STRUCTURAL RESTORATION OF MASONRY CHURCHES IN PERU

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CONTENT OF PRESENTATION

- SEISMIC BEHAVIOR OF LATIN AMERICAN CHURCHES
- LOCAL SEISMIC CULTURE IN SOUTH AMERICA – EVOLUTION OF CONSTRUCTION SYSTEM
- METHODOLOGY FOR STRUCTURAL EVALUATION
- THE CATHEDRAL OF MOQUEGUA – A COMPATIBLE RING BEAM IN A THREE LEAF STONE CHURCH
- THE CHURCH OF SECHURA – USING POLYMER GRID TO ENHANCE CONTINUITY IN A BRICK MASONRY CHURCH

SEISMIC BEHAVIOR OF LATIN AMERICAN CHURCHES
TWO DIRECTION EARTHQUAKE
LOCAL SEISMIC CULTURE – EVOLUTION OF CONSTRUCTION SYSTEM
PHASE ONE

Earthquake of 1655 in Lima caused extensive damage to several churches in Lima.

Friar Diego Maroto's proposal was to demolish and rebuild with better materials.

Another builder, Manuel de Escobar, proposed a new technique using the same materials: clay bricks and lime mortar.
PERFORMANCE OF REBUILT CHURCHES IN THE 1678 EARTHQUAKE

Friar Diego Maroto decided to change the heavy materials of vaults and domes by timber, cane and a mud/lime mortar plaster.

PHASE TWO

Friar Diego Maroto

Manuel de Escobar
PHASE 2 OF THE PROCESS OF EVOLUTION OF CONSTRUCTION SYSTEM

Materiales ligeros (cerchas de madera y cubiertas de yeso por debajo y por encima de la bóveda)

Materiales rígidos y pesados (cal y ladrillo consolidados)

Friar Diego Maroto

Manuel de Escobar

PHASE 3 OF THE PROCESS OF EVOLUTION OF CONSTRUCTION SYSTEM

Three consecutive earthquakes in 1687, 1688 and 1690 proved that the use of lighter materials was necessary to avoid he collapse of the vaults and cupolas.

Daños muy leves y fácilmente reparables

Daño severo frente a estos sismos

Friar Diego Maroto

Manuel de Escobar

Imágenes: Ramón Lóvin “INTERVENCIÓN ESTRUCTURAL EN UN MONUMENTO HISTÓRICO DE ADOBE”
On June 7th, 1692, the Viceroy Conde de la Monclova gather all «alarifes» in the palace and decreed that the final solution for this type of structures was the use of lightweight materials for cupolas and vaults.

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SAN JOSE CHURCH, ICA
TIMBER TOWER WITH CANE AND MUD-LIME PASTERL
TIMBER ARCHES «CAMONES»

IGLESIA SAN JOSÉ, ICA
WHOLE CANE COVERED BY MUD-LIME PLASTER

Light weight roof and tower
CATEDRAL DE ICA
PLAN LAYOUT OF ICA CATHEDRAL

FIGURE 4.6
Cross section A-A, Cathedