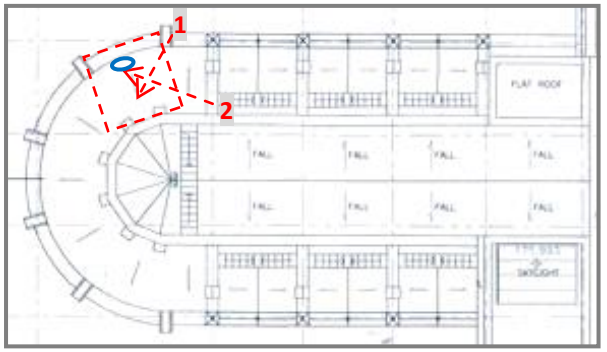
Infrared Image No. 20 (IR20)



2016/08/22 10:15

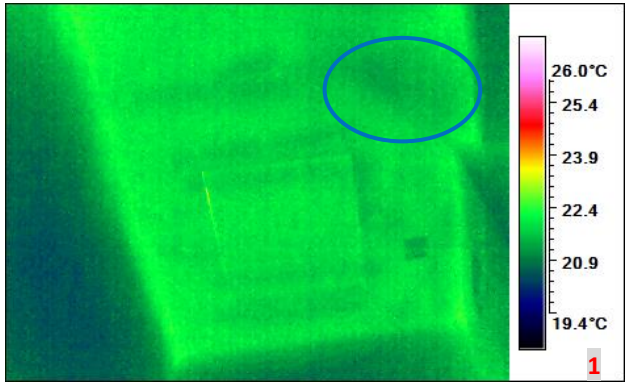


2016/08/22 10:15

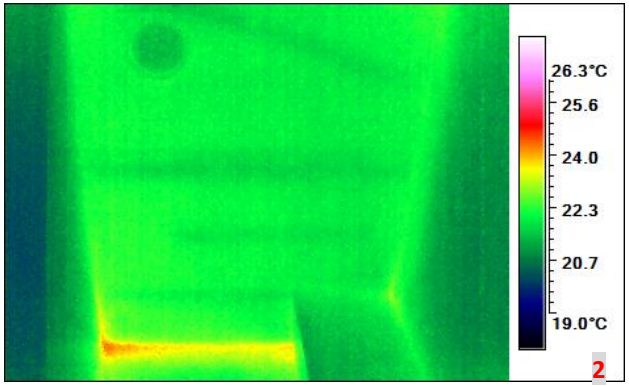


Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

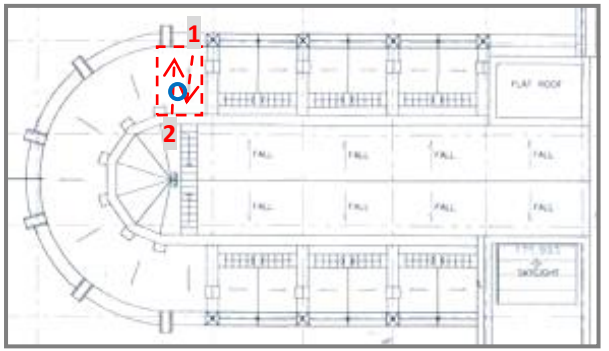
Infrared Image No. 21 (IR21)



2016/08/22 10:16

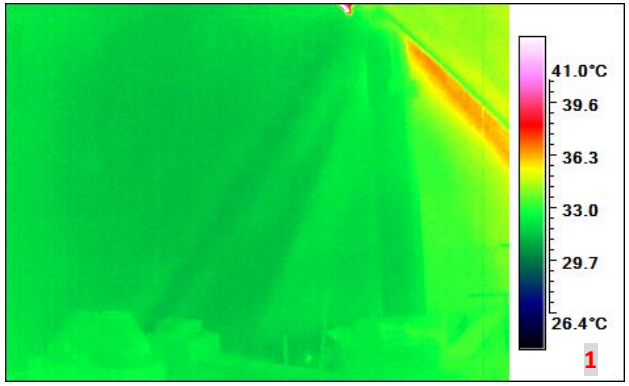


2016/08/22 10:16



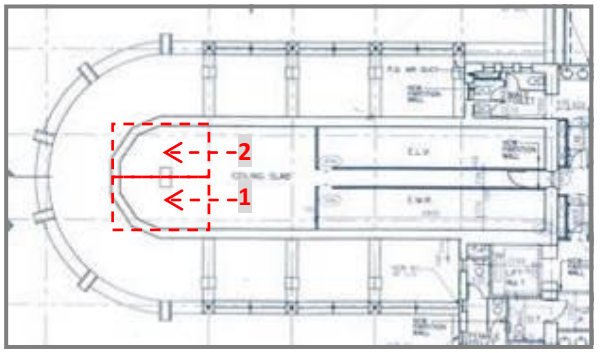
Bethanie Chapel	
Location	G/F
Remarks	Sign of water/moisture was noted after raining

Infrared Image No. 22 (IR22)



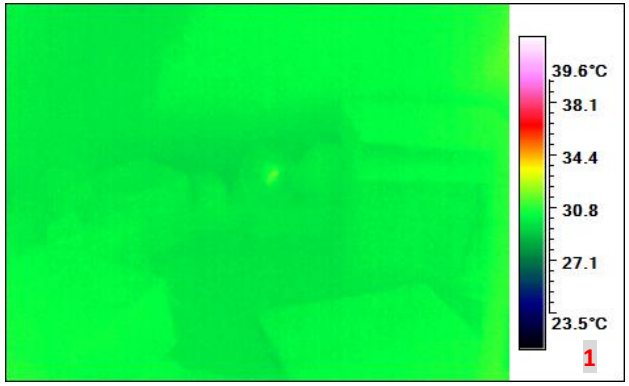
2016/08/22 11:28

2016/08/22 11:28

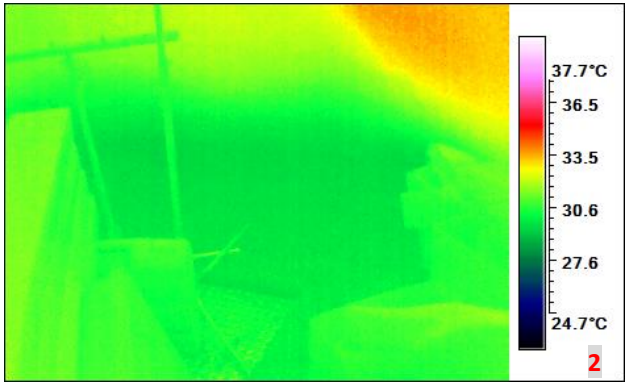


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

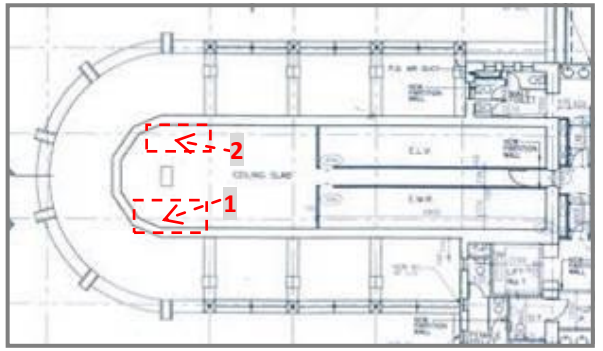
Infrared Image No. 23 (IR23)



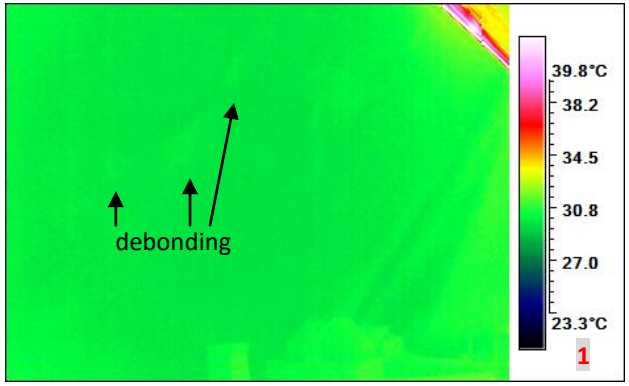
2016/08/22 11:29

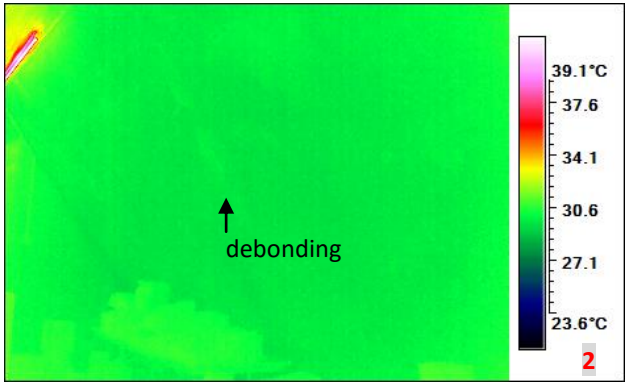


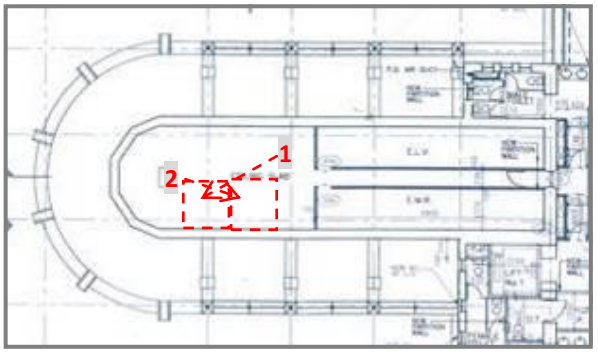
2016/08/22 11:29



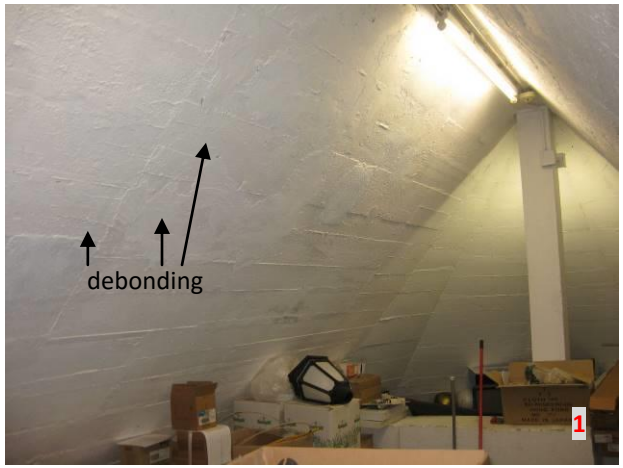
Infrared Image No. 24 (IR24)





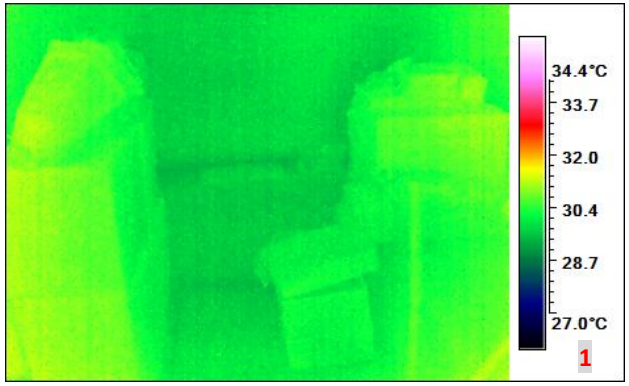


2016/08/22 11:29

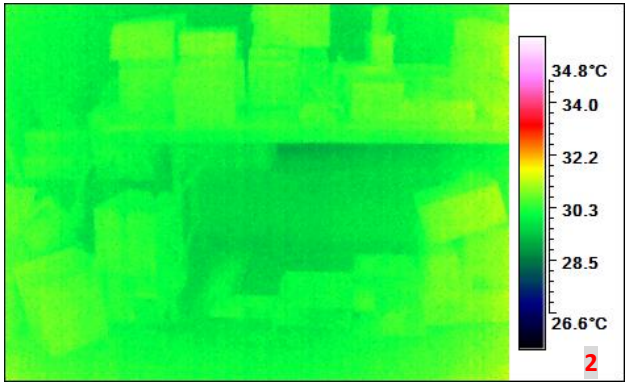


2016/08/22 11:29

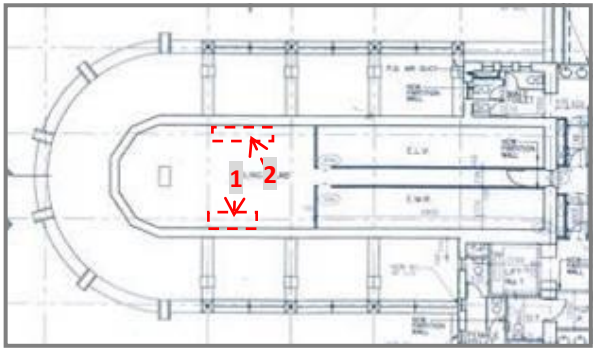
Infrared Image No. 25 (IR25)



2016/08/22 11:30

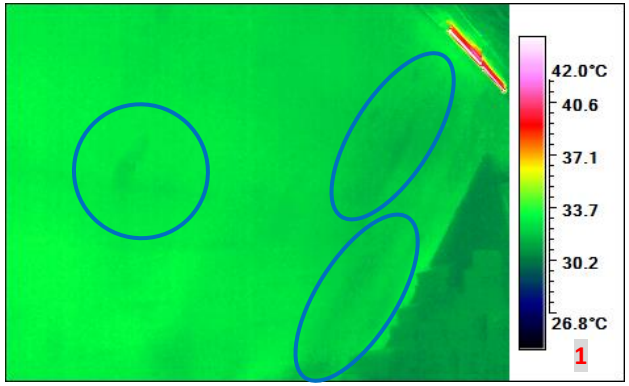


2016/08/22 11:30

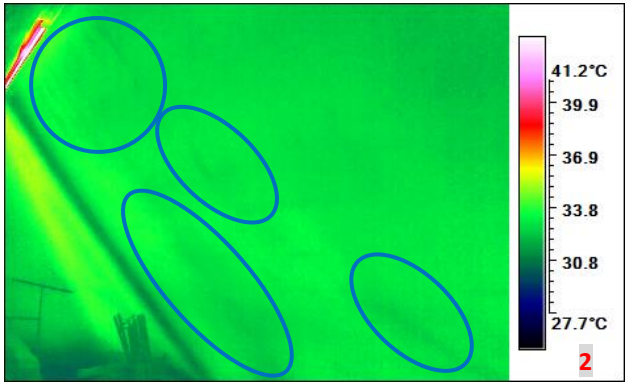


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

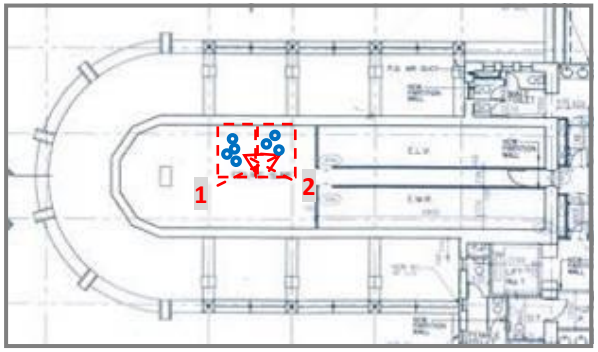
Infrared Image No. 26 (IR26)



2016/08/22 11:30

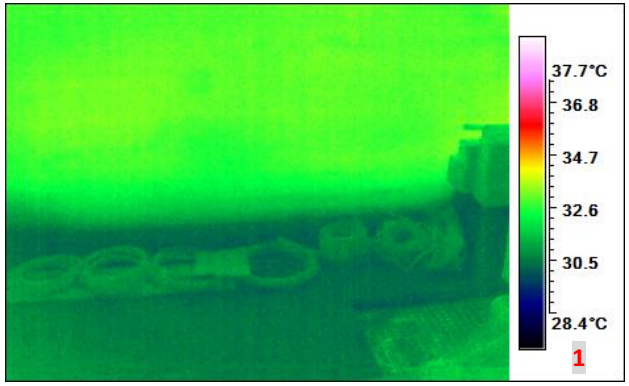


2016/08/22 11:30

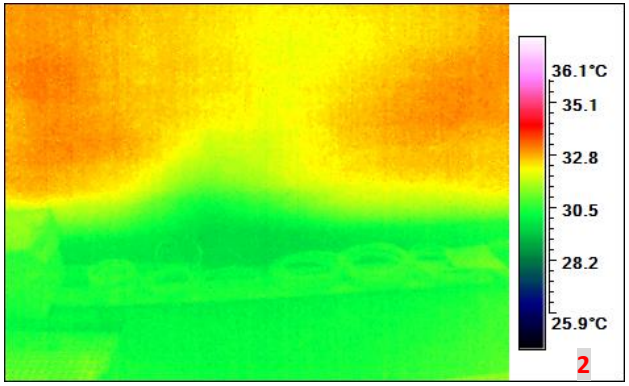


Bethanie Chapel	
Location	2/F
Remarks	Sign of water/moisture was noted after raining

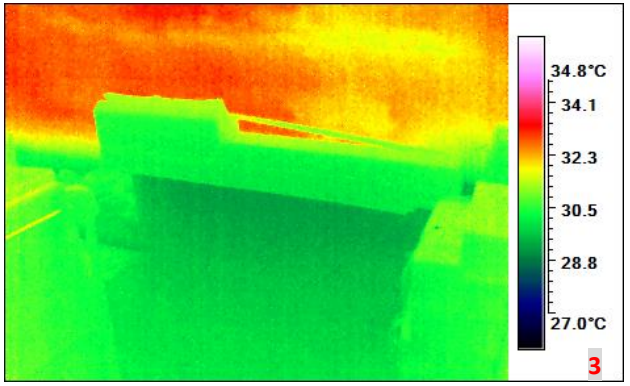
Infrared Image No. 27 (IR27)



