BOHOL HERITAGE CHURCHES

Summary of Findings & Recommendations - STRUCTURAL

ummary of Findings & Recommendations - STRUCTURAL

he JV Digiscript and EM2A Partners & Co was commissioned by the National Museum to undertake a detailed investigation of the Causative mechanisms, environmental factors(Geology and Geotechnical considerations) to come up with General Conclusions nd recommendations on the directions for Repair, remediation and econstruction for each of the specific 9 Heritage Structures assigned o the JV.

side from the field investigations (Phographic records, Soil Borings nd GPR Scanning, the JV also conducted drone aerial and laser scans o determine geometries and Layouts.

his Presentation is to summarize the findings and recommendations n the proposed actions to be undertaken for each of the Heritage tructures.

An Important Note on the Classification of the Heritage Churches

- In General, but more specifically for most of the Bohol Structures, the term “URM” is a misnomer.
- The main wall system is the Argamasa or Lechada and not the Limestone Blocks.
- The limestone blocks are not in anyway load bearing elements but really used as formworks and *veneer.*
- *Thus, focus on the Blocks in the Repair or remediation procedures is misdirected except if only to prevent falling hazards or delamnations.*

ummary of Findings & Recommendations - STRUCTURAL

As a Result, a *General Summary Main Engineering Report* and a *General Guidelines Report* were prepared as well as the following pecific Reports for each of the Structures:

- 2015-005A-G-PR Engineering Evaluation Report Capitol, Bohol (18 October 2015) ### Rev 2
- 2015-005B-G-PR Engineering Evaluation Report Dimiao Church (October 18 2015) FINAL ### REV 1.0
- 2015-005C-G-PR Engineering Evaluation Report Cortes Church, Bohol (October 18, 2015) ### REV 1...
- 2015-005D-G-PR EVALUATION REPORT Loboc Church, Bohol $$$ (OCTOBER 18, 2015) Rev 2.0
- 2015-005E-G-PR Engineering Evaluation Report Maribojoc Church, Bohol (October 18, 2015) FINAL ...
- 2015-005F-G-PR Engineering Evaluation Report Punta Cruz Watchtower (October 18, 2015) FINAL #...
- 2015-005G-G-PR Albuquerque Church, Bohol REPORT 25Nov2015 ###
- 2015-005H-G-PR Panglao Church, Bohol REPORT (28December2015)
- 2015-005I-G-PR Engineering Evaluation Report GUIUAN Church (Nov. 10, 2015) @@@

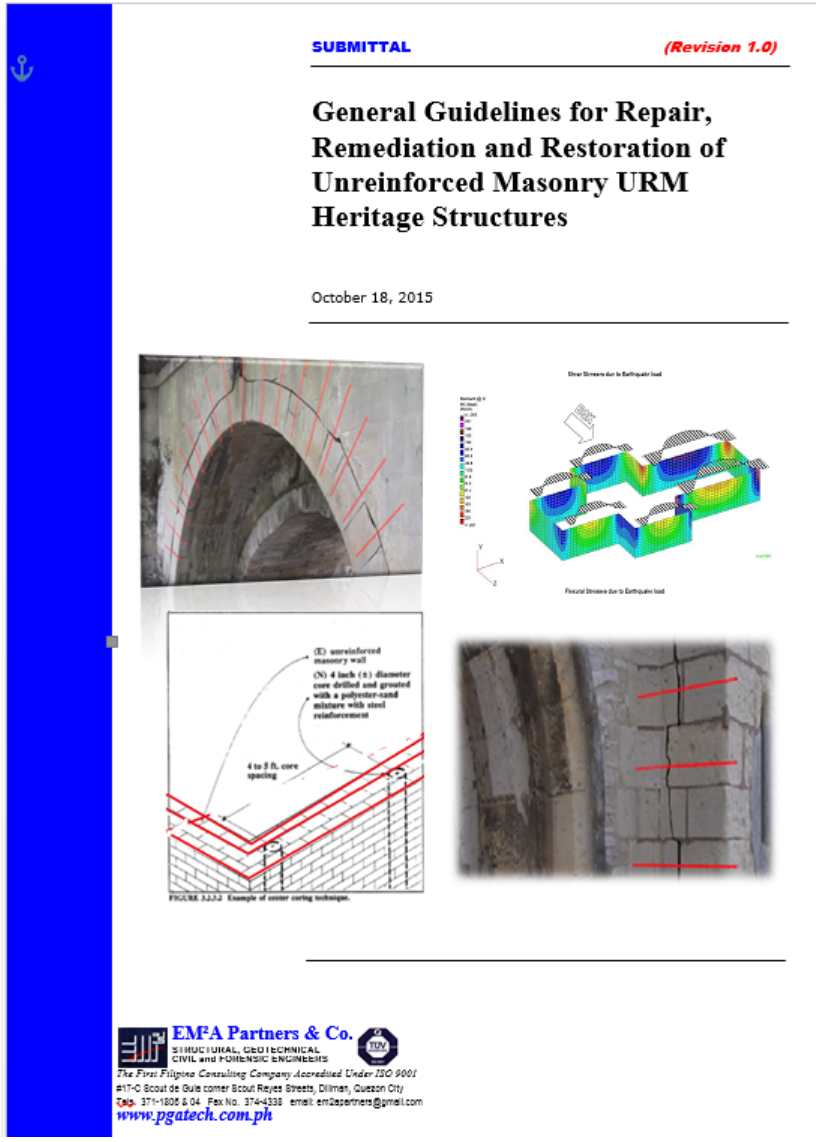
SUMMARY OF INTERVENTIONS

- Repair of wall Cracks and Disturbed Blocks by Nailing using Helical Nails.
- Repair of Dislodged *“Voussoirs” and individual blocks*
- Provision of Buttresses and proper connections including the use of Dissipative Dampers to absorb the energy.
- Provision of “ Belt Bands “ at the top to provide confinement and also strengthen wall to Truss system connections.
- Reconstruction of Damaged walls using Period Construction practices but providing adequate “*Reentrant corner” reinforcement using stainless steel* corner reinforcement.
- Reinforcement of Critical Reentrant corners and intersecting Orthogonal walls using Mechanical Stitching.

Summary of Findings & Recommendations - STRUCTURAL

The "*General Guidelines for Repair , Remediation and Restoration of Unreinforced Masonry URM Heritage Structures*" was intended to give a general guideline in the Planning and Implementation of the Repair and Restoration Programme and in some cases for Total Reconstruction.

This is Intended as a companion Volume to the individual Reports to guide the Stakeholders in a General understanding of the Structures Report.


SUBMITTAL (Revision 1.0)

General Guidelines for Repair, Remediation and Restoration of Unreinforced Masonry URM Heritage Structures

October 18, 2015

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Summary of Findings & Recommendations - STRUCTURAL

In addition to the Guidelines a Main Engineering Report was also prepared to aid in the General overall assessment of the structures involved.

This includes our General findings and Failure mechanisms observed.

It also includes general recommendations and the way forward.

INDIVIDUAL Structures Report

Summary of Findings & Recommendations – STRUCTURAL BOHOL CAPITOL BUILDING

- The Bohol Capitol Building is in the Priority list.
- Our findings indicate that the structure would need structural intervention due to the existing damage as well as added loads which could significantly impact the future structural performance of the building if not retrofitted.
- It is important to undertake a more detailed structural Engineering Analyses to address existing vulnerabilities as well as critical added loads.
- In addition GPR scanning indicates cavities of significant size underlying the footprint of the building.

ENGINEERING EVALUATION REPORT *(Revision 2.0)*

Detailed Engineering Studies *(DES)*of Heritage Structures Declared NCI/ICP in Bohol and Samar Affected by Calamities *Rev 2.0*

FOR THE

PROVINCIAL CAPITOL BUILDING
Tagbilaran City, Bohol

OCTOBER 18, 2015

PF-2015-005A-G-PR

Submitted to:

Mr. Jeremy R. Barns
Director IV
NATIONAL MUSEUM
Old Congress Building
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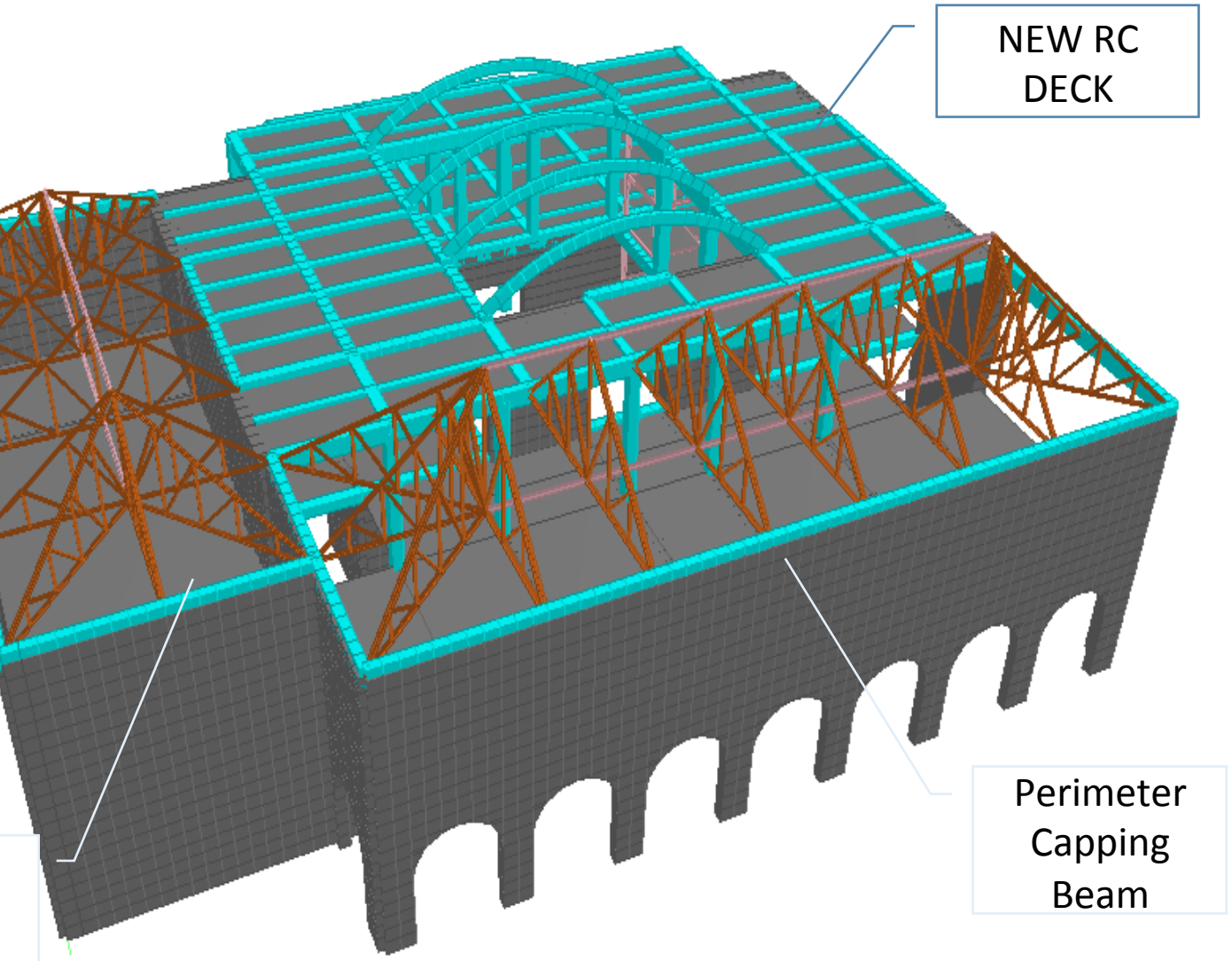
BOHOL CAPITOL BUILDING

Due to the addition of an RC concrete deck at the 2nd Floor Level, lateral loads have aggravated the already Damaged Structure.

The solution is to beef up interior walls and convert these as shear walls by providing a continuous Reinforced *Boxed* shotcrete wall to provide confinement as well as Structural Rigidity.

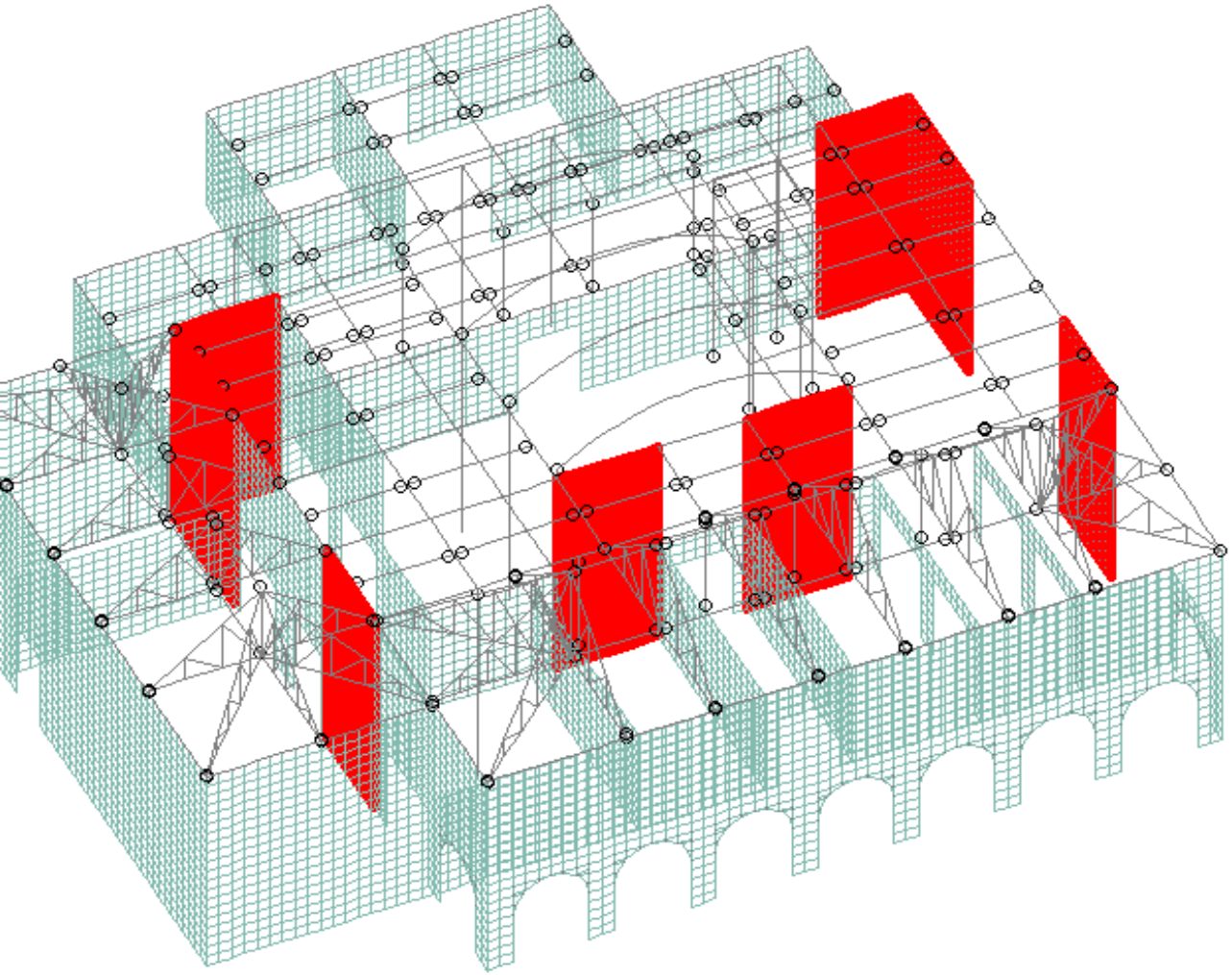
The Existing Timber flooring as well as the existing framework have been augmented to serve as the Lateral force Transmission system by letting these act as Horizontal Diaphragms directly transferring the Lateral forces to the beefed up wall system.

Conversion to Museum and Floor Additions Complicate the Remediation and Retrofitting Interventions Requiring Shear wall Elements



To the left is the rendered view o the modified FEA of the Capitol building. Proposed alterations in the design made by the NM Mani are incorporated in the analysis. I order to support the new loads applied to the building, additiona structural members are provided. This includes additional transfer beams and columns to support th new roof. Portions of the existing masonry walls are also used and reinforced to act as Shear walls b using steel rebars and shotcrete t make it more rigid to carry the additional loads and also to resist the lateral loads from earthquake or wind. This reinforced masonry walls will serve as rigid shear wal

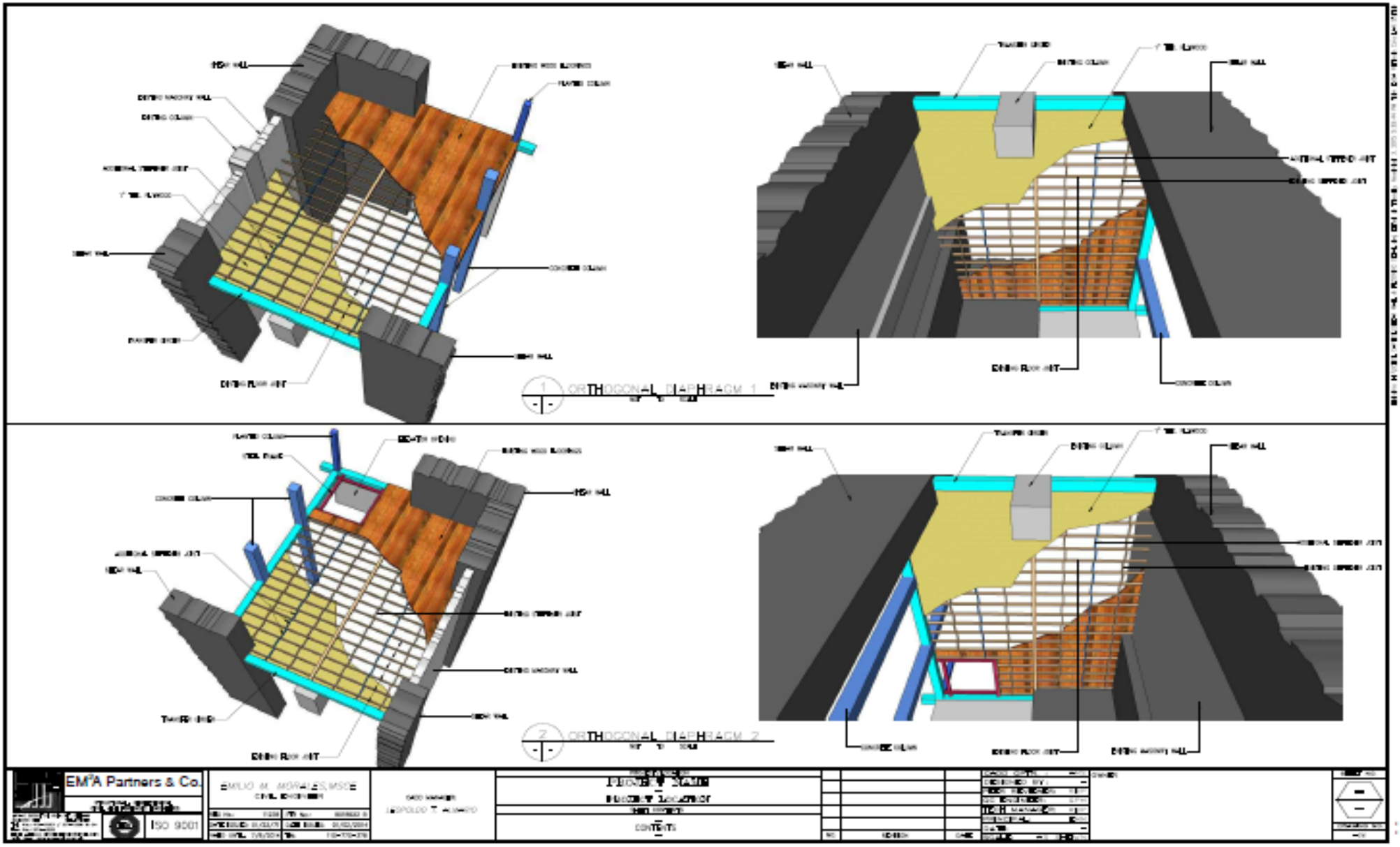
The lateral Resisting Elements –URM WALLS STIFFENED AND CONFINED TO ACT AS SHEAR WALLS.



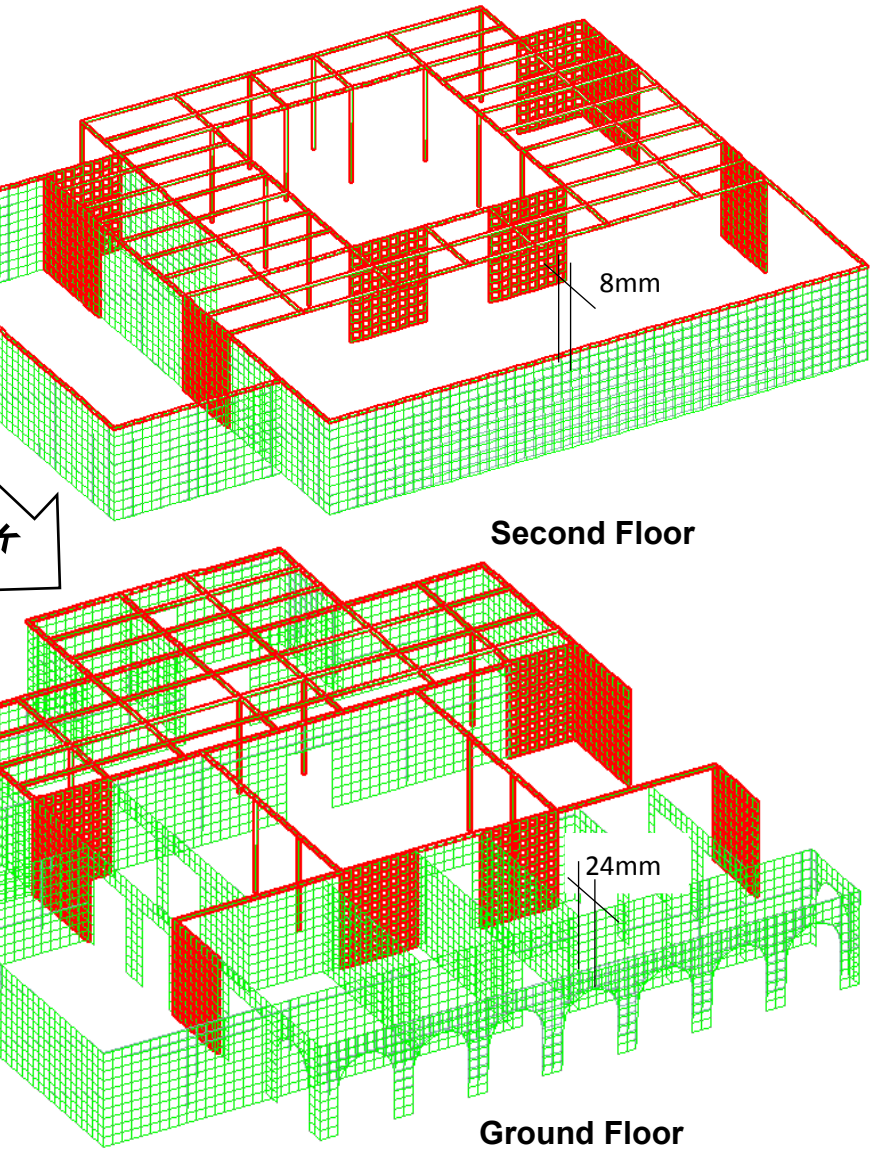
Highlighted in Red are proposed shear wall locatio These shear walls start from subgrade up to the roof be level. The confinement effec Reinforced Shotcrete Make upgraded walls rigid with unravelling.

Additional beams/girders attached to these walls serves as horizontal Trans Girders..

OF HORIZONTAL TIMBER FLOOR DIAPHRAGMS STIFFENED BY PLYWOOD IN BOTH ORTHOGONAL DIRECTIO



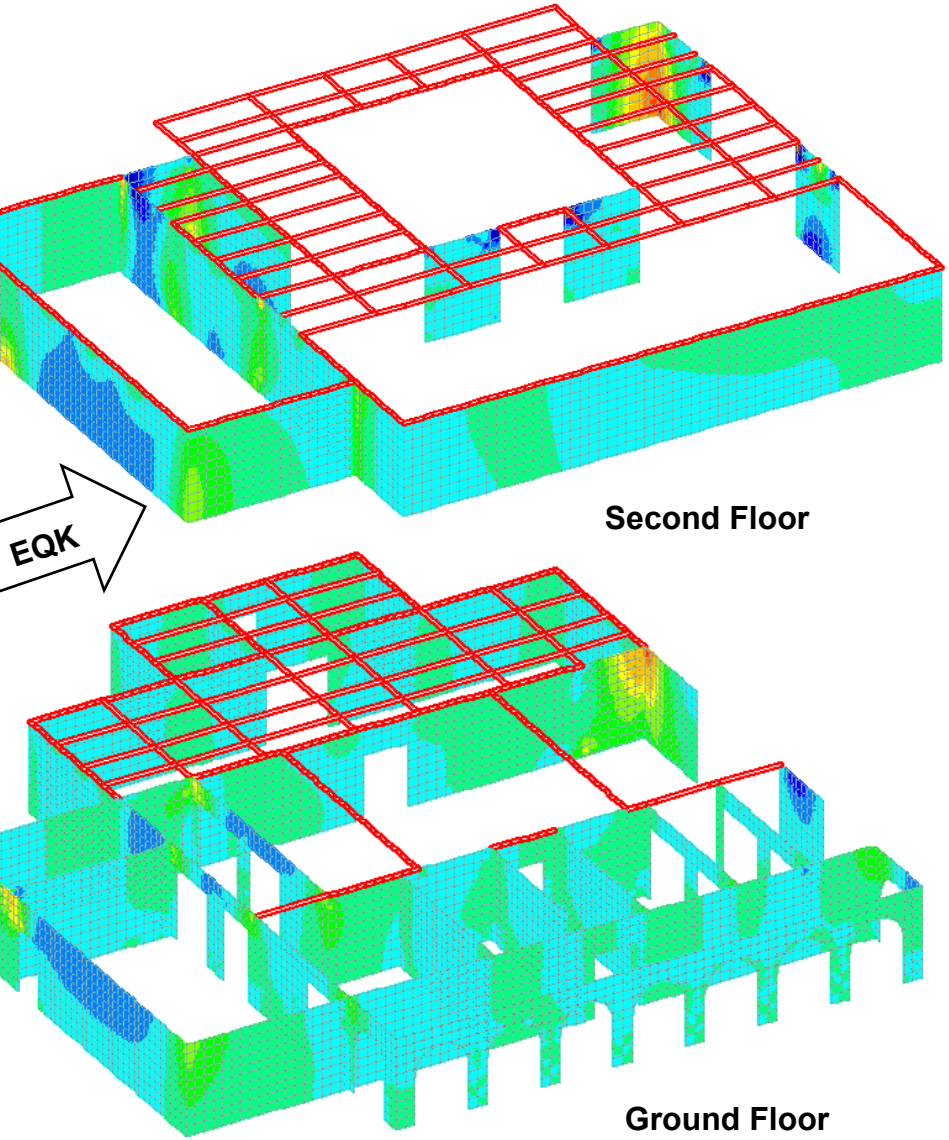
The lateral load resisting System- Using the Stiffened Timber Floor as Horizontal Diaphragms and Transfer girders to Funnel Load to the Shear Walls.



To the Left are the lateral deflections of the existing masonry walls when retrofitting is applied using Horizontal Diaphragms and Shear Walls. The highlighted lines are the additional structural framing used to carry the new loads. These structural framing are also supported by the shear walls (highlighted plates). It is observed that theoretical lateral deflections have been greatly reduced from 589 mm to 8 mm on the middle top of the façade wall. This proves that horizontal diaphragms play a big contribution in distributing the lateral stresses on the walls..

DEFLECTIONS AFTER REMEDIATION IS CA
OUT WITH SHEAR WALLS

Horizontal Stresses in Terms of Moments on the Reinforced Structure



Flexural stress contour of the walls when subjected to a lateral earthquake load in the +X direction.

Observed magnitude of the stresses are greatly reduced and most of the stresses occurred on the plates where shear walls are located.

BOHOL CAPITOL

nmary of Findings & Recommendations – STRUCTURAL
BOC CHURCH

The major damage sustained were on ***the unbuttressed transepts*** as well as the front and rear facades of the church which were also not buttressed.

It would be necessary during the reconstruction to **provide retrofit buttresses** to the transept walls to include the intersection or reentrant corners.

Effective coupling of the existing walls to the retrofitted buttresses would require the use of Dampers or dissipative devices to absorb the energy during seismic excitation to prevent major separation of the wall/buttress interface.

The buttressed walls are only lightly damaged. This is clearly due to the presence of the buttresses serving as stiffener along the walls of the church nave but not on the transept sections.

ENGINEERING EVALUATION REPORT (Revision 1.0)

Detailed Engineering Studies *(DES)* of Heritage Structures Declared NCI/ICP in Bohol and Samar Affected by Calamities

FOR THE

LOBOC CHURCH
Loboc, Bohol

OCTOBER 18, 2015

PF-2015-005D-G-PR

Submitted to:

Mr. Jeremy R. Barns
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LOBOC CHURCH

Summary of Findings & Recommendations – STRUCTURAL
CORTES CHURCH

Damage to Walls

The damage to walls are in general relatively minor ***with the exception of the extensive damage suffered by the transept walls initiated at the reentrant corners***.

The wall damage consisted mostly of cracks and delamination of plaster. These are generally amenable to repair and remediation to prevent further crack propagation.