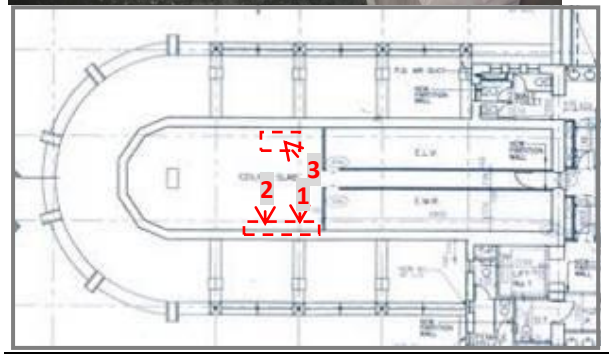
2016/08/22 11:31



2016/08/22 11:31

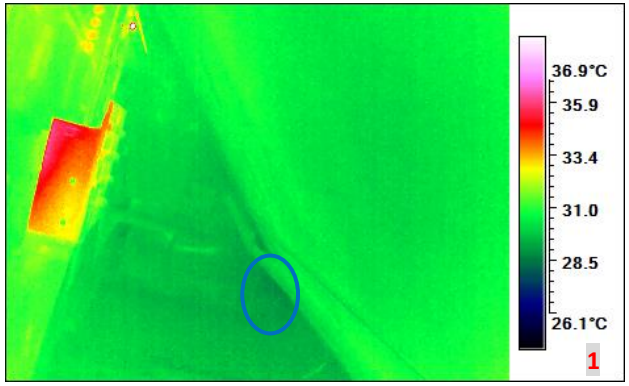


2016/08/22 11:31

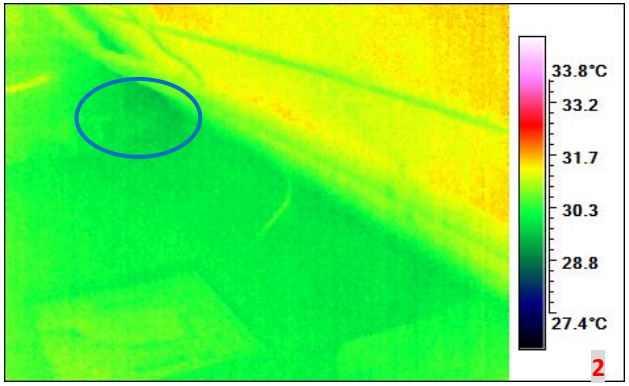


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

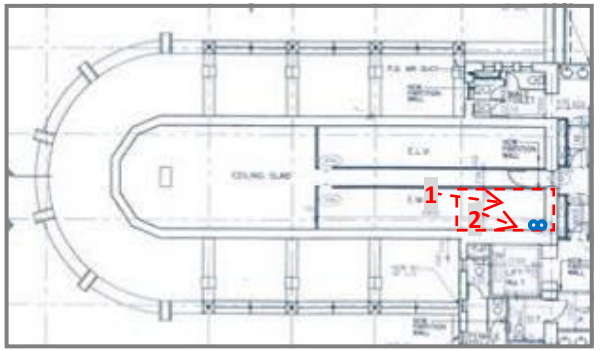
Infrared Image No. 28 (IR28)



2016/08/22 11:32

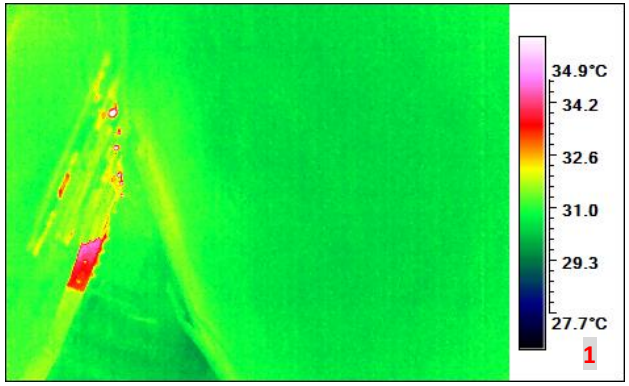


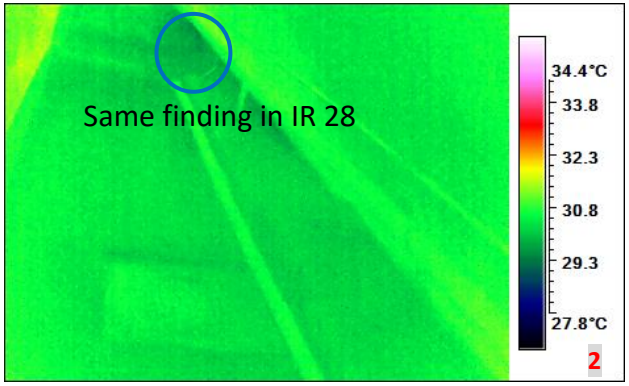
2016/08/22 11:32

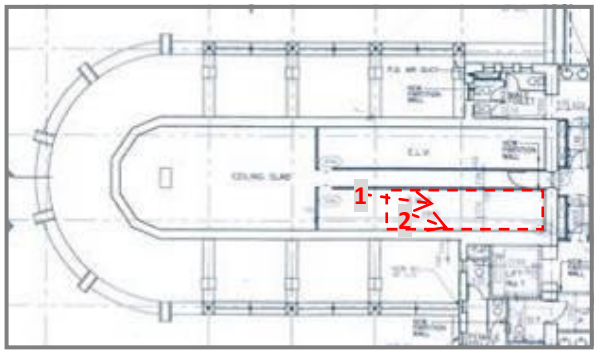


Bethanie Chapel	
Location	2/F
Remarks	Sign of water/moisture was noted after raining

Infrared Image No. 29 (IR29)





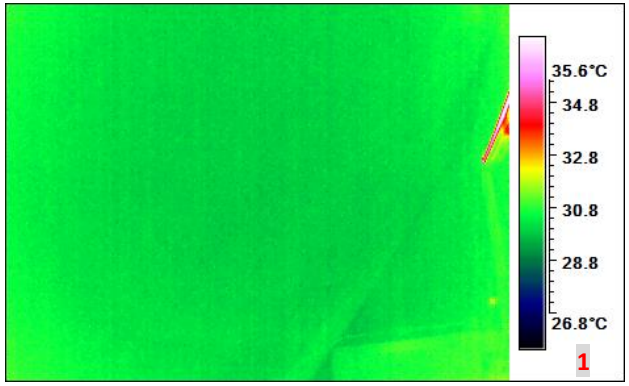


2016/08/22 11:33

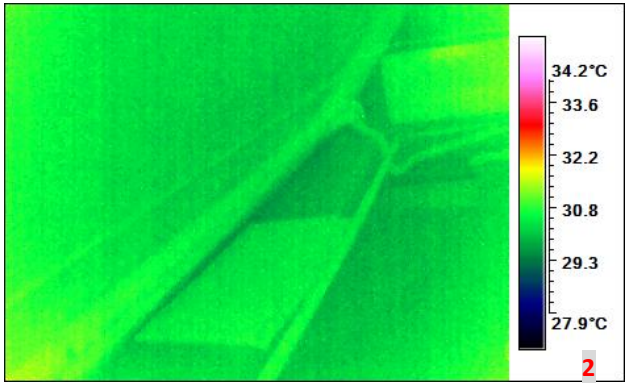
2016/08/22 11:33

Bethanie Chapel	
Location	2/F
Remarks	Sign of water/moisture was noted after raining

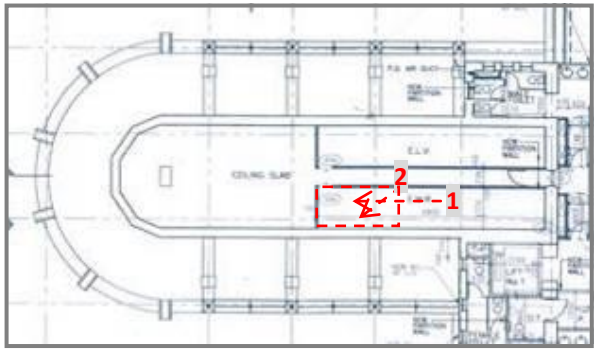
Infrared Image No. 30 (IR30)



2016/08/22 11:33

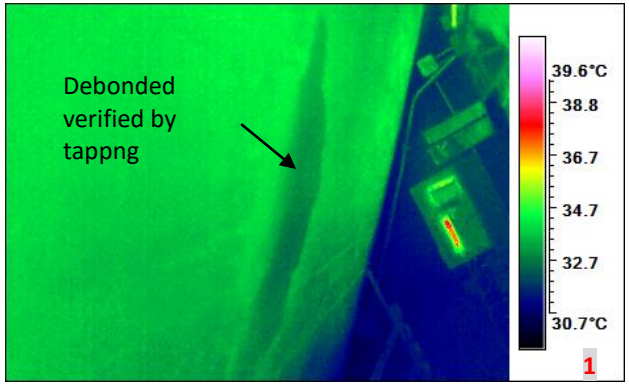


2016/08/22 11:34

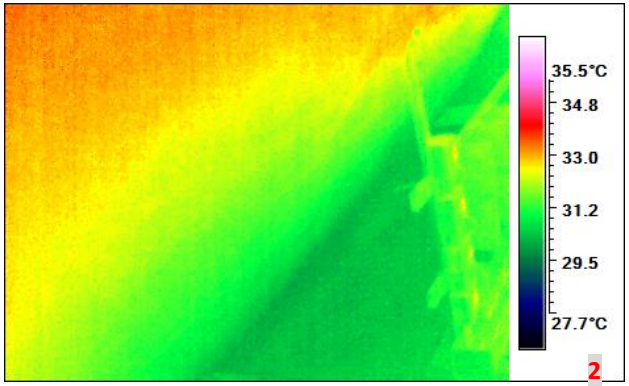


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

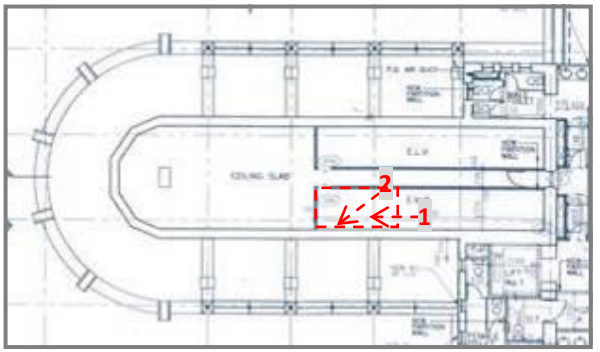
Infrared Image No. 31 (IR31)



2016/08/22 11:35

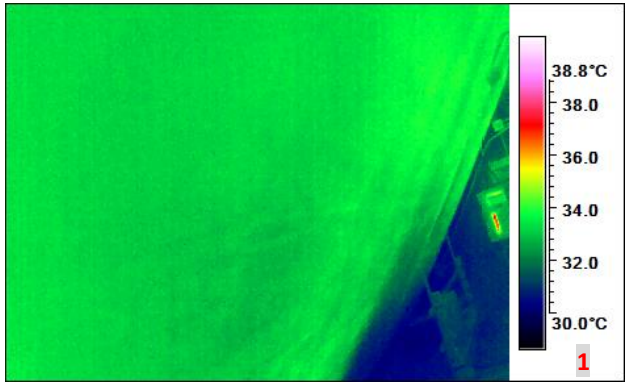


2016/08/22 11:35

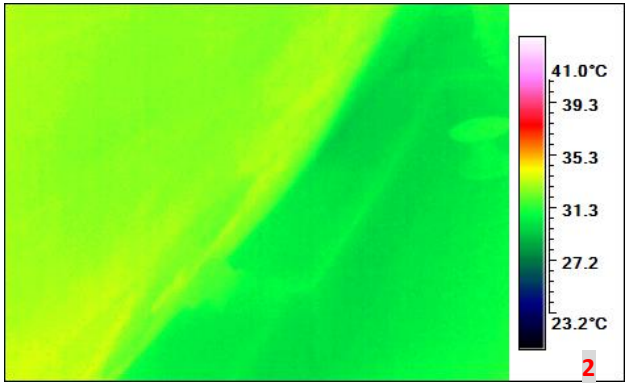


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

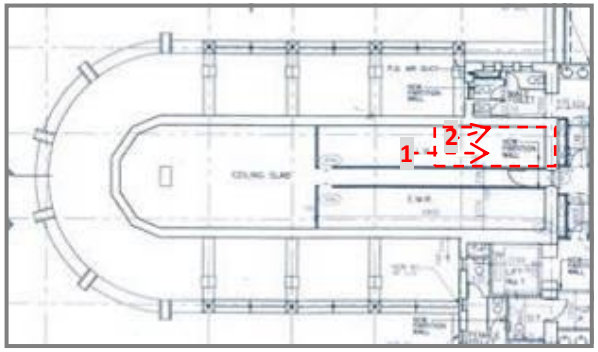
Infrared Image No. 32 (IR32)



2016/08/22 11:35

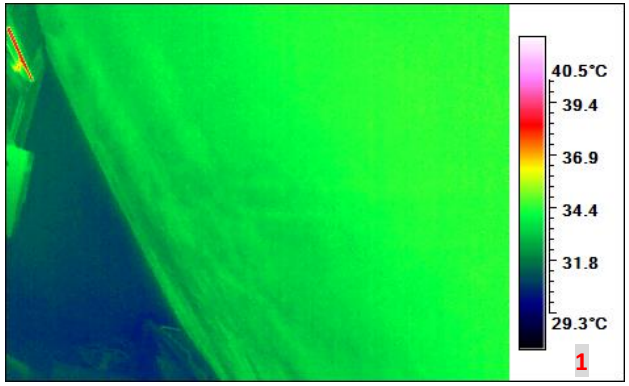


2016/08/22 11:36

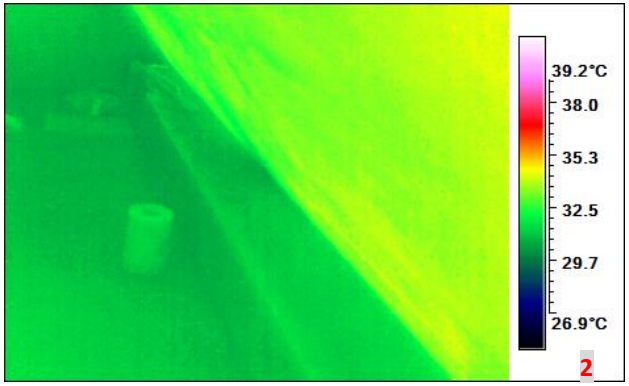


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

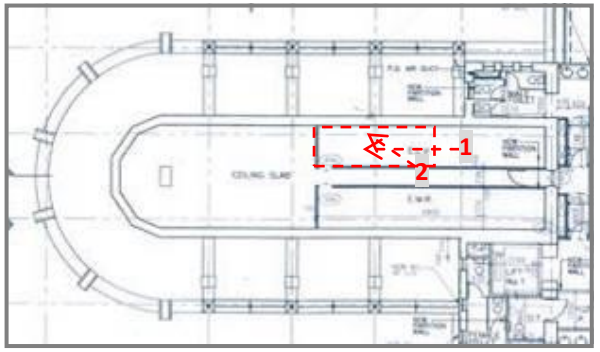
Infrared Image No. 33 (IR33)



2016/08/22 11:36

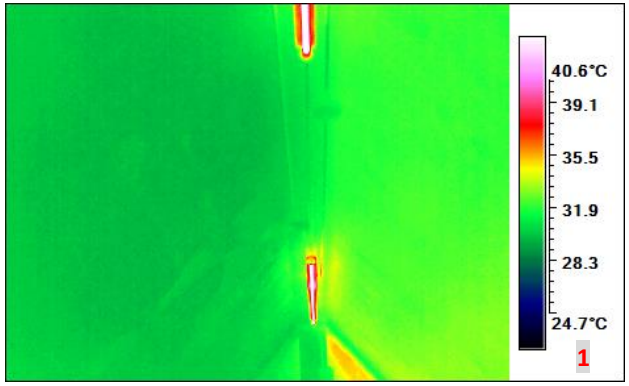


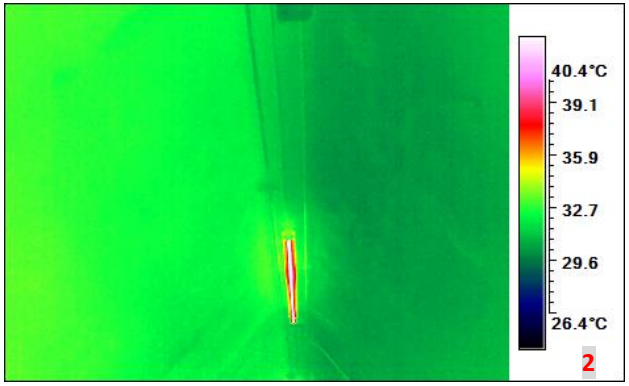
2016/08/22 11:36

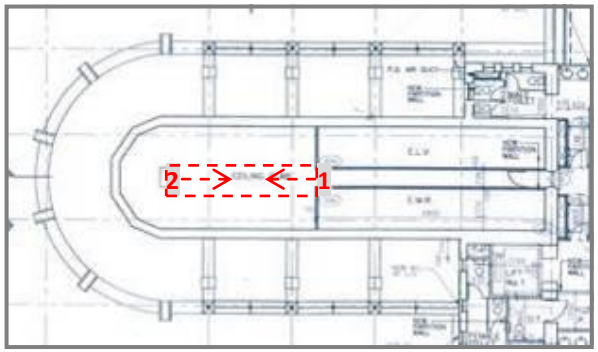


Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

Infrared Image No. 34 (IR34)