Damage to Walls

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The wall damage consisted mostly of cracks and delamination of plaster. These are generally amenable to repair and remediation to prevent further crack propagation.

CORTES CHURCH

ECOMMENDATIONS

rovision of Wall Buttresses at the Transept walls

rovision of Corner Buttresses

rovision of Stiffening Elements to Front and rear açade after reconstruction.

ffective coupling of the existing walls to the etrofitted buttresses would require the use of ampers or dissipative devices to absorb the energy uring seismic excitation to prevent major separation f the wall/buttress interface.

he transept walls can be reconstructed using a Lime Mortar wall with independent foundation footings hen provided with a veneer wall at the interior and xterior that is bonded to the existing wall by lime nortar with wire mesh anchored to the concrete.

CORTES CHURCH

Summary of Findings & Recommendations – STRUCTURAL DIMIAO CHURCH

- Large Cavities underlie Church Footprint.
- Wall cracks need to be repaired to avoid falling hazards

ENGINEERING EVALUATION REPORT (Revision 1.0)

Detailed Engineering Studies *(DES)* of Heritage Structures Declared NCI/ICP in Bohol and Samar Affected by Calamities

FOR THE

DIMIAO CHURCH
Dimiao, Bohol

OCTOBER 18, 2015

PF-2015-005B-G-PR

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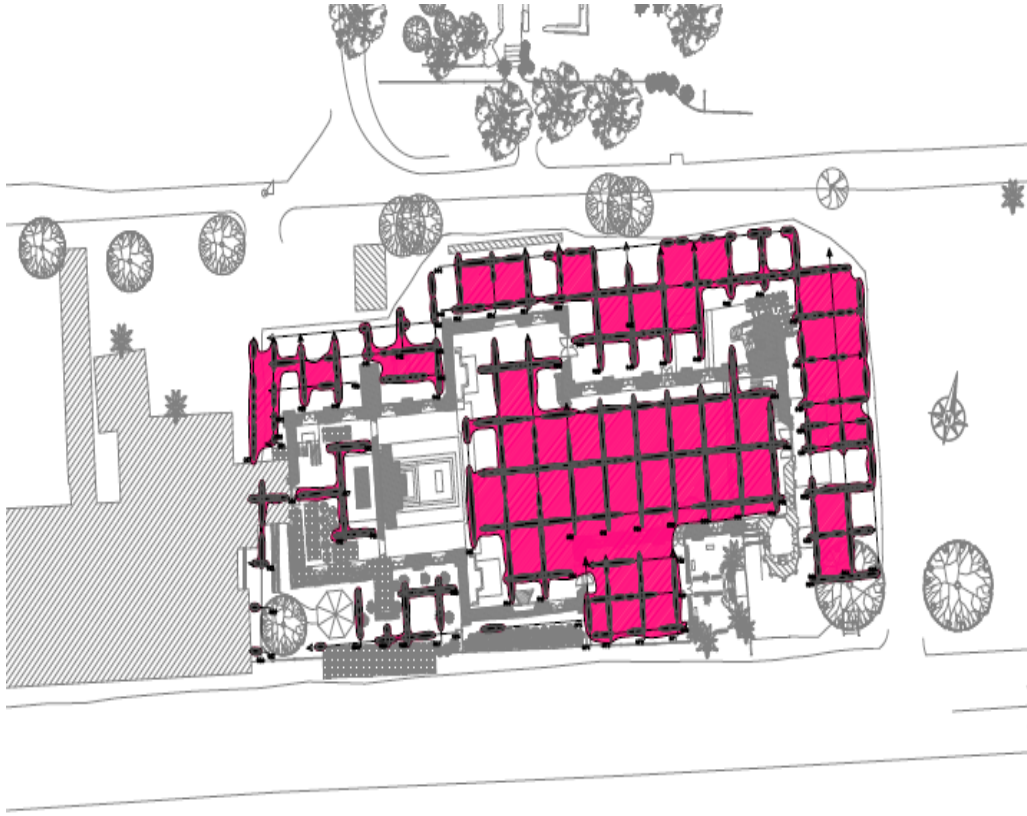
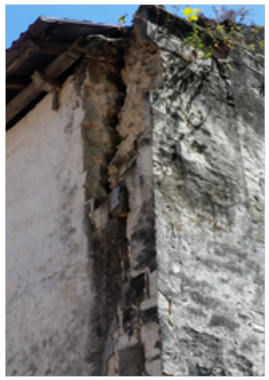
FINDINGS

Significant Cavities detected under the footprint. It is recommended that the depth and volume of cavities be determined by additional exploration and sealed before any reconstruction.



DIMIAO CHURCH

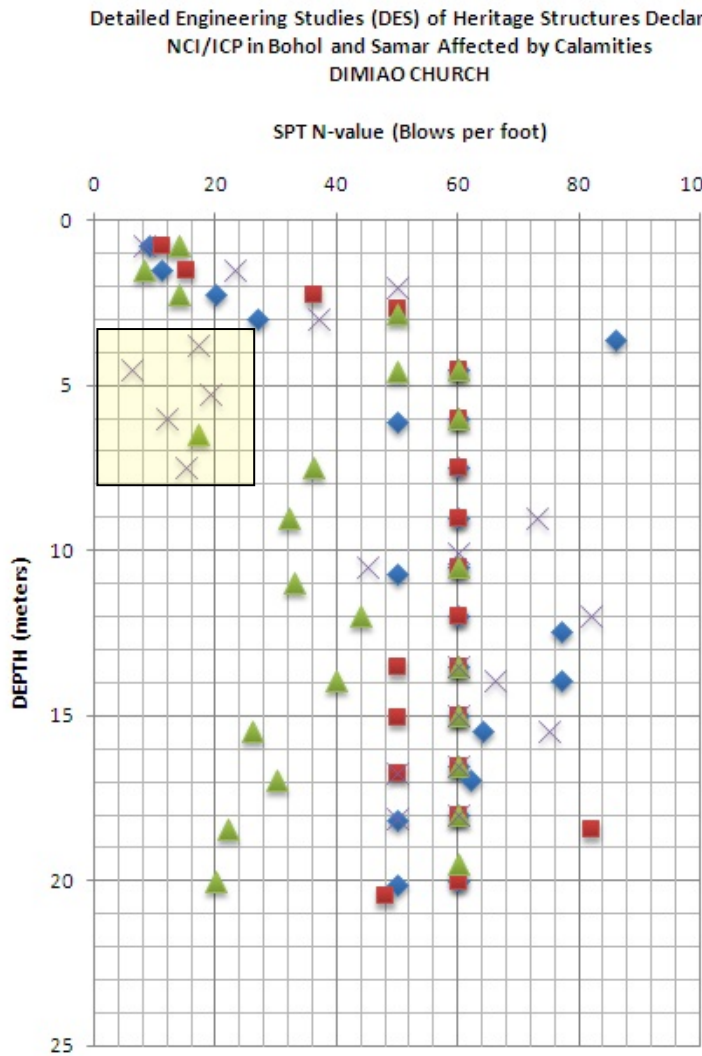


arge delamination of wall at corner requires nchoring and repair to prevent falling hazard

Walls separation at corners needs repair to prevent accidents.

xtend to the corner. Reinforcement

Exterior wall cracks with growth of moss requires repair, strengthening and sealing.