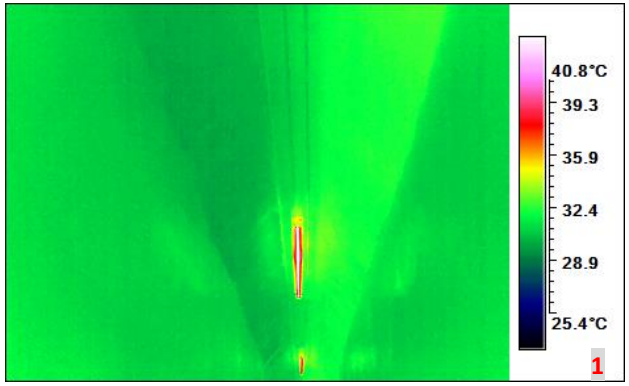


2016/08/22 11:37

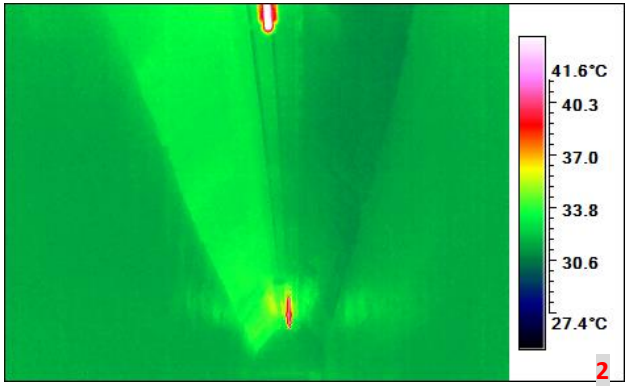
2016/08/22 11:37

Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

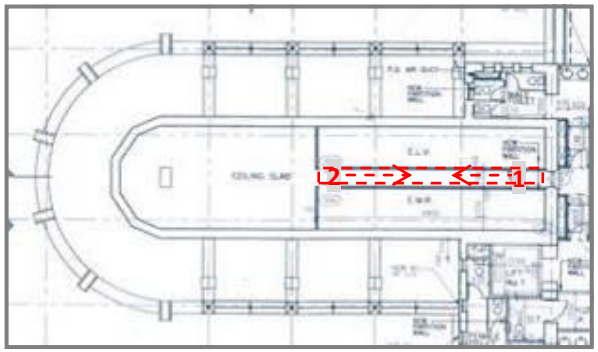
Infrared Image No. 35 (IR35)



2016/08/22 11:38



2016/08/22 11:38



Bethanie Chapel	
Location	2/F
Remarks	No sign of water/moisture was noted after raining

Protimeter Reading

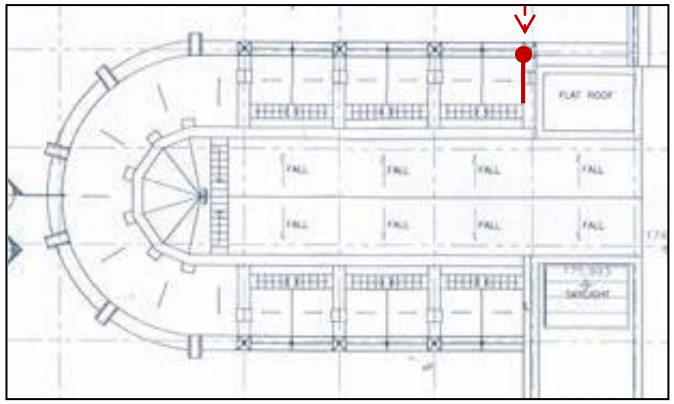
Protimeter Moisture Test (Relative Moisture Reading Test)

Wall R1	Test Point	R1-1	R1-2									
	Reading	7.8	8.6									
Wall R2	Test Point	R2-1	R2-2	R2-3	R2-4	R2-5	R2-6	R2-7	R2-8	R2-9	R2-10	R2-11
	Reading	7.7	16.6	19.6	10.8	8.5	16.8	16.2	7.6	8.8	8.9	8.2
Wall R3	Test Point	R3-1	R3-2	R3-3	R3-4	R3-5	R3-6	R3-7	R3-8	R3-9	R3-10	R3-11
	Reading	8.1	10.7	16.0	11.5	11.5	9.8	17.9	8.7	15.8	15.4	19.8
Wall R3	Test Point	R3-12	R3-13	R3-14	R3-15	R3-16	R3-17					
	Reading	7.2	8.6	14.5	14.3	6.7	9.7					
Wall R4	Test Point	R4-1	R4-2	R4-3	R4-4							
	Reading	9.0	6.4	6.9	7.7							

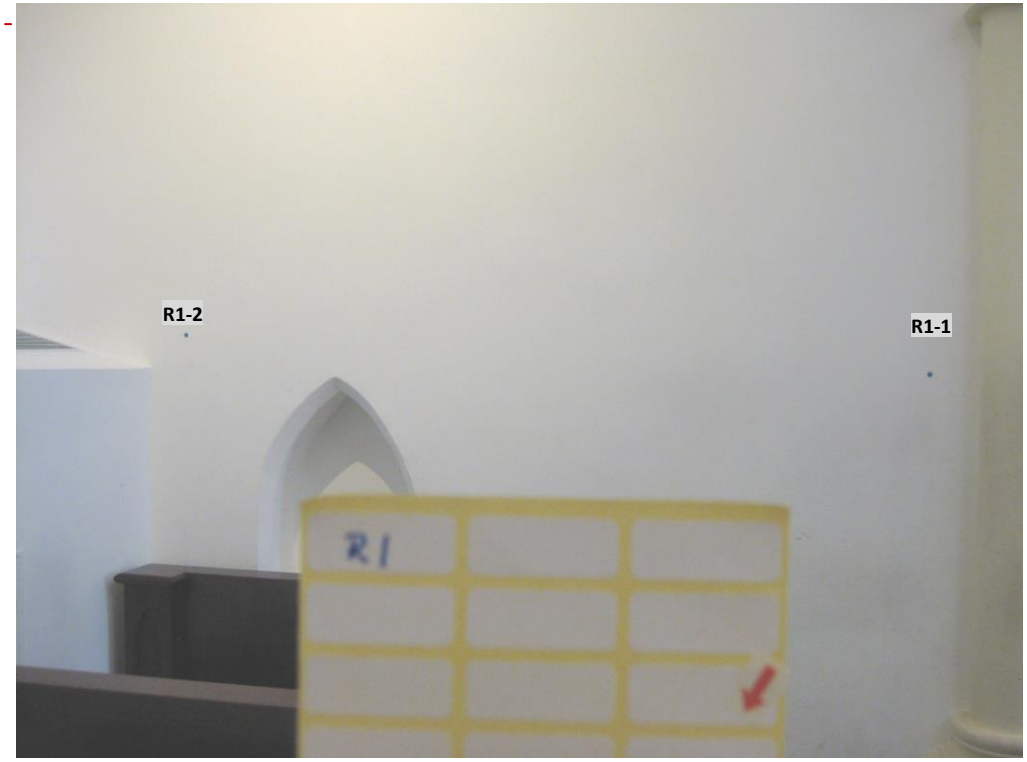
Wall L1	Test Point	L1-1	L1-2	L1-3	L1-4	L1-5	L1-6	L1-7	L1-8			
	Reading	14.3	14.4	12.0	8.1	7.1	6.3	8.1	7.2			
Wall L2	Test Point	L2-1	L2-2	L2-3	L2-4	L2-5	L2-6					
	Reading	11.8	7.8	10.1	11.8	8.6	8.5					
Wall L3	Test Point	L3-1	L3-2	L3-3	L3-4	L3-5						
	Reading	6.9	11.3	12.0	11.1	11.3						
Wall L4	Test Point	L4-1	L4-2	L4-3								
	Reading	8.7	7.5	8.3								

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall R1



Moisture Reading Relative High Under Moisture Test

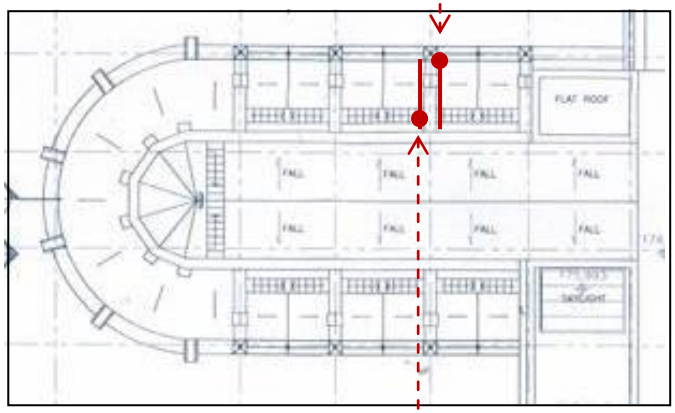


Location of Protimeter Measuring Test at Wall R1

Wall R1	Test Point	R1-1	R1-2
	Reading	7.8	8.6

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall R2



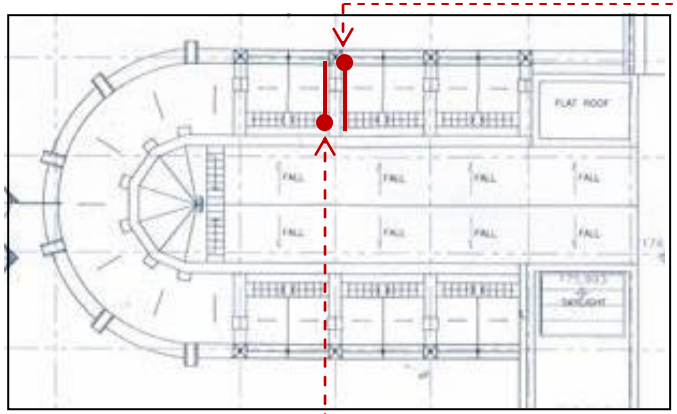
Moisture Reading Relative High Under Moisture Test

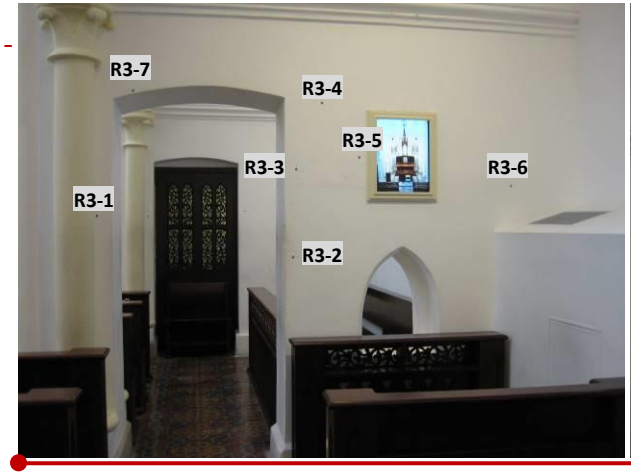
Location of Protimeter Measuring Test at Wall R2

Wall R2	Test Point	R2-1	R2-2	R2-3	R2-4	R2-5	R2-6	R2-7	R2-8	R2-9	R2-10	R2-11
	Reading	7.7	16.6	19.6	10.8	8.5	16.8	16.2	7.6	8.8	8.9	8.2

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall R3





Moisture Reading Relative High Under Moisture Test

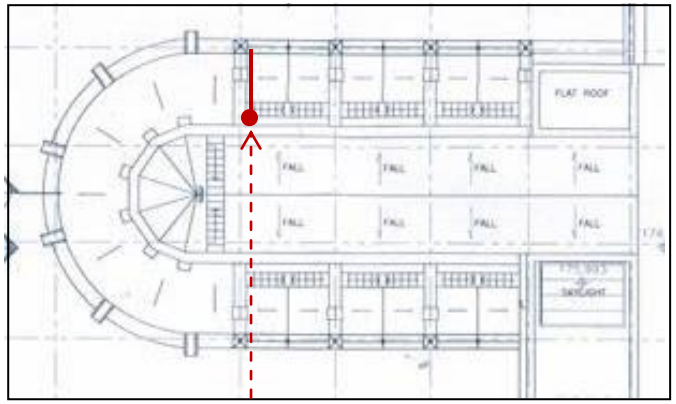
Location of Protimeter Measuring Test at Wall R3

Remark:
Reading in RED : Relative high reading (>30)

Wall R3	Test Point	R3-1	R3-2	R3-3	R3-4	R3-5	R3-6	R3-7	R3-8	R3-9	R3-10	R3-11
	Reading	8.1	10.7	16.0	11.5	11.5	9.8	17.9	8.7	15.8	15.4	19.8

Wall R3	Test Point	R3-12	R3-13	R3-14	R3-15	R3-16	R3-17
	Reading	7.2	8.6	14.5	14.3	6.7	9.7

Protimeter Moisture Test - Wall R4



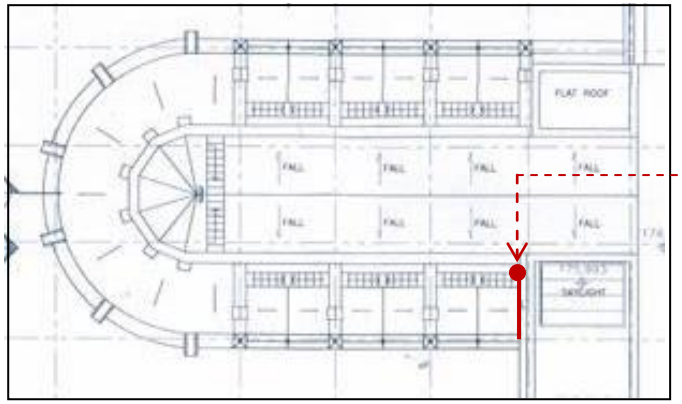
Moisture Reading Relative High Under Moisture Test

Location of Protimeter Measuring Test at Wall R4

Wall R4	Test Point	R4-1	R4-2	R4-3	R4-4
	Reading	9.0	6.4	6.9	7.7

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall L1



Moisture Reading Relative High Under Moisture Test

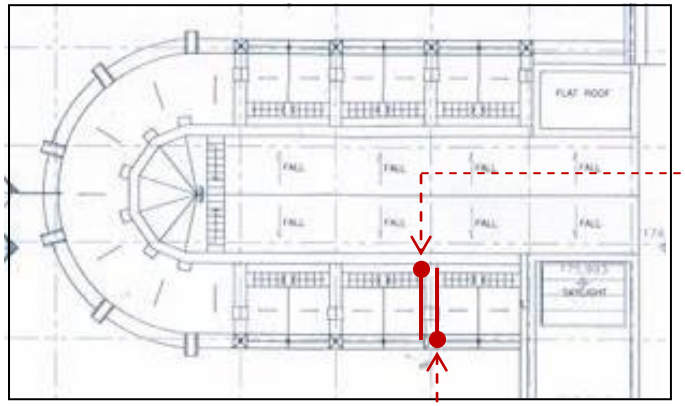
Location of Protimeter Measuring Test at Wall L1

Wall L1	Test Point	L1-1	L1-2	L1-3
	Reading	14.3	14.4	12.0

Wall L1	Test Point	L1-4	L1-5	L1-6	L1-7	L1-8
	Reading	8.1	7.1	6.3	8.1	7.2

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall L2



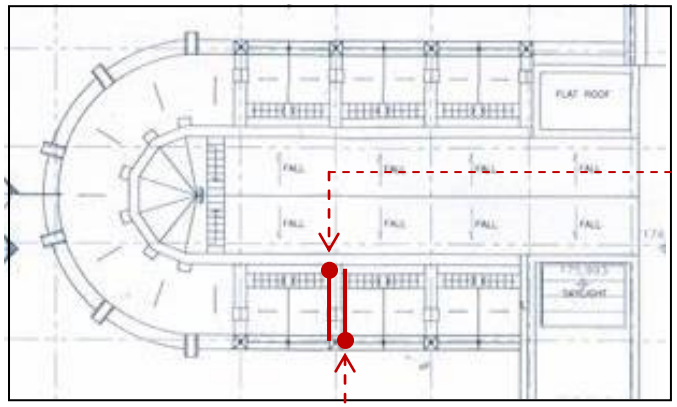
Moisture Reading Relative High Under Moisture Test

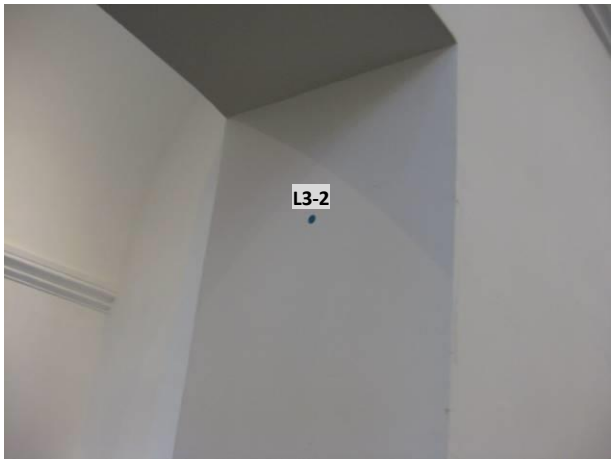
Location of Protimeter Measuring Test at Wall L2

Wall L2	Test Point	L2-1	L2-2	L2-3	L2-4	L2-5	L2-6
	Reading	11.8	7.8	10.1	11.8	8.6	8.5

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall L3





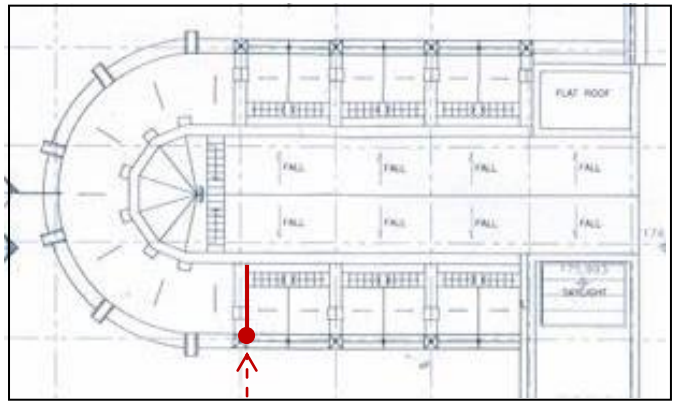
Moisture Reading Relative High Under Moisture Test

Location of Protimeter Measuring Test at Wall L3

Wall L3	Test Point	L3-1	L3-2	L3-3	L3-4	L3-5
	Reading	6.9	11.3	12.0	11.1	11.3

Remark:
Reading in RED : Relative high reading (>30)

Protimeter Moisture Test - Wall L4



Moisture Reading Relative High
Under Moisture Test

Location of Protimeter Measuring Test at Wall L4

Wall L4	Test Point	L4-1	L4-2	L4-3
	Reading	8.7	7.5	8.3

Remark:
Reading in RED : Relative high reading (>30)

Annex B

Summary of Visual Inspection

Summary of Visual Inspection

Visual inspections have been carried out on 13-14 July and 14 September 2016 to record defects observed at the Chapel of the Béthanie. Inspections cover the both the interior and exterior of the Chapel, including the attic area above the vault.

Generally, vegetations are commonly found at the exterior of the Chapel, mainly at the roof parapets and flying buttresses. Cracks and spalling are recorded at localized areas. Water stains concentrated at the two sides of the flying buttresses and the edges of windows. Obvious cracks are observed along the roof of the Corridor, which is believed to be the cause of various water stains in the interior. Extensive flaking of plaster with a few spots of spalling are recorded at the attic area. The interior of the Chapel is recorded with various defects including water stains, rusting of windows, minor cracks on columns and walls, and some flaking and popping of plaster, which altogether suggest water seepage is happening here and there within the Chapel.

The defects identified have been numbered and set out in table format for easy reference. Descriptions of defects with estimated extent, possible causes and recommendations to refer to are all summarized in the table. Note that the cause of defect usually is a combination of few factors rather than just one.

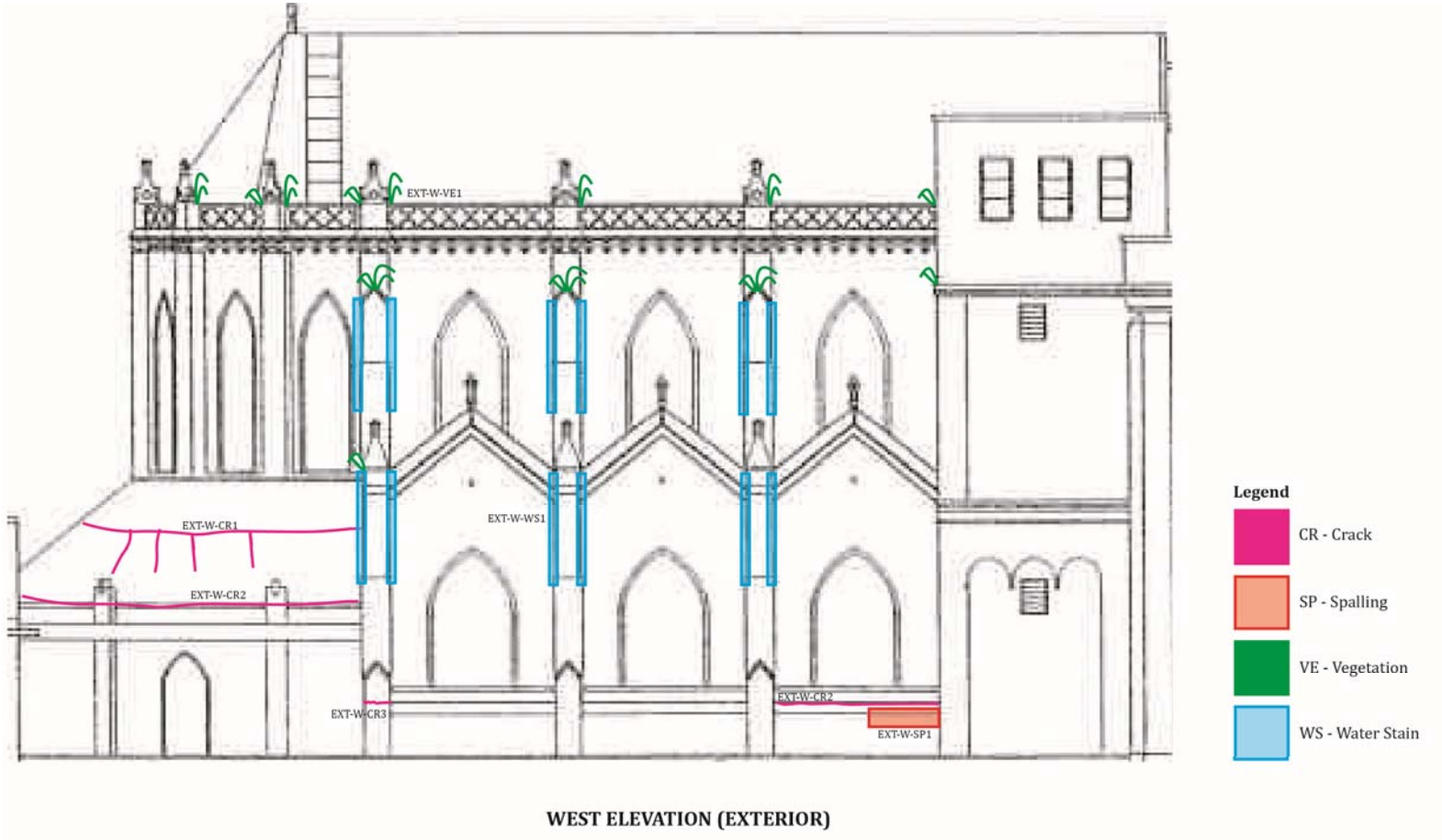
The defects are shown according to the following order:

1. Exterior (EXT)
   - 1.1 West Elevation
   - 1.2 East Elevation
2. Ceiling Slab (CEI)
   - 2.1 West Side
   - 2.2 East Side
3. Interior (INT)
   - 3.1 West Elevation
   - 3.2 East Elevation
   - 3.3 Corridor

Defects identified have been categorized into 8 types (see below). Each defect has its own numbering, showing its location and type of defect, and provide cross-referencing with the defect mapping plans. For example EXT-W-VE1, means it is the first vegetation (VE) defect found on the West Elevation (W) of the Exterior (EXT) of the Chapel.

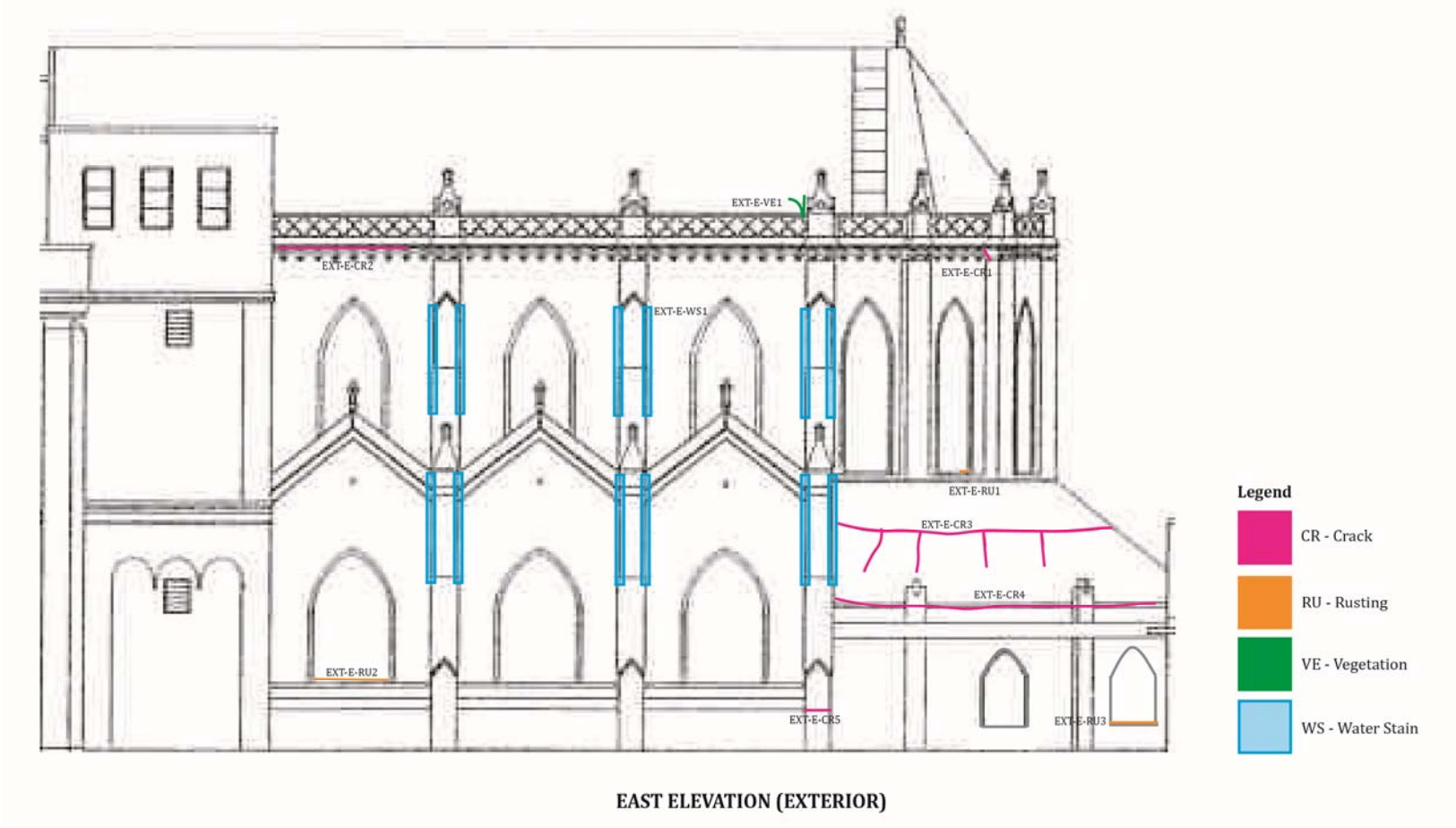
Types of Defects	**Abbreviation**
Crack	CR
Damage	DA
Discoloration	DS
Flaking	FL
Rusting	RU
Spalling	SP
Vegetation	VE
Water Stain	WS

Defect Mapping Plan: West Elevation (Exterior)

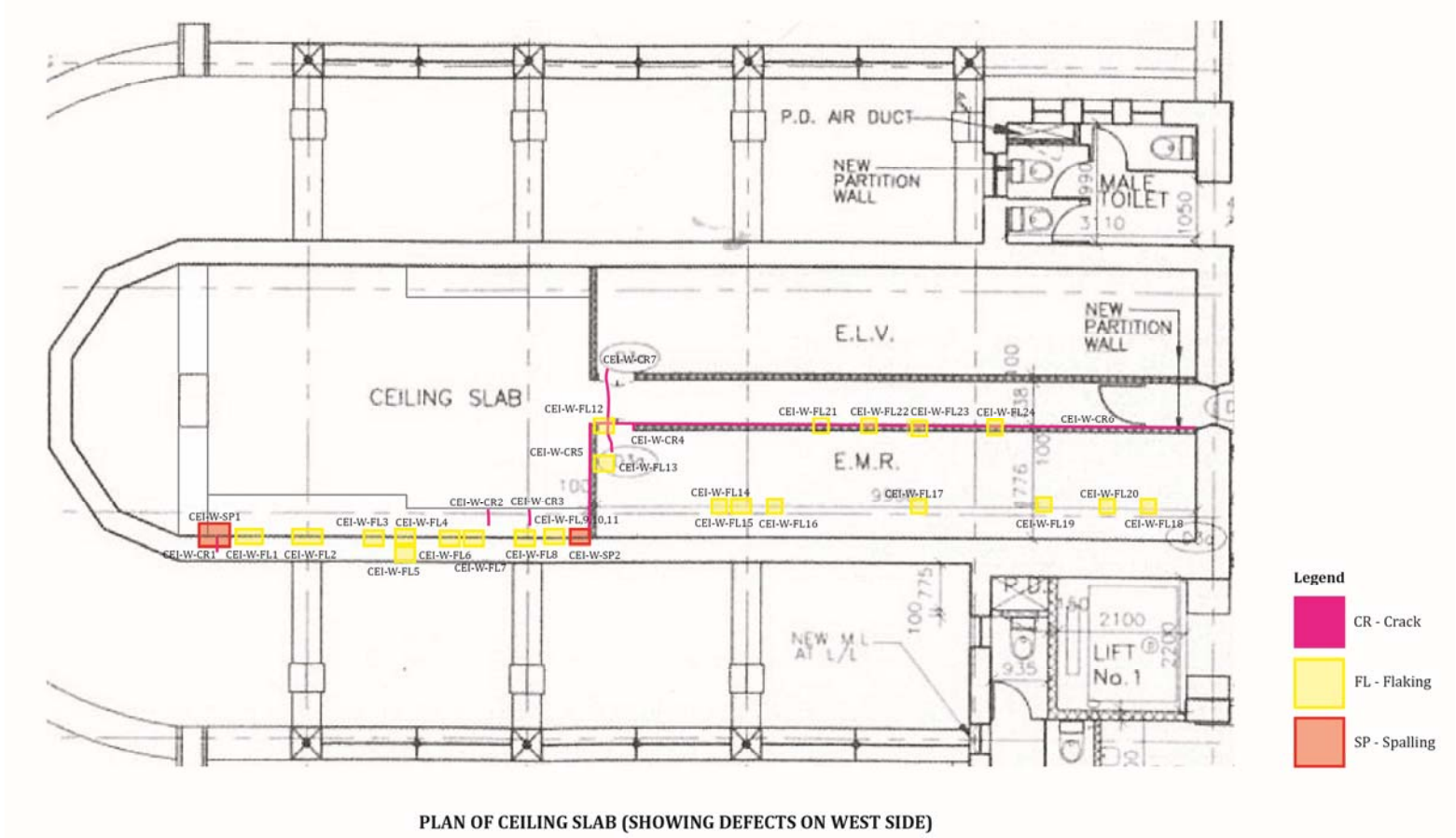


WEST ELEVATION (EXTERIOR)

Defect Mapping Plan: East Elevation (Exterior)

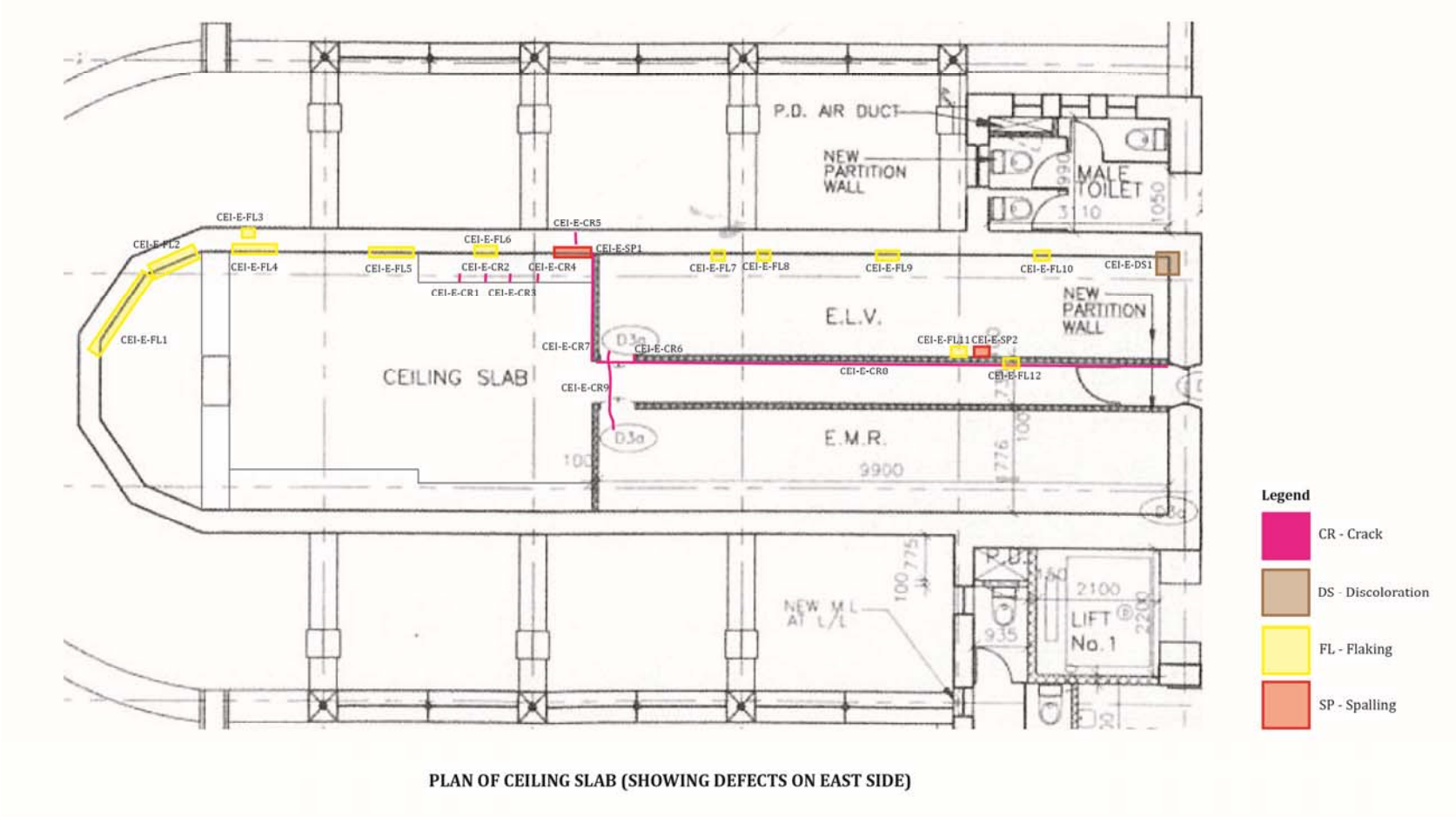


Defect Mapping Plan: West Elevation (Ceiling Slab)