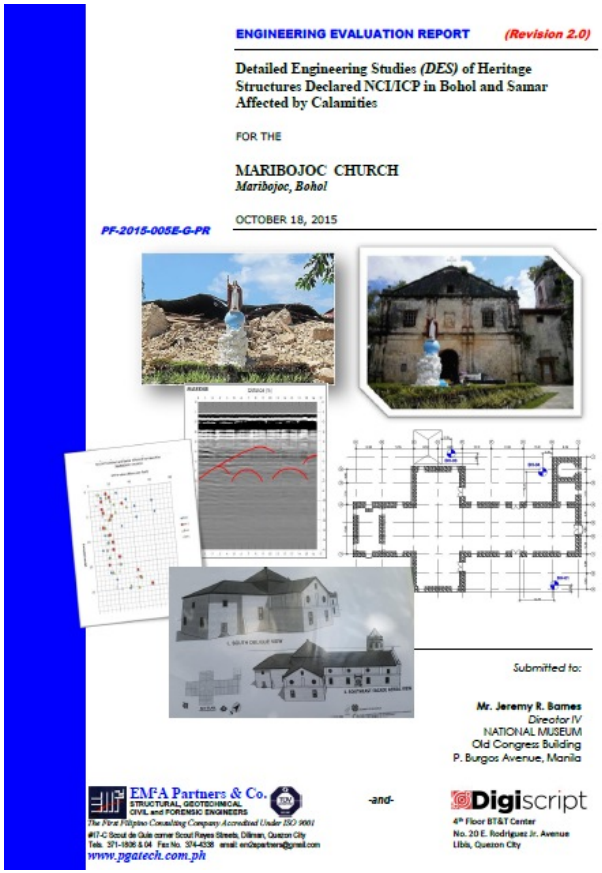


DIMIAO CHURCH

Cracked walls above arched doorway needs repair and strengthening.

Arch shows movement of Voussoirs. Repair required.

Summary of Findings & Recommendations – STRUCTURAL
MARIBOJOC CHURCH



ENGINEERING EVALUATION REPORT *(Revision 2.0)*

Detailed Engineering Studies *(DES)* of Heritage Structures Declared NCI/ICP in Bohol and Samar Affected by Calamities

FOR THE

MARIBOJOC CHURCH
Maribojoc, Bohol

OCTOBER 18, 2015

PF-2015-005E-G-PR

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MARIBOJOC CHURCH

Full Reconstruction Required.

Faithful reconstruction, tracing the original footprint of the church, would be a realistic direction to take to do away with any geotechnical concerns such as settlement or bearing capacity failure due to past preloading history.

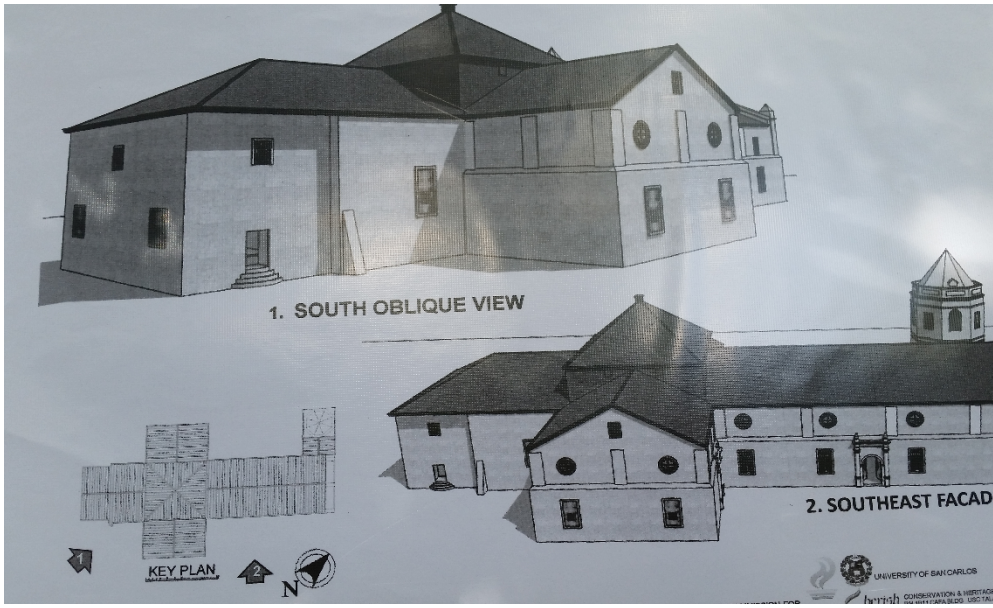
Reconstruction using URM would need to be provided with **buttresses** in order to stiffen the walls against out of Plane bending. In addition, buttresses should also be provided at the reentrant corners of the Transepts.

The buttresses should be properly connected to the walls to ensure adequate performance.

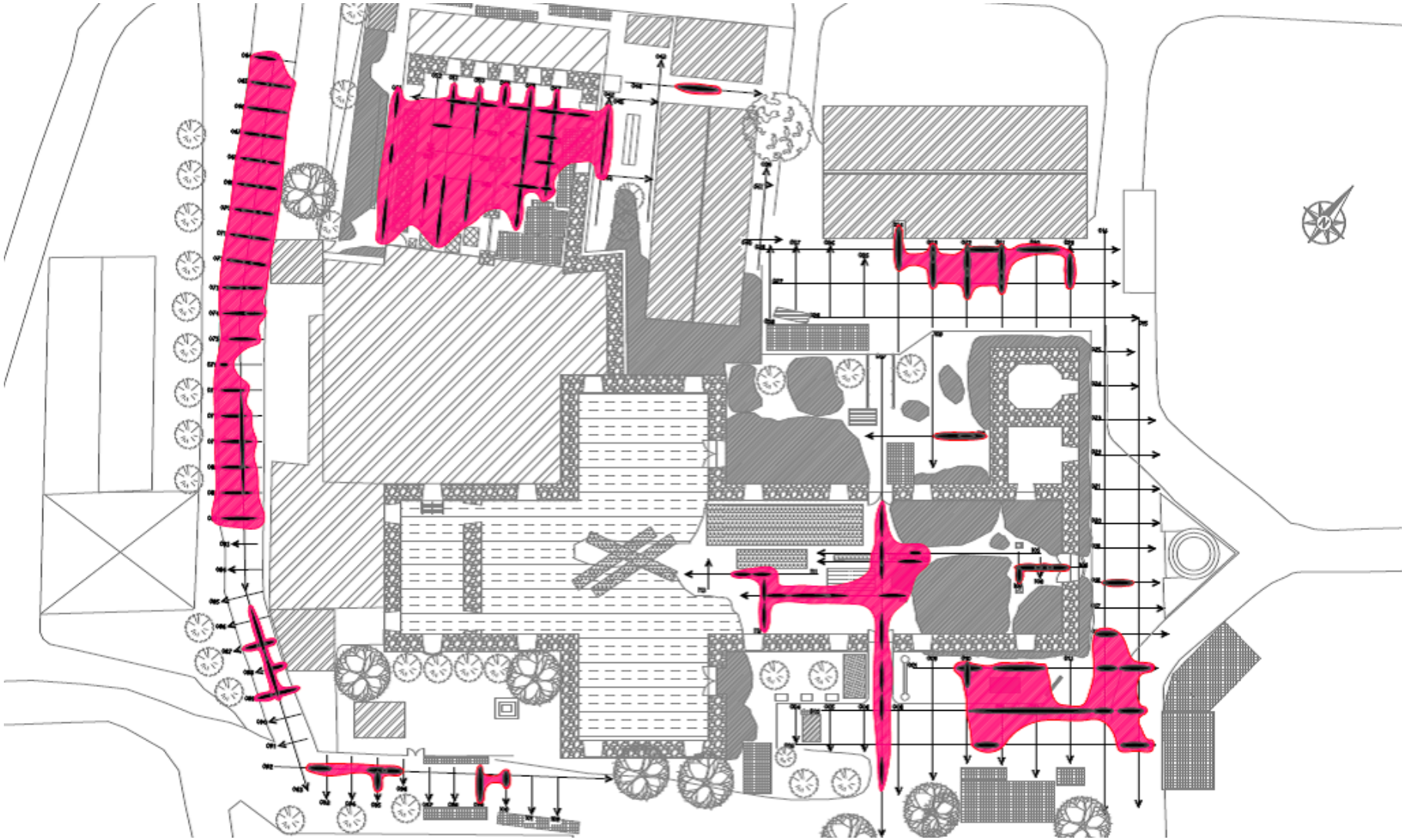
In the case of URM Reconstruction, Effective coupling of the masonry walls to the retrofitted buttresses would require the use of Dampers or dissipative devices to absorb the energy during seismic excitation to prevent major separation of the wall/buttress interface.