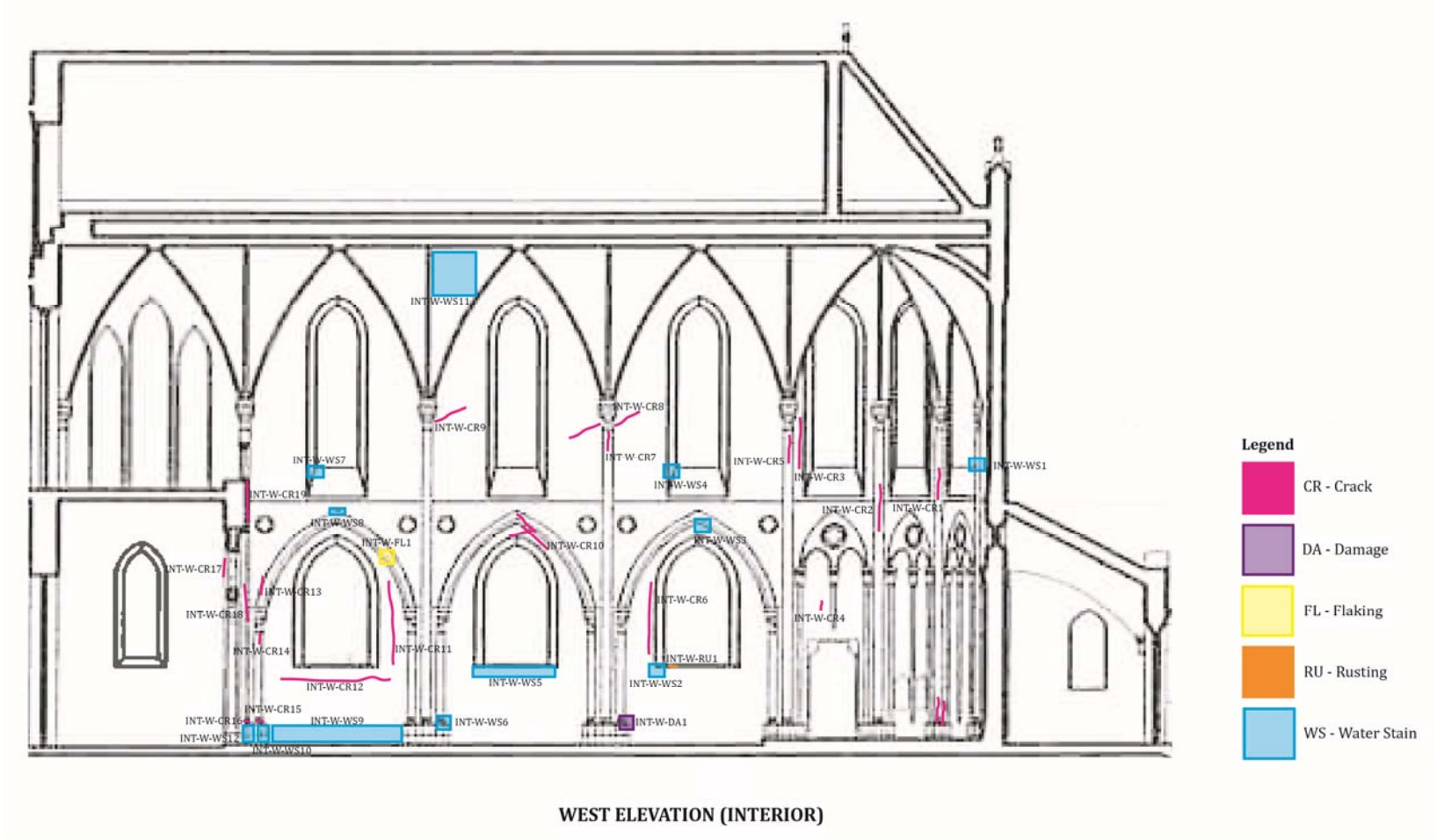
PLAN OF CEILING SLAB (SHOWING DEFECTS ON WEST SIDE)

Defect Mapping Plan: East Elevation (Ceiling Slab)



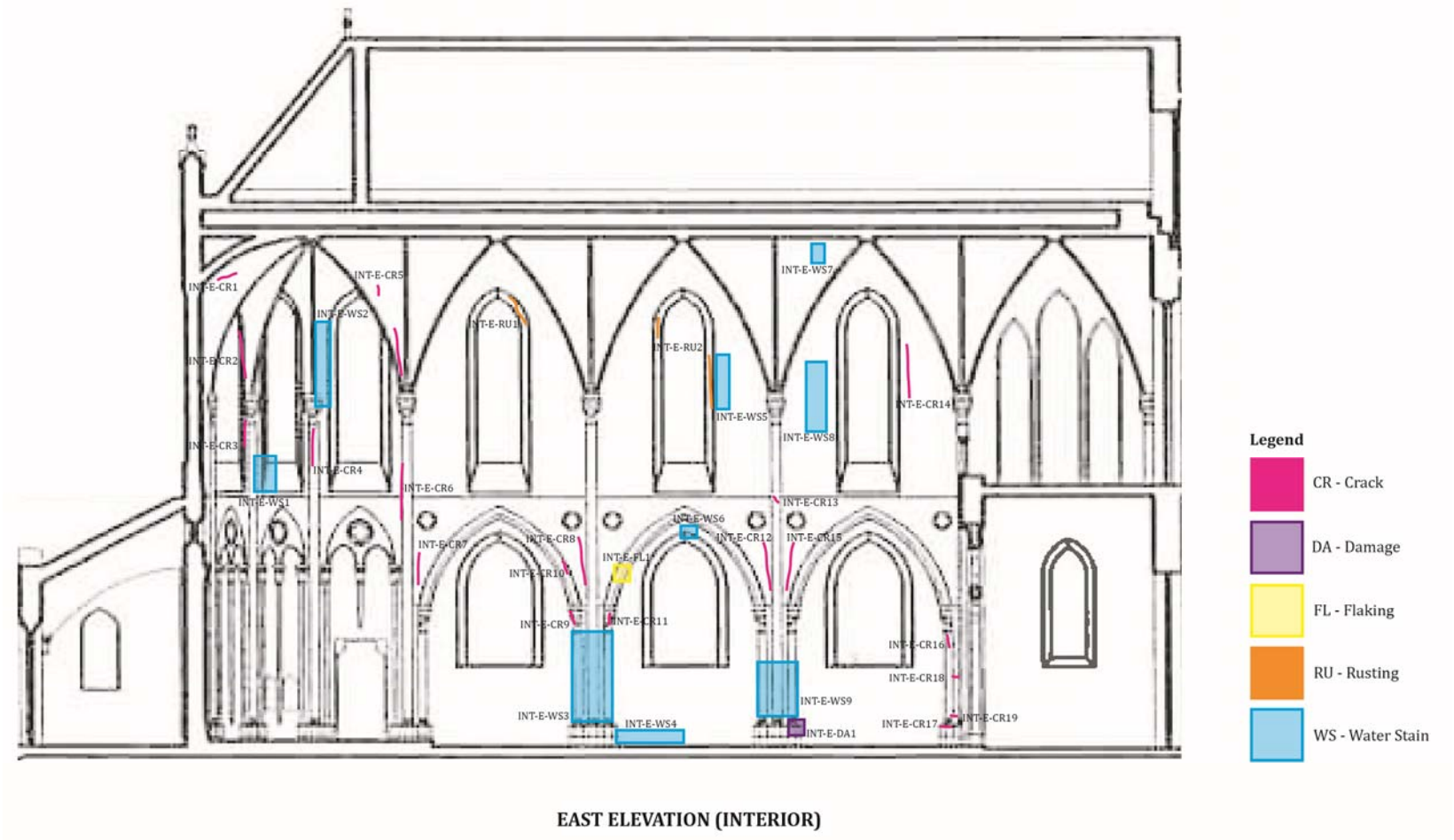
PLAN OF CEILING SLAB (SHOWING DEFECTS ON EAST SIDE)

Defect Mapping Plan: West Elevation (Interior)



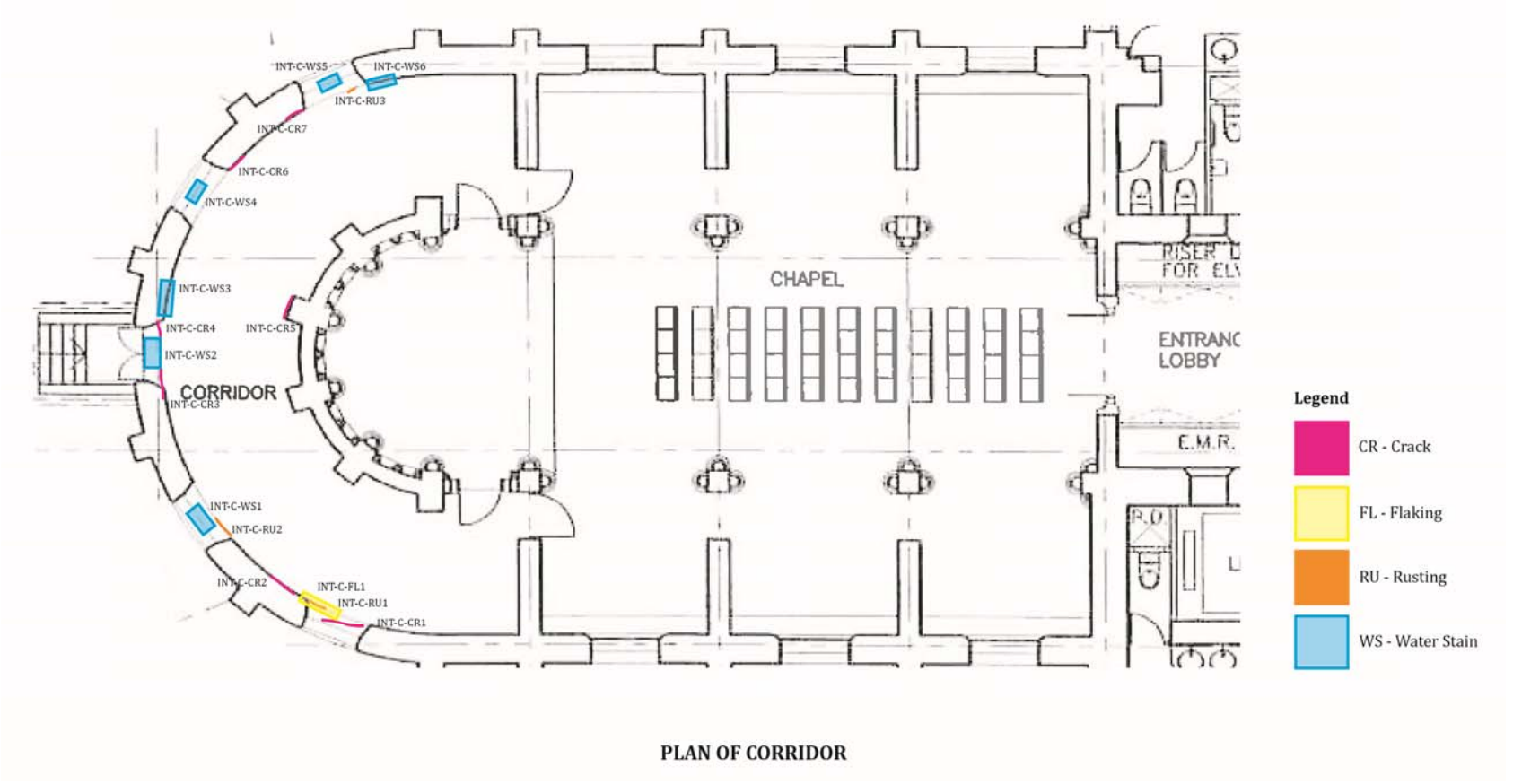
WEST ELEVATION (INTERIOR)

Defect Mapping Plan: East Elevation (Interior)



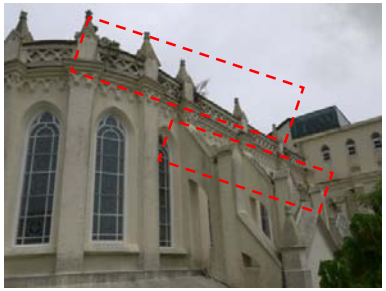
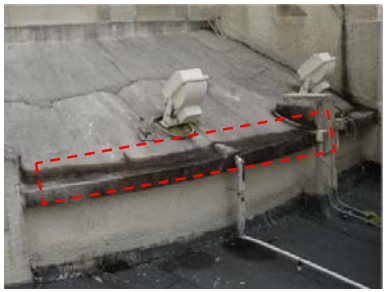
EAST ELEVATION (INTERIOR)

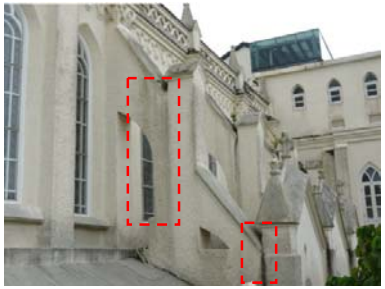
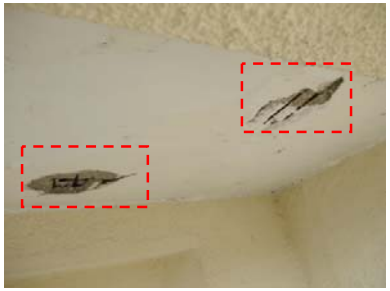
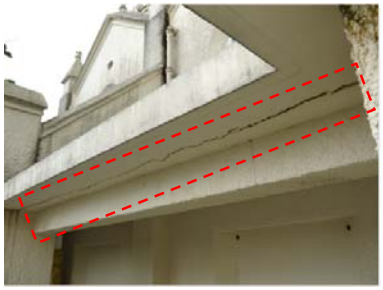
Defect Mapping Plan: Corridor



PLAN OF CORRIDOR

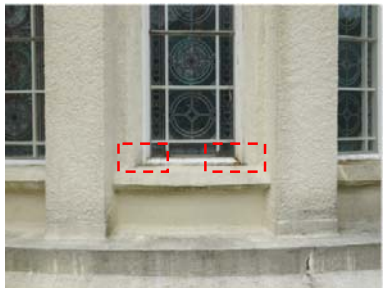
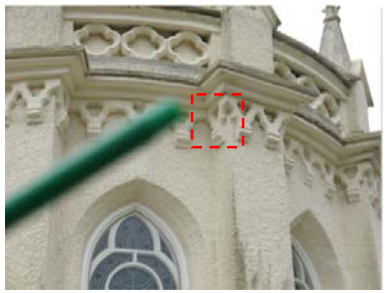
Exterior - West Elevation (EXT-W)

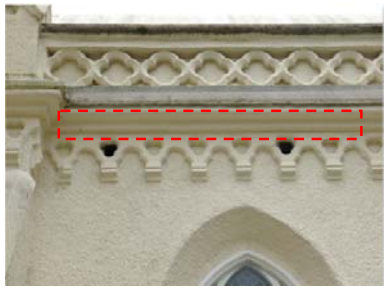
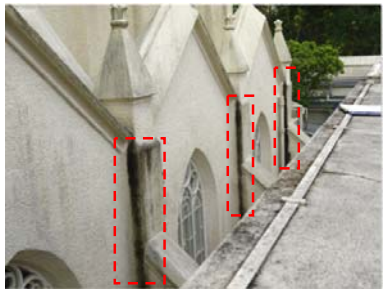
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-W-VE1		Vegetation is found at a total of 13 locations at the roof parapets and flying buttresses.	Locations: 13 Area: 200mm (W) x 200mm (H) (on average)	• Fissures and moisture allow growth of plantation. • Lack of periodic maintenance. • Lack of safety access.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.4(a)
EXT-W-CR1		A crack is found on the external roof above the corridor. It is noted that the crack is visible along the entire roof. (Cross reference with EXT-E-CR3)	Thickness: 10mm Length: 7000mm	• Thermal movement as the roof is directly exposed to sunlight. • Poor bonding of concrete that was formed at different times.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(b)
EXT-W-CR2		A crack is found on the external roof above the corridor. (Cross reference withEXT-E-CR3)	Thickness: 8mm Length: 8000mm	• Thermal movement as the roof is exposed to sunlight. • Poor bonding of concrete that was formed at different times.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(b)

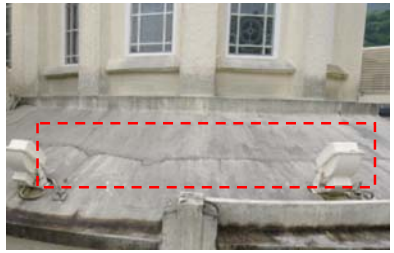
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-W-WS1		Black and vertical water stains are generally found on the flying buttresses.	Area: 150mm (W) x 1000mm (H) (on average)	• Lack of periodic maintenance. • Lack of safety access.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(c)
EXT-W-SP1		Spalling of concrete and corrosion of reinforcement are found on the later-added canopy.	Area: 900mm (W) x 1000mm (H)	• Accumulation of water on the canopy. • Corrosion of steel reinforcement.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.2(a)
EXT-W-CR2		A crack is found on the later-added canopy, which is parallel to the beam.	Thickness: 10mm Length: 1300mm	• Corrosion of steel reinforcement. • Accumulation of water due to failure of drainage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.2(a)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-W-CR3		A minor crack is found on the buttress.	Thickness: 2mm Length: 800mm	• Poor bonding of plaster mix between new and old. • Differential thermal expansion. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(d)

Exterior - East Elevation (EXT-E)

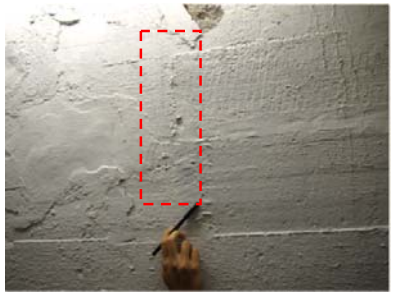
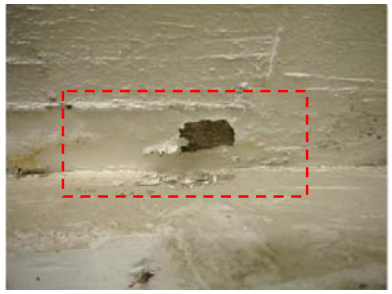
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-E-VE1		Vegetation is found at the roof parapet.	<u>Area:</u> 100mm (W) x 100mm (H)	• Fissures and moisture allow growth of plantation. • Lack of periodic maintenance. • Lack of safety access.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.4(a)
EXT-E-RU1		Rusts are found on bottom corners of the window frame.	<u>Area:</u> 80mm (W) x 100mm (H) (on average)	• Accumulation of water at the bottom corners. • Failure of paint in avoiding rusting.	<u>Material(s) involved:</u> Metal and paint Refer to Section 4.4.1(a)
EXT-E-CR1		A hairline crack is found on the capital of the column.	<u>Thickness:</u> 5mm <u>Length:</u> 100mm	• Thermal or slight movement crack.	<u>Material(s) involved:</u> Brick and plaster Refer to Section 4.2.4(b)

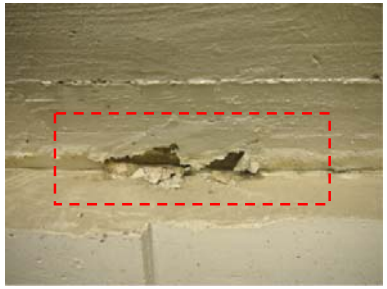
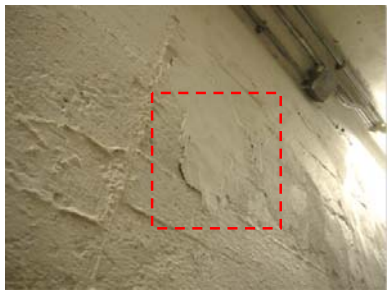
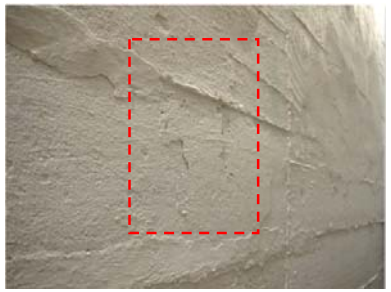
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-E-CR2		A hairline crack is found along the air vents.	Thickness: 5mm Length: 200mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.4(c)
EXT-E-RU2		Rusts are found on bottom part of the window frame.	Area: 500mm (W) x 50mm (H)	• Accumulation of water at the bottom corners. • Failure of paint in avoiding rusting.	Material(s) involved: Metal and paint Refer to Section 4.4.1(a)
EXT-E-WS1		Black and vertical water stains are generally found on walls adjoining the flying buttresses.	Area: 150mm (W) x 900mm (H) (on average)	• Lack of periodic maintenance. • Lack of safety access.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(c)

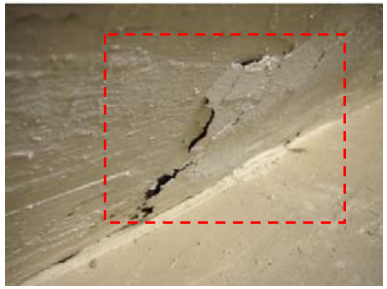
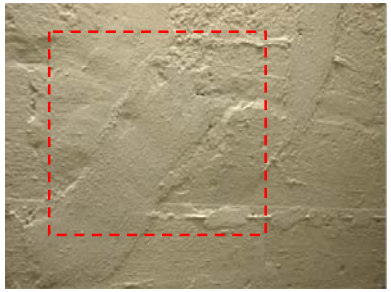
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-E-RU3		Rusting of window frame, with flaking of paint is found.	Area: 200mm (W) x 50mm (H)	• Accumulation of water at the bottom corners. • Failure of paint in avoiding rusting.	Material(s) involved: Metal and paint Refer to Section 4.4.1(a)
EXT-E-CR3		A crack is found on the external roof above the corridor. It is noted that the crack is visible along the entire roof. (Cross reference withEXT-W-CR1)	Thickness: 10mm Length: 7000mm	• Thermal movement as the roof is exposed to solar radiation. • Poor bonding, inadequate key to background.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section4.3.1(b)
EXT-E-CR4		A crack is found on the external roof above the corridor. (Cross reference withEXT-W-CR2)	Thickness: 8mm Length: 8000mm	• Thermal movement as the roof is exposed to solar radiation. • Poor bonding, inadequate key to background.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section4.3.1(b)

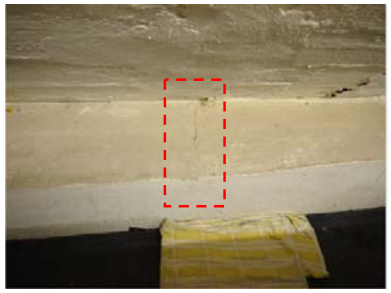
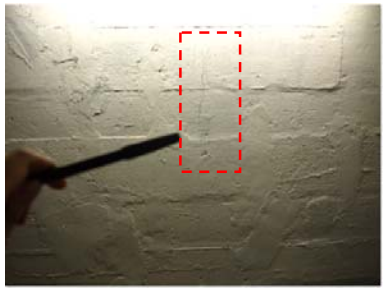
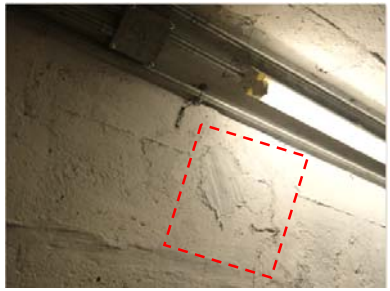
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
EXT-E-CR5		A minor vertical and horizontal crack is found on the column.	Thickness: 2mm Length: 400mm	• Poor bonding of plaster mix between new and old. • Cracks created by installation of lighting or expansion of metal. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(d)

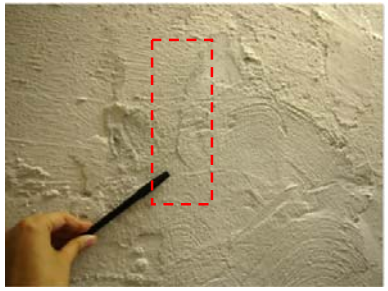
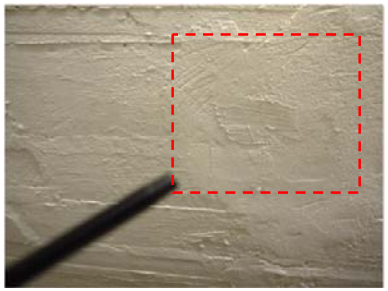
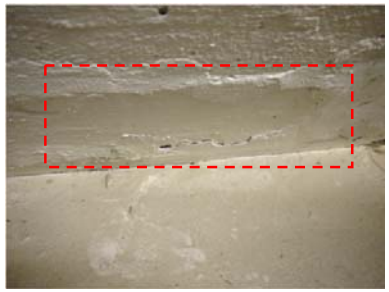
Ceiling Slab - West Side (CEI-W)

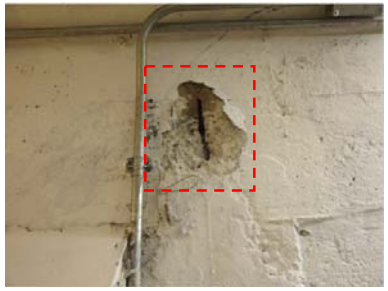
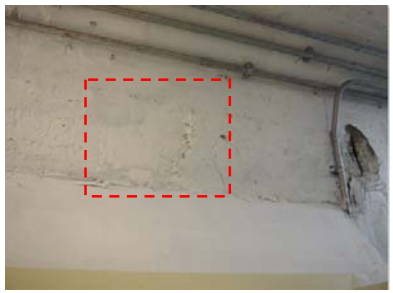
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-SP1		Spalling of plastering and concrete is found on the upper level of the wall and reinforcement is exposed.	Area: 300mm (W) x 300mm (H)	• Corrosion of reinforcement.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.2(a)
CEI-W-CR1		A hairline crack is found on the middle level of the wall.	Thickness: 3mm Length: 150mm	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-W-FL1		Flaking of plastering is found on the lower level of the wall.	Area: 100mm (W) x 8mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

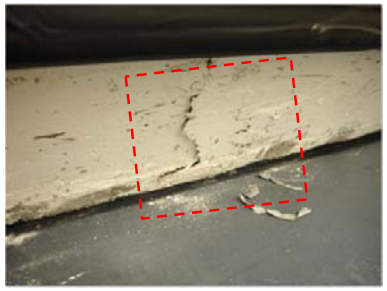
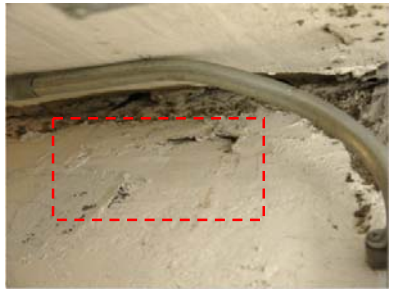
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-FL2		Flaking of plastering is found on the lower level of the wall.	Area: 500mm (W) x 230mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL3		Flaking of plastering is found on the upper level of the wall.	Area: 140mm (W) x 280mm (H)	• Low level of workmanship in past repair.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL4		Flaking of plastering is found on the upper level of the wall.	Area: 220mm (W) x 220mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

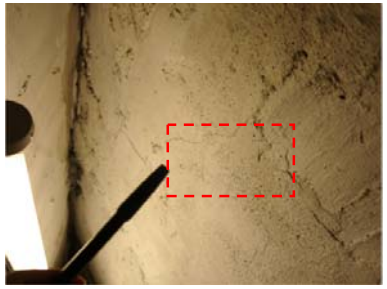
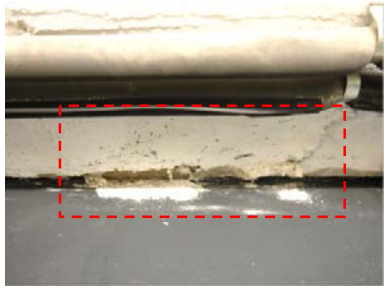
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-FL5		Flaking of plastering is found on the lower level of the wall.	Area: 450mm (W) x 140mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL6		Flaking of plastering is found on the lower level of the wall.	Area: 350mm (W) x 400mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL7		Flaking of plastering is found on the middle level of the wall.	Area: 140mm (W) x 180mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

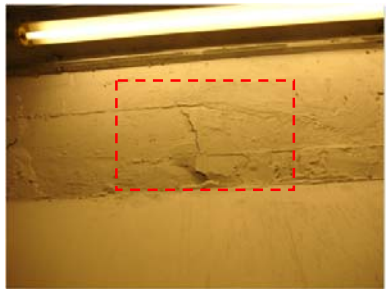
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-CR2		A hairline crack is found on the lower level of the wall.	Thickness: 3mm Length: 250mm	• Inadequate time in curing the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-W-CR3		A hairline crack is found on the upper level of the wall.	Thickness: 3mm Length: 730mm	• Inadequate time in curing the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-W-FL8		Flaking of plastering is found on the upper level of the wall.	Area: 270mm (W) x 280mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

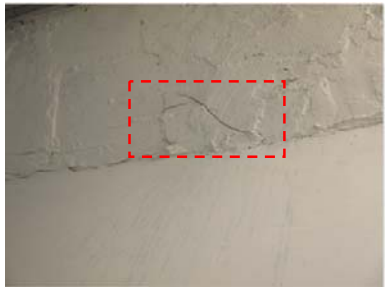
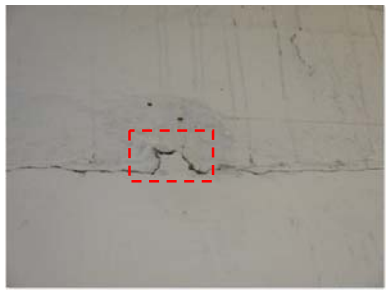
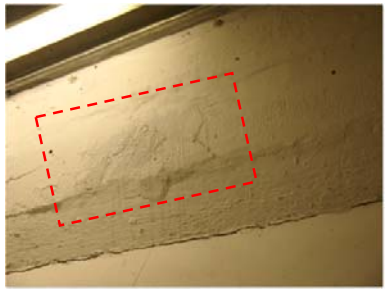
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-FL9		Flaking of plastering is found on the upper level of the wall.	Area: 200mm (W) x 300mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL10		Flaking of plastering is found on the middle level of the wall.	Area: 140mm (W) x 220mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL11		Flaking of plastering is found on the lower level of the wall.	Area: 340mm (W) x 120mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

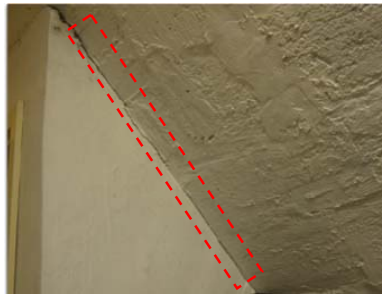
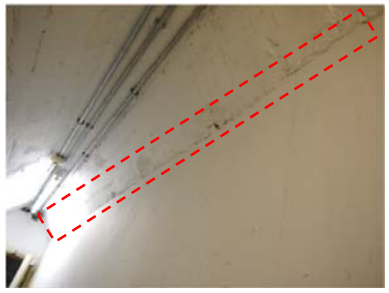
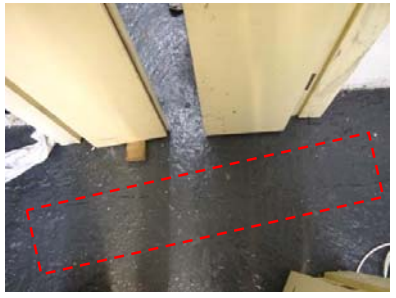
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-SP2		SpallingofReinforced Concrete and Plastering is found on the upper level of the wall and reinforcement is exposed.	Area: 330mm (W) x 700mm (H)	• Corrosion of reinforcement.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.2(a)
CEI-W-FL12		Flaking of plastering is found on the upper level of the wall.	Area: 500mm (W) x 260mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL13		Flaking of plastering is found on the upper level of the wall.	Area: 160mm (W) x 260mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-CR4		A hairline crack is found above the top left corner of the door frame.	Thickness: 5mm Length: 70mm	• Inadequate time in curing the plaster. • Swing of door.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-W-FL14		Flaking of plastering is found on the lower level of the wall.	Area: 150mm (W) x 80mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL15		Flaking of plastering is found on the upper level of the wall.	Area: 400mm (W) x 300mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

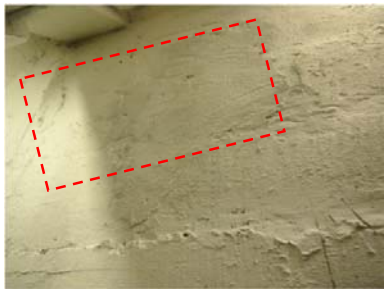
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-FL16		Flaking of plastering is found on the upper level of the wall.	Area: 200mm (W) x 200mm (H)	• Plastering too strong and too wet resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL17		Flaking of plastering is found on the lower level of the wall.	Area: 200mm (W) x 200mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL18		Flaking of plastering is found on the middle level of the wall.	Area: 500mm (W) x 450mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

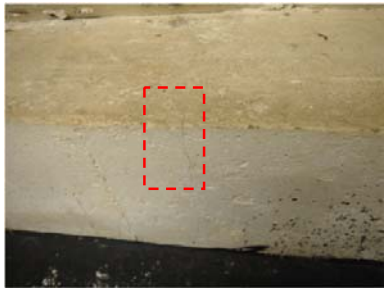
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-FL19		Flaking of plastering is found on the middle level of the wall.	Area: 400mm (W) x 300mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL20		Flaking of plastering is found on the middle level of the wall.	Area: 300mm (W) x 470mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL21		Flaking of plastering is found on the middle level of the wall.	Area: 260mm (W) x 300mm (H)	• Plastering used too wet, resulting in shrinkage and separation from backing.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

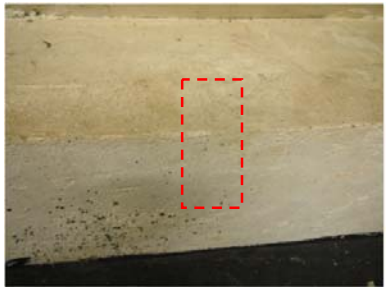
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-FL22		Flaking of plastering is found on the upper level of the wall.	Area: 200mm (W) x 150mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL23		Flaking of plastering is found on the upper level of the wall.	Area: 50mm (W) x 50mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-W-FL24		Flaking of plastering is found on the upper level of the wall.	Area: 300mm (W) x 200mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