Any deviation from this footprint would require further investigation as the preloading in the past may not be enough compared to the proposed loading.

However, there is still the concern of the occurrence of interconnected cavities within the church footprint and elsewhere. These would have to be verified and addressed before reconstruction plans are even contemplated.



Maribojoc Church PARTIAL CAVITIES MAP



Summary of Findings & Recommendations – STRUCTURAL
PUNTA CRUZ WATCH TOWER

ENGINEERING EVALUATION REPORT

Detailed Engineering Studies *(DES)* of Heritage Structures Declared NCI/ICP in Bohol and Samar Affected by Calamities

FOR THE

PUNTA CRUZ WATCHTOWER FINAL
Punta Cruz, Bohol

OCTOBER 18, 2015

PF-2015-005F-G-PR

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Close up of Tower showing extent of delamination

Top portion of Tower showing extent of damage

Damaged or missing Timbers require replacement

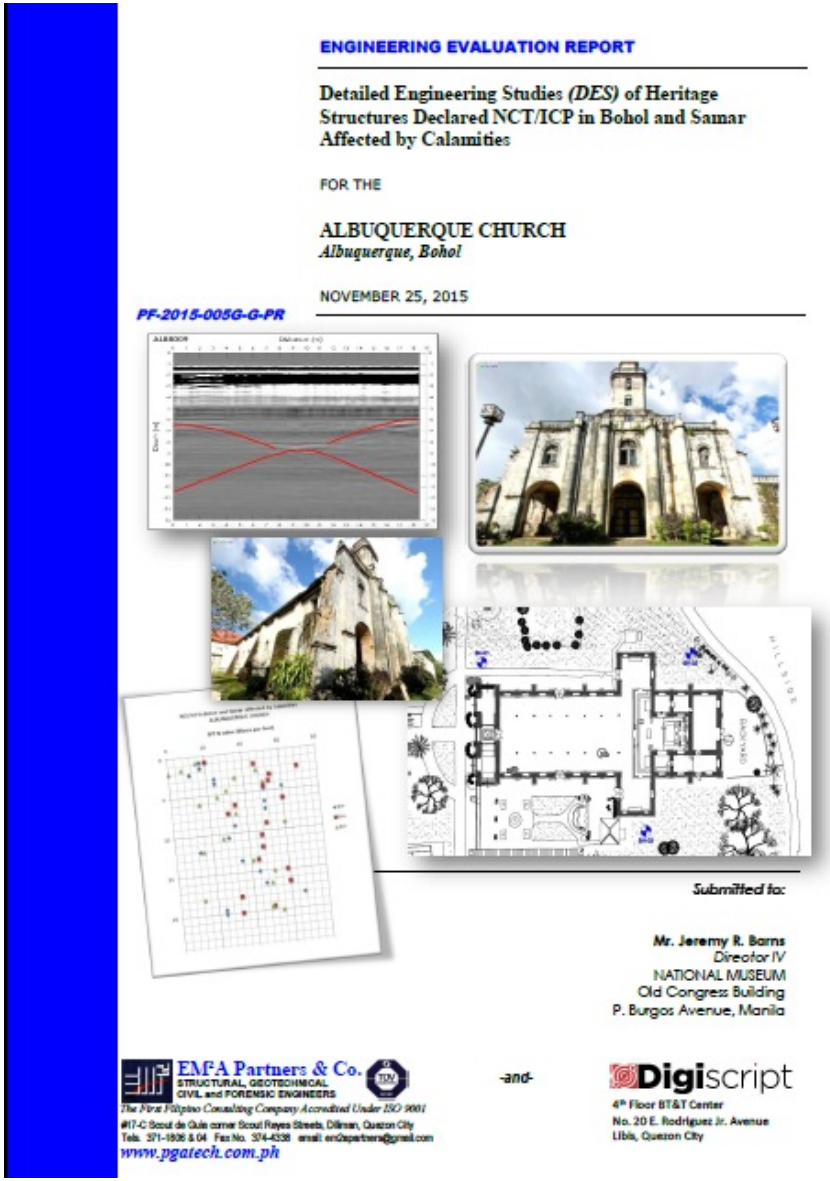
View of interior Floor Support show damaged

Summary of Findings & Recommendations – STRUCTURAL ALBUQUERQUE CHURCH

The damage sustained by the Sta. Monica Church in *Albuquerque, Bohol* is relatively light and no major structural damage due to the earthquake has been observed based on various accounts.

The soil exploration results reveal the presence relatively poor to medium soils in a thin overburden layer particularly for BH-01 and BH-03. These are underlain by fairly competent layers of soil starting at shallow depths of approximately 2 to 2.5 meters below NGL except for BH-02 where near surface layers of overburden soils extending down to maximum drilling depth of (-) 20.0 meters are relatively competent soil strata.

The underlying soils in general are comparatively competent strata of Sands and are not Limestone bedrock which may be the basis of discounting the possibility of occurrence of cavities. However, traces of weathered coralline limestone are present in the sand layers making it also susceptible to dissolution. Supplementing geophysical method conducted on site as presented in the ensuing discussions indicates the extent of cavities underneath the areas not influenced by the point locations of boreholes.



ENGINEERING EVALUATION REPORT

Detailed Engineering Studies *(DES)* of Heritage Structures Declared NCT/ICP in Bohol and Samar Affected by Calamities

FOR THE

ALBUQUERQUE CHURCH
Albuquerque, Bohol

NOVEMBER 25, 2015

PF-2015-005G-G-PR

Submitted to:

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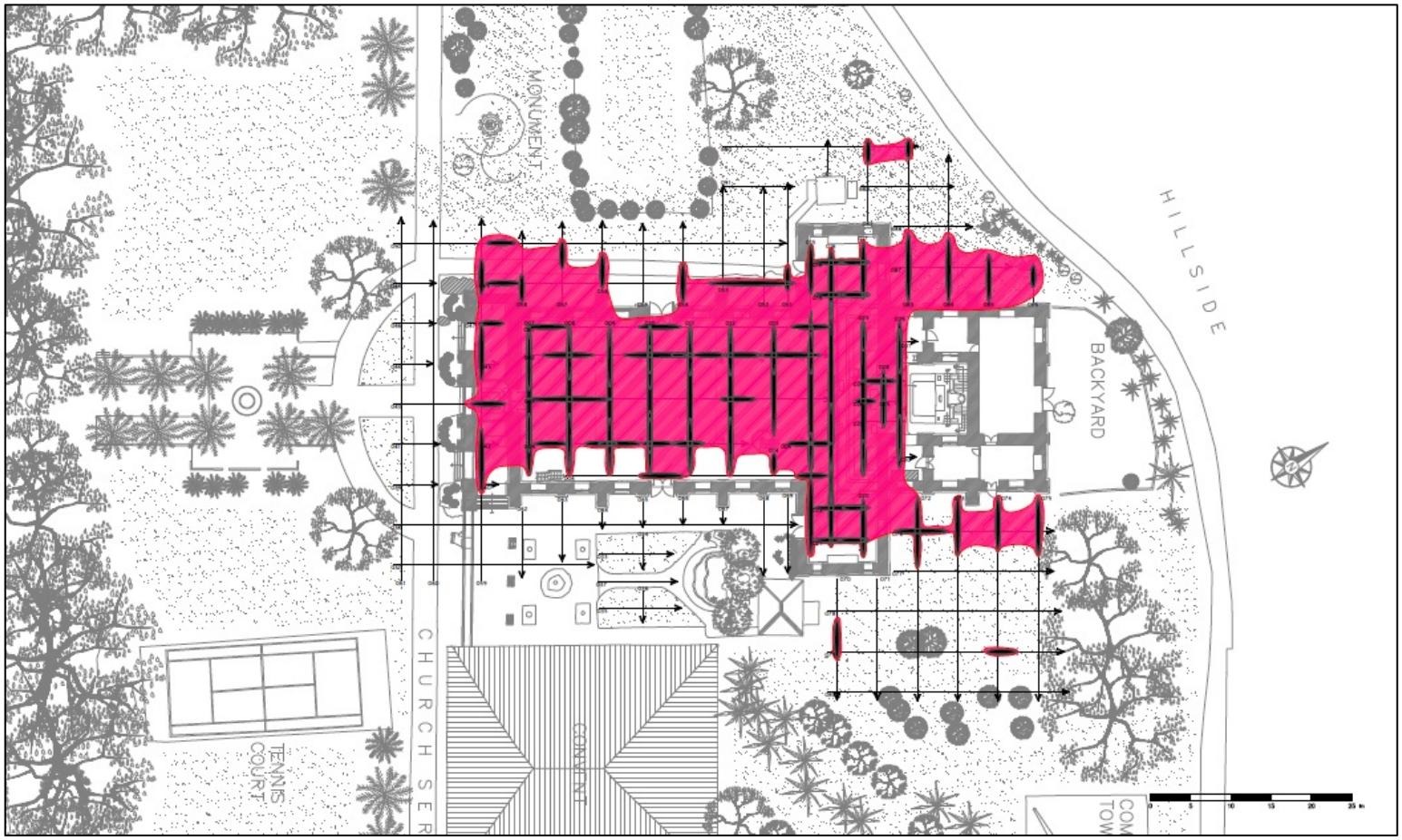
GPR MAPPING OF CAVITIES



Albuquerque Church has no major structural damage due to the earthquake and was able to sustain relatively light damage compared to other structures, thus no engineering intervention would be necessary to be implemented except for minor architectural repairs of slight damage due to the seismic event.

Verification of the presence of the suspected cavities underlying the church must be done first. This could be done by drilling additional boreholes at the areas where cavities have been identified.

In case of the occurrence of interconnected cavities within the church footprint and elsewhere are confirmed, these are to be injected with grout to seal the voids. The grouting must be done by a specialist company to ensure that no damage is caused by the grouting pressure in case grouting will be required.

In areas where occurrence of cavities has been confirmed, care must be exercised during grouting procedure. It is important that information regarding the type of void infill shall be determined prior to grouting as the infill is of significant factor in ease of grouting execution.

We recommend that all existing buried water utilities (Domestic and Sewage) should be decommissioned and replaced with abov ground PVC pipes in Concrete trenches. This will allow inspection of any leaks that may occur. This will prevent injection of water that can dissolve the coralline rocks.

Summary of Findings & Recommendations – STRUCTURAL
PANGLAO CHURCH

ENGINEERING EVALUATION REPORT

Detailed Engineering Studies *(DES)*of Heritage Structures Declared NCT/ICP in Bohol and Samar Affected by Calamities

FOR THE

PANGLAO CHURCH
Panglao, Bohol

DECEMBER 28, 2015

PF-2015-005H-G-PR

Photo from Bohol-philippines.com Website

Submitted to:

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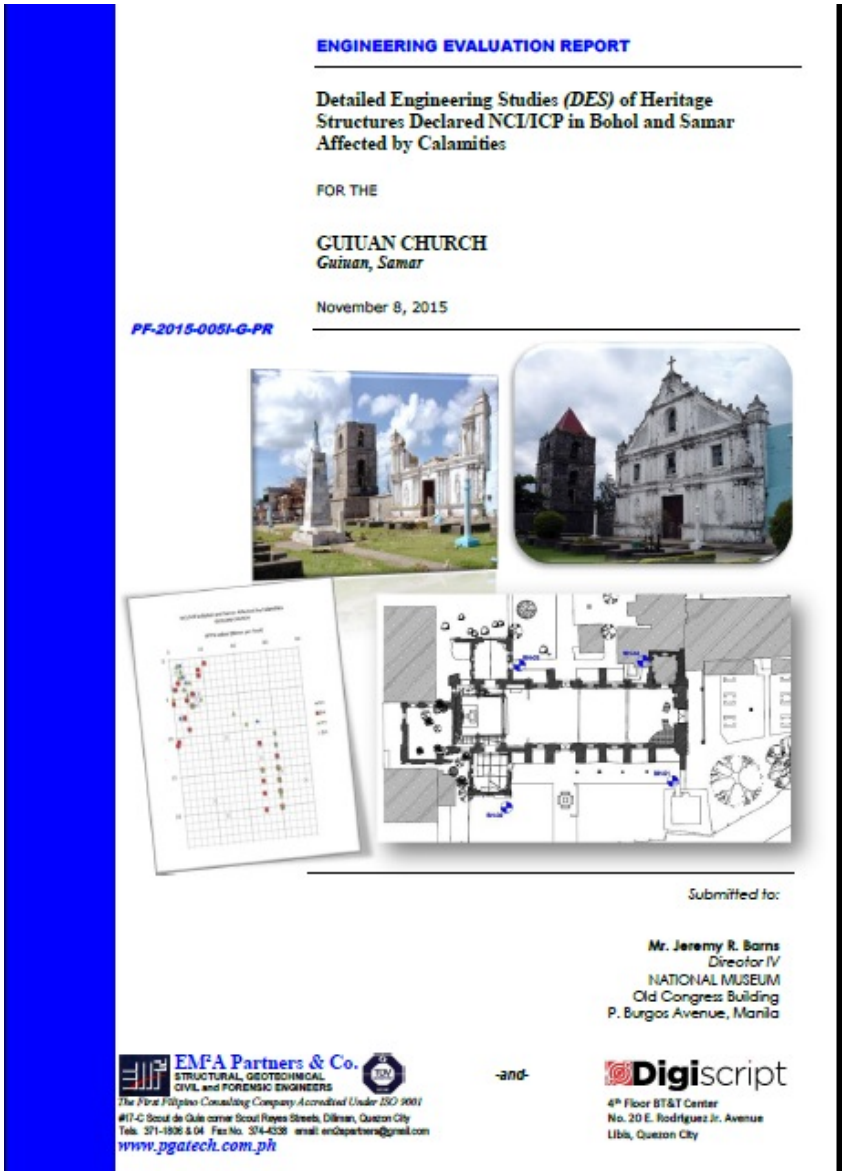
Summary of Findings & Recommendations – STRUCTURAL
GUIUAN CHURCH



ENGINEERING EVALUATION REPORT

Detailed Engineering Studies *(DES)* of Heritage Structures Declared NCI/ICP in Bohol and Samar Affected by Calamities

FOR THE

GUIUAN CHURCH
Guiuan, Samar

November 8, 2015

PF-2015-005I-G-PR

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