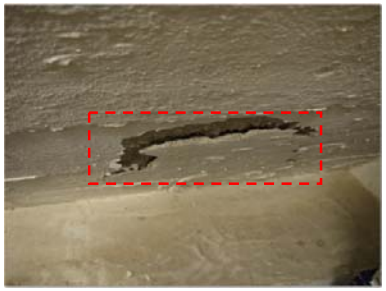
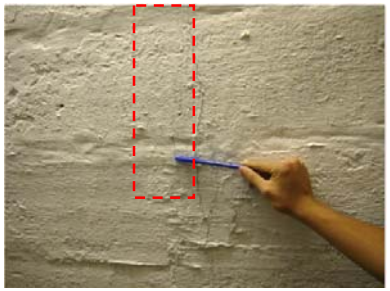
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-W-CR5		A crack is found between the gable and the concrete partition wall.	Thickness: 8mm Length: 2000mm	• Low level of workmanship in past installation of partition walls.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(c)
CEI-W-CR6		A crack is found between the gable and the concrete partition wall.	Thickness: 8mm Length: 5000mm	• Low level of workmanship in past installation of partition walls.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(c)
CEI-W-CR7		A crack is found on the cement screeding, connecting the two manholes on both east and west sides. (Refer to CEI-E-CR9)	Thickness: 5mm Length: 1500mm	• Shrinkage of cement screeding.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)

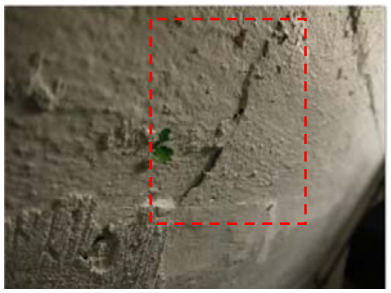
Ceiling Slab - East Elevation (CEI-E)

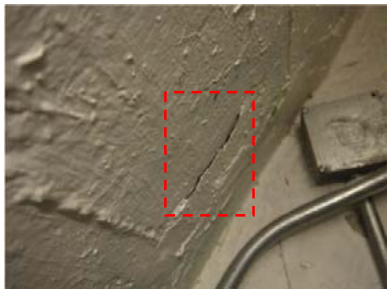
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-FL1		Powdering plaster is found on the lower level of the wall.	Area: 150mm (W) x 100mm (H)	• Moisture of wall creates powder on the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-FL2		Powdering plaster is found on the lower level of the wall.	Area: 300mm (W) x 100mm (H)	• Moisture of wall creates powder on the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-FL3		Flaking of plastering is found on the upper level of the wall.	Area: 100mm (W) x 100mm (H)	• Low level of workmanship in past repair.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-FL4		Powdering plaster is found on the lower level of the wall.	Area: 100mm (W) x 300mm (H)	• Moisture of wall creates powder on the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-FL5		Powdering plaster is found on the lower level of the wall.	Area: 100mm (W) x 300mm (H)	• Moisture of wall creates powder on the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-CR1		A hairline crack is found perpendicular to the beam.	Thickness: 2mm Length: 100mm	• Shrinkage of concrete.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)

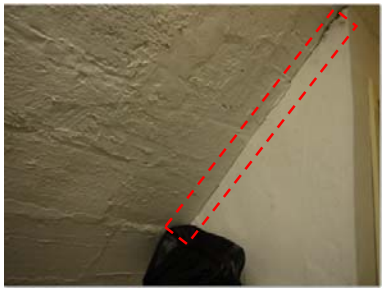
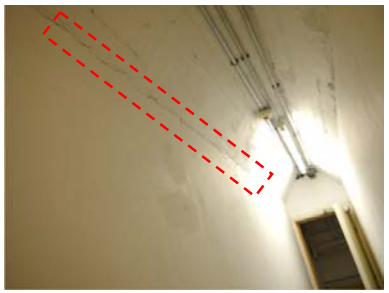
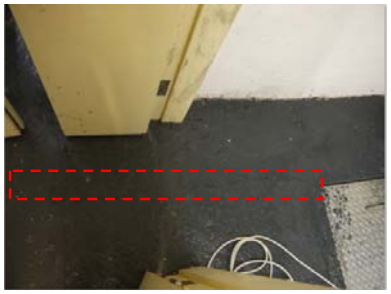
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-CR2		A hairline crack is found perpendicular to the beam.	Thickness: 2mm Length: 100mm	• Shrinkage of concrete.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-E-CR3		A hairline crack is found perpendicular to the beam.	Thickness: 2mm Length: 400mm	• Shrinkage of concrete.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-E-CR4		A hairline crack is found perpendicular to the beam.	Thickness: 2mm Length: 400mm	• Shrinkage of concrete.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-SP1		Spalling of plastering is found on the lower level of the wall.	Area: 500mm (W) x 600mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.2(a)
CEI-E-CR5		A hairline crack is found on the upper level of the wall.	Thickness: 2mm Length: 400mm	• Inadequate time for curing the plaster.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-E-FL6		Flaking of plasteringis found on the lower level of the wall.	Area: 600mm (W) x 800mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-FL7		Flaking of plasteringis found on the lower level of the wall.	Area: 50mm (W) x 50mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-FL8		Flaking of plasteringis found on the lower level of the wall.	Area: 40mm (W) x 30mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-FL9		Flaking of plasteringis found on the lower level of the wall.	Area: 60mm (W) x 60mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

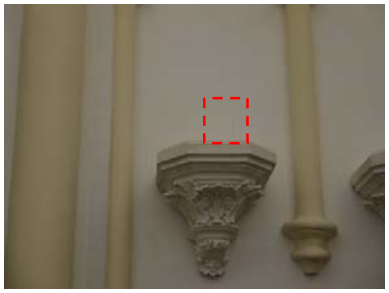
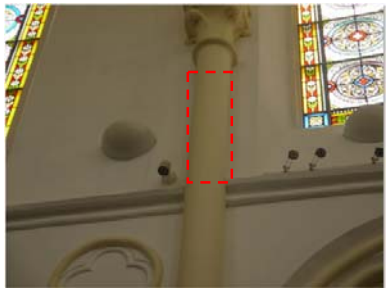
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-DS1		Discoloration (Brownishstain) is found on the lower level of the wall.	Area: 200mm (W) x 300mm (H)	• Presence of iron in the plaster mix.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.4(a)
CEI-E-FL10		Flaking of plastering is found on the middle level of the wall.	Area: 100mm (W) x 100mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-SP2		Spalling of plastering and concrete is foundright behind the steel bar.	Area: 100mm (W) x 100mm (H)	• Low level of workmanship in past installation of building services.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.2(a)

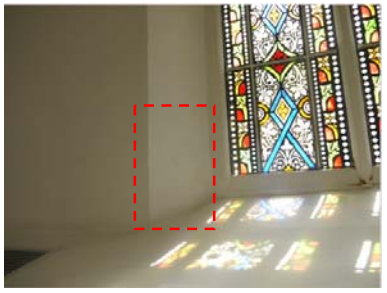
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-FL11		Flaking of plastering is found on the middle level of the wall.	Area: 500mm (W) x 200mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)
CEI-E-CR6		A hairline crack is found above the top right corner of the door frame.	Thickness: 4mm Length: 70mm	• Inadequate time in curing the plaster. • Swing of door.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)
CEI-E-FL12		Flaking of plastering is found on the upper level of the wall.	Area: 400mm (W) x 300mm (H)	• Plastering too wet and too strong resulting in shrinkage.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.3(a)

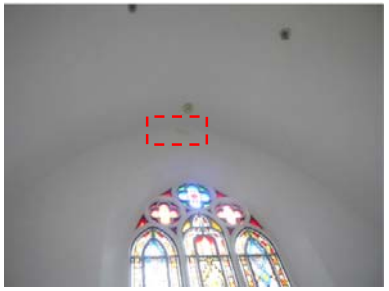
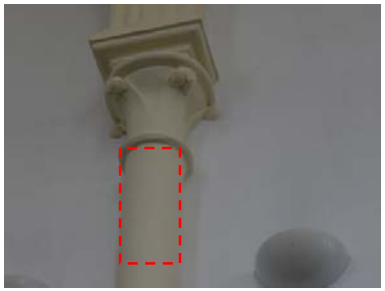
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
CEI-E-CR7		A crack is found between the gable and the concrete partition wall.	Thickness: 8mm Length: 2000mm	• Low level of workmanship in past installation of partition walls.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(c)
CEI-E-CR8		A crack is found between the gable and the concrete partition wall.	Thickness: 8mm Length: 5000mm	• Low level of workmanship in past installation of partition walls.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(c)
CEI-E-CR9		A crack is found on the cement screeding, connecting the two manholes on both east and west sides. (Refer to CEI-W-CR5)	Thickness: 5mm Length: 1500mm	• Shrinkage of cement screeding.	Material(s) involved: Reinforced Concrete and Plaster Refer to Section 4.3.1(a)

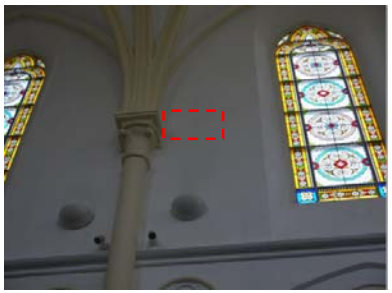
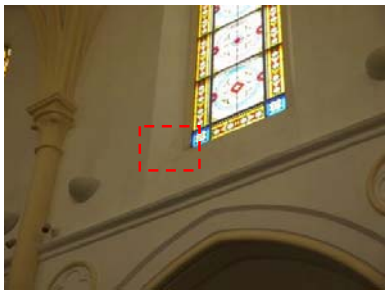
Interior- West Elevation (INT-W)

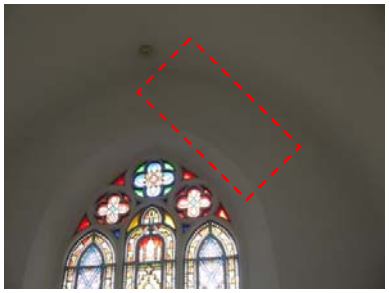
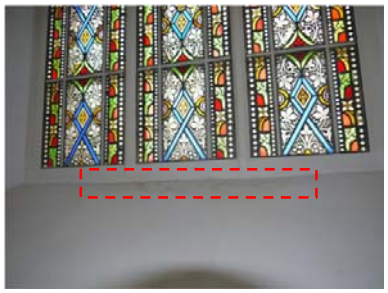
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-WS1		Yellow water stain is found under the bottom right corner of the window.	Area: 50mm (W) x 50mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-W-CR1		A hairline crack is found on the column.	Thickness: 1mm Length: 250mm	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)
INT-W-CR2		A hairline crack is found on the column.	Thickness: 5mm Length: 500mm	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)

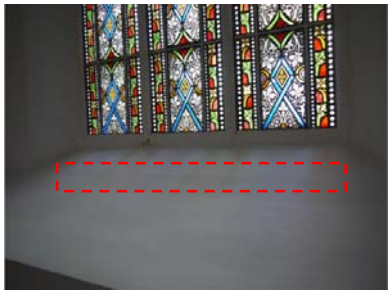
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-CR3		A hairline crack is found on the wall, in between the column and the window. (**Note:** rainwater poured in from this window as recorded in mid-October)	Thickness: 5mm Length: 500mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-CR4		A hairline crack is found on the wall.	Thickness: 1mm Length: 100mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-CR5		A hairline crack is found on the column.	Thickness: 5mm Length: 300mm	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-RU1		Rusts are found on bottom part of the window frame.	<u>Area:</u> 100mm (W) x 100mm (H)	• Accumulation of water. • Failure of paint in avoiding rusting.	<u>Material(s) involved:</u> Metal and paint Refer to Section 4.4.1(a)
INT-W-WS2		Yellow water stain is found under the bottom left corner of the window.	<u>Area:</u> 150mm (W) x 150mm (H)	• Water seepage.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.2(b)
INT-W-CR6		A hairline crack is found on the wall.	<u>Thickness:</u> 5mm <u>Length:</u> 1800mm	• Thermal or slight movement crack.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.1(b)

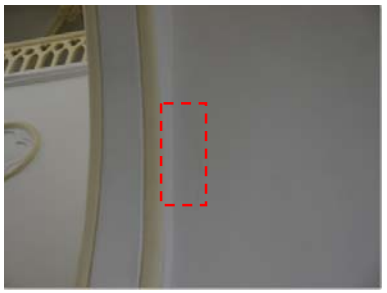
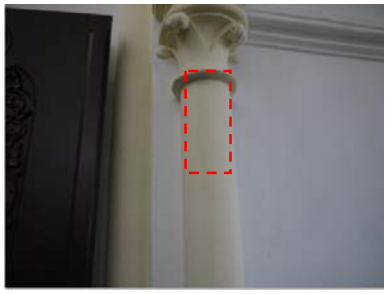
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-WS3		Yellow water stain is found above the window.	Area: 200mm (W) x 200mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-W-DA1		Missing of plaster is found on the top edge of the baseboard.	Area: 80mm (W) x 50mm (H)	• Physical damage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.5(a)
INT-W-CR7		A hairline crack is found on the column.	Thickness: 5mm Length: 400mm	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)

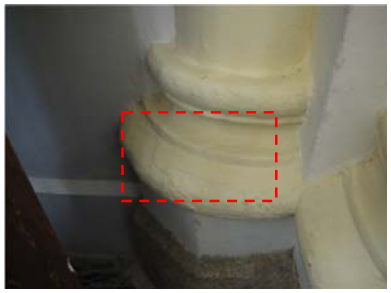
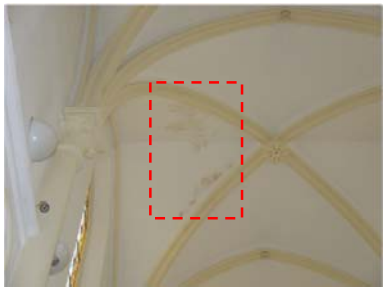
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-CR8		A hairline crack is found on the wall, in between the column and the window.	Thickness: 5mm Length: 1000mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-WS4		Yellow water stain is found on the bottom left corner of the window.	Area: 200mm (W) x 200mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-W-CR9		Hairline cracks are found on the wall, near the capital of the column. (**Note:** rainwater poured in from this window as recorded in mid-October)	Thickness: 2mm Length: 400mm (on average)	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

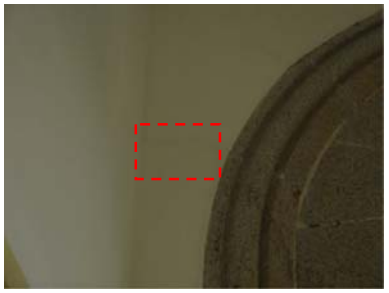
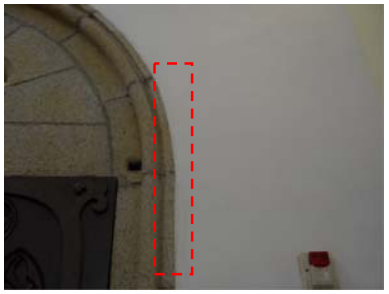
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-CR10		Hairline cracks are found on the wall, which developed from one crack into several in between the two site visits.	Thickness: 5mm Length: 1300mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-WS5		Bubbling and water stain is found right under the window frame.	Area: 600mm (W) x 100mm (H)	• Water seepage. • Use of paint with impermeable nature.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)
INT-W-WS6		Initial stage of flaking is found on the wall.	Area: 200mm (W) x 50mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)

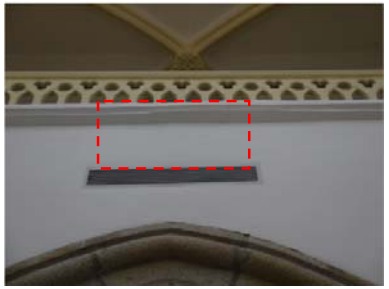
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-WS7		Yellow water stain is found on the bottom left corner of the window frame.	Area: 200mm (W) x 200mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-W-CR11		A number of interconnected hairline cracks are found on the wall.	Thickness: 4mm Length: 700mm (on average)	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-CR12		A hairline crack is found under the window frame.	Thickness: 6mm Length: 1500mm	• Differential thermal expansion at the intersection between different materials.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-WS8		Water stain is found on the wall.	Area: 100mm (W) x 100mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-W-WS9		Large scale of water stain is found near the ground level of the wall.	Area: 2000mm (W) x 200mm (H)	• Suspected water leakage	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(d)
INT-W-FL1		Flaking of plaster is found on the arch.	Area: 100mm (W) x 50mm (H)	• Improper workmanship.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.3(a)

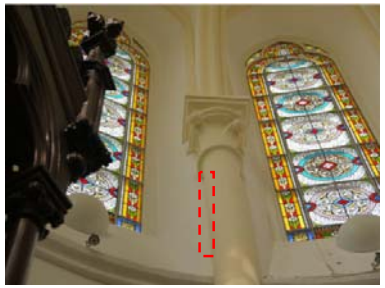
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-WS10		Bubbling of plaster is found near the ground level of the wall.	Area: 1500mm (W) x 200mm (H)	• Use of paint with impermeable nature. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)
INT-W-CR13		A hairline crack is found on the wall.	Thickness: 1mm Length: 200mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-CR14		A number of hairline cracks are found on the column.	Thickness: 6mm Length: 300mm (on average)	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)

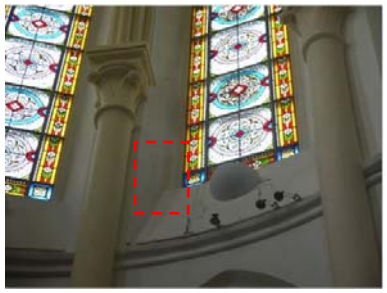
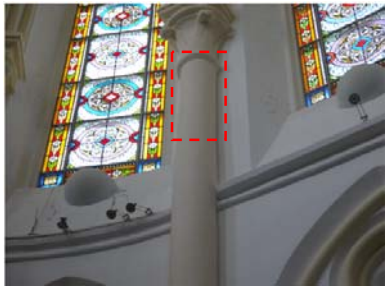
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-CR15		A hairline crack is found on the base of the column.	Thickness: 7mm Length: 300mm	• Thermal or slight movement crack. • Physical damage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)/4.2.5(a)
INT-W-CR16		A hairline crack is found on the base of the column.	Thickness: 7mm Length: 300mm	• Thermal or slight movement crack. • Physical damage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)/4.2.5(a)
INT-W-WS11		Yellow water stain is found on the vault.	Area: 2000mm (W) x 1500mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)

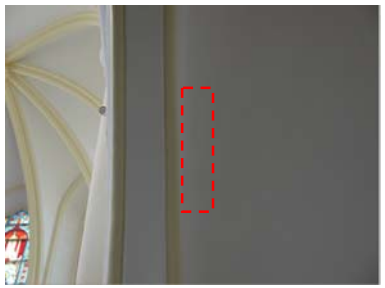
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-CR17		A hairline crack is found on the wall.	Thickness: 4mm Length: 1000mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-W-WS12		Initial stage of popping are found on the wall.	Area: 400mm (W) x 300mm (H)	• Presence of unslaked lime in the plaster mix. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)
INT-W-CR18		A hairline crack is found on the wall.	Thickness: 4mm Length: 600mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

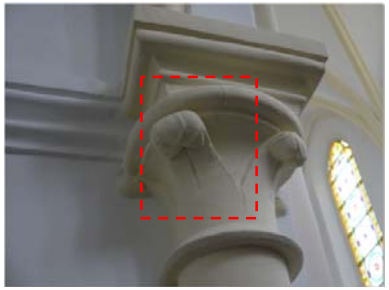
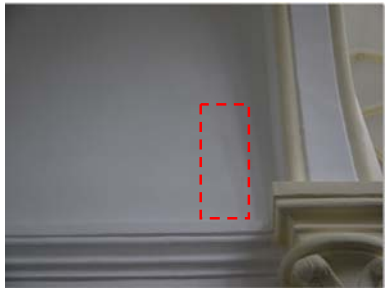
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-W-CR19		A hairline crack is found on the wall.	Thickness: 4mm Length: 600mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

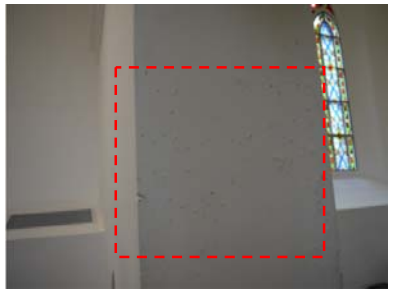
Interior- East Elevation (INT-E)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-CR1		A hairline crack is found above the window.	Thickness: 1mm Length: 300mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-CR2		A hairline crack is found next to the window.	Thickness: 2mm Length: 400mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-CR3		A hairline crack is found in between the wall and the column.	Thickness: 2mm Length: 100mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

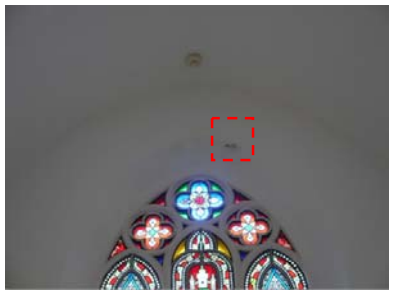
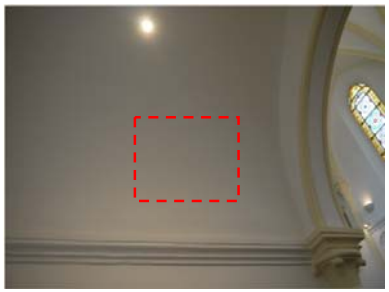
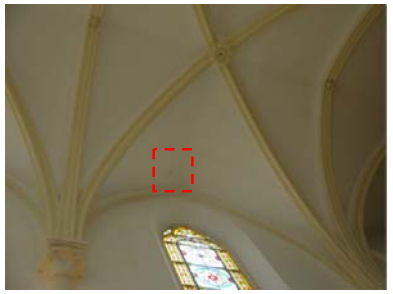
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-WS1		Yellow water stain is found under the bottom left corner of the window.	<u>Area:</u> 400mm (W) x 1500mm (H)	• Water seepage.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.2(b)
INT-E-CR4		A hairline crack is found on the column.	<u>Thickness:</u> 4mm <u>Length:</u> 150mm	• Presence of various mix of plasters. • Differential thermal expansion.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.1(a)
INT-E-WS2		Bubbling and yellow water stain is found on the wall.	<u>Area:</u> 400mm (W) x 3000mm (H)	• Water seepage. • Use of paint with impermeable nature.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.2(a)

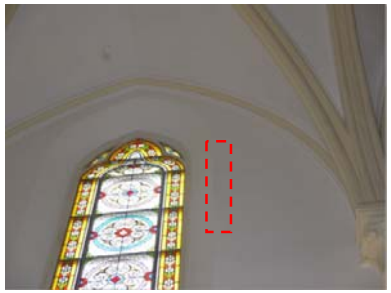
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-CR5		A hairline crack is found on the wall.	Thickness: 2mm Length: 600mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-CR6		A hairline crack is found on the column.	Thickness: 1mm Length: 600mm	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)
INT-E-CR7		A hairline crack is found on the wall.	Thickness: 1mm Length: 300mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

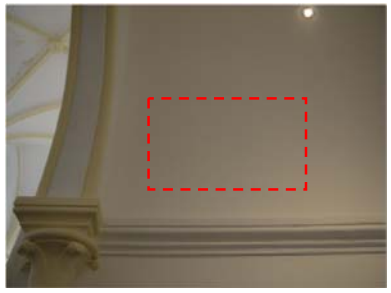
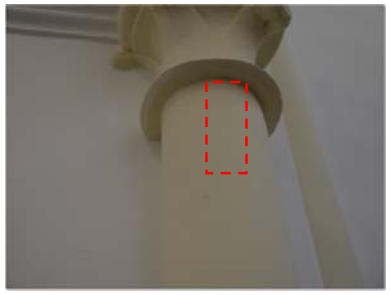
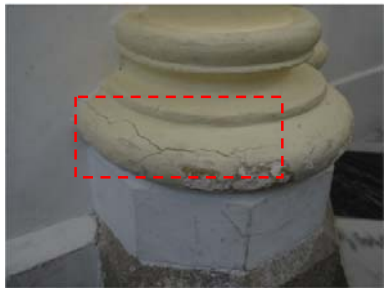
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-RU1		Rusts are found on upper right part of the window frame. (**Note:** rainwater poured in from this window as recorded in mid-October)	Area: 100mm (W) x 400mm (H)	• Accumulation of water. • Failure of paint in avoiding rusting.	Material(s) involved: Metal and paint Refer to Section 4.4.1(a)
INT-E-CR8		A number of hairline cracks are found on the head of the column.	Thickness: 5mm Length: 100mm (on average)	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)
INT-E-CR9		A hairline crack is found on the wall.	Thickness: 4mm Length: 1800mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

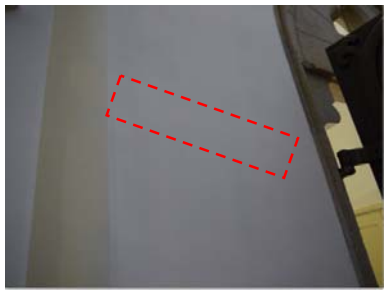
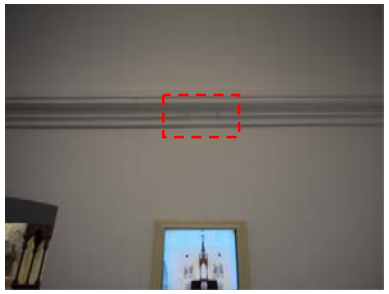
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-CR10		A hairline crack is found on the arch.	Thickness: 4mm Length: 150mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-WS3		Large scale of popping, flaking and powdery plaster are found on the wall.	Area: 500mm (W) x 1000mm (H)	• Presence of unslaked lime in the plaster mix. • Salt efflorescence. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)
INT-E-WS4		Water stain is found near the ground level of the wall.	Area: 800mm (W) x 200mm (H)	• Suspected water leakage	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(d)

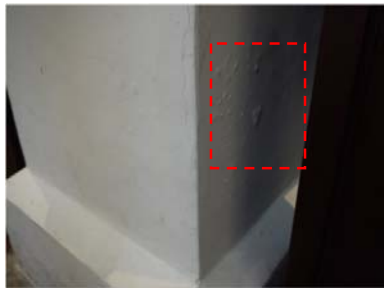
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-CR11		A number of hairline cracks are found on the head of the column.	Thickness: 5mm Length: 200mm (on average)	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)
INT-E-RU2		Rusts are found on upper part of the window frame.	Area: 200mm (W) x 1000mm (H)	• Accumulation of water. • Failure of paint in avoiding rusting.	Material(s)involved:Metal and paint Refer to Section 4.4.1(a)
INT-E-WS5		Yellow water stain is found on the wall.	Area: 600mm (W) x 600mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-WS6		Yellow water stain is found on the wall.	Area: 300mm (W) x 400mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-E-CR12		A hairline crack is found on the wall.	Thickness: 2mm Length: 600mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-WS7		Yellow water stain is found on the vault.	Area: 300mm (W) x 300mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)

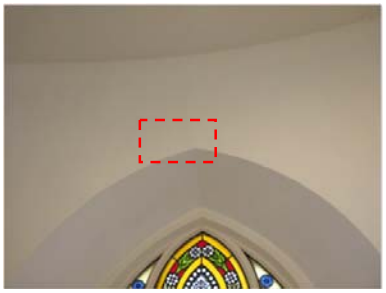
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-WS8		Yellow water stain is found on the wall.	Area: 600mm (W) x 1000mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-E-CR13		A hairline crack is found on the column.	Thickness: 1mm Length: 100mm	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)
INT-E-CR14		A hairline crack is found on the wall.	Thickness: 3mm Length: 1200mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

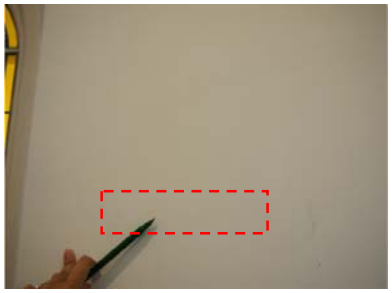
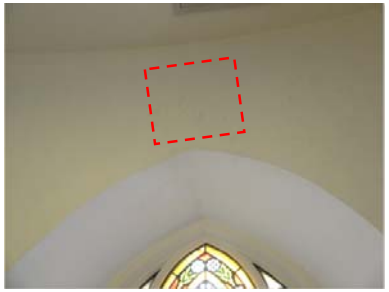
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-CR15		A hairline crack is found on the wall.	Thickness: 3mm Length: 700mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-CR16		A number of hairline cracks are found on the column.	Thickness: 3mm Length: 150mm (on average)	• Presence of various mix of plasters. • Differential thermal expansion.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(a)
INT-E-CR17		A hairline crack is found on the base of the column.	Thickness: 6mm Length: 350mm	• Physical damage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.5(a)

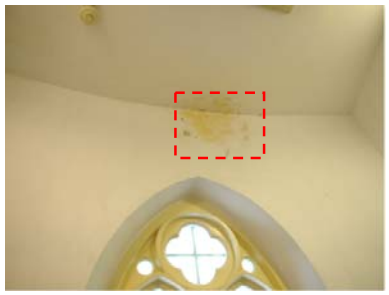
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-CR18		A hairline crack is found on the wall.	Thickness: 3mm Length: 600mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-E-CR19		A hairline crack is found on the wall.	Thickness: 3mm Length: 250mm	• Physical damage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.5(a)
INT-E-FL1		Flaking of plaster is found on the moulding of the wall.	Area: 50mm (W) x 50mm (H)	• Presence of unslaked lime in the plaster mix. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)

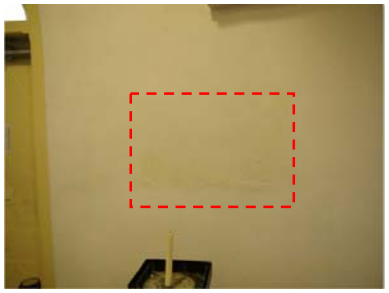
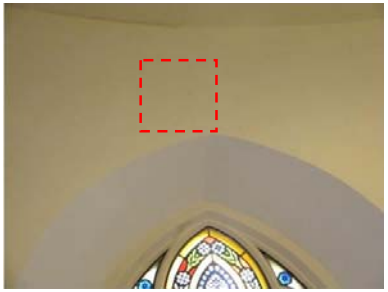
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-E-WS9		Initial stage of popping is found on the wall.	Area: 500mm (W) x 1000mm (H)	• Presence of unslaked lime in the plaster mix. • Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)
INT-E-DA1		Missing of plaster is found on the top edge of the baseboard.	Area: 100mm (W) x 100mm (H)	• Physical damage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.5(a)

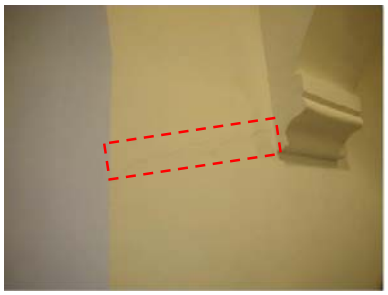
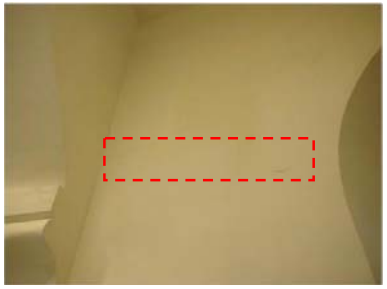
Interior -Corridor (INT-C)

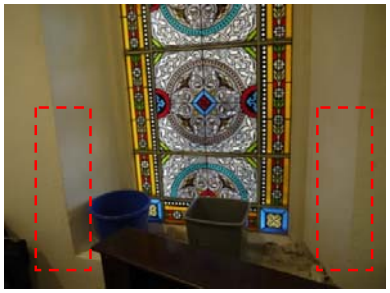
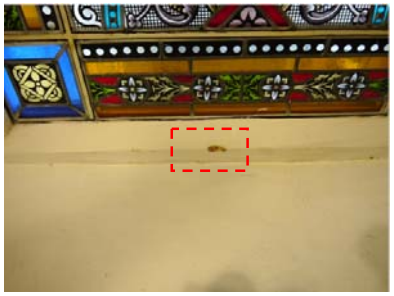
No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-C-RU1		Rusts are found on bottom part of the window frame.	Area: 50mm (W) x 50mm (H)	• Accumulation of water. • Failure of paint in avoiding rusting.	Material(s) involved: Metal and paint Refer to Section 4.4.1(a)
INT-C-FL1		Flaking of paint is found on the window frame.	Area: 100mm (W) x 100mm (H)	• Accumulation of water.	Material(s) involved: Metal and paint Refer to Section 4.4.1(a)
INT-C-CR1		A hairline crack is found on the wall.	Thickness: 3mm Length: 2000mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-C-CR2		A hairline crack is found on the wall.	Thickness: 2mm Length: 1000mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-C-RU2		Rusts are found on bottom part of the window frame.	Area: 200mm (W) x 50mm (H)	• Accumulation of water. • Failure of paint in avoiding rusting.	Material(s) involved: Metal and paint Refer to Section 4.4.1(a)
INT-C-WS1		Yellow water stain is found on the wall.	Area: 700mm (W) x 700mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-C-WS2		Yellow water stain with flaking of plaster is found on the wall.	Area: 700mm (W) x 700mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)
INT-C-CR3		A number of hairline cracks are found on the wall.	Thickness: 2mm Length: 2000mm (on average)	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-C-CR4		A hairline crack is found on the wall.	Thickness: 1mm Length: 1300mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-C-WS3		Yellow water stain is found on the wall. Unslaked lime seems to present.	Area: 500mm (W) x 200mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(a)/4.2.2(b)
INT-C-CR5		A hairline crack is found on the arch.	Thickness: 3mm Length: 1000mm	• Thermal or slight movement crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-C-WS4		Yellow water stain is found on the wall.	Area: 600mm (W) x 600mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-C-CR6		A crack is found on the wall.	Thickness: 3mm Length: 1000mm	• Re-cracking of repaired crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-C-CR7		A crack is found on the wall.	Thickness: 3mm Length: 800mm	• Re-cracking of repaired crack.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.1(b)
INT-C-WS5		Yellow water stain with flaking of plaster is found on the wall. (**Note:** water poured in from this location as recorded in September)	Area: 600mm (W) x 600mm (H)	• Water seepage.	Material(s) involved: Plaster with brick substrate Refer to Section 4.2.2(b)

No.	Photo	Description	Extent	Possible Cause(s)	Recommendation(s)
INT-C-WS6		Bubbling of plasteris found on the wall adjacent to the two sides of the window.	<u>Area:</u> 600mm (W) x 300mm (H)	• Water seepage. • Use of paint with impermeable nature.	<u>Material(s) involved:</u> Plaster with brick substrate Refer to Section 4.2.2(a)
INT-C-RU3		Rusts are found on bottom part of the window frame.	<u>Area:</u> 50mm (W) x 50mm (H)	• Accumulation of water. • Failure of paint in avoiding rusting.	<u>Material(s) involved:</u> Metal and paint Refer to Section 4.4.1(a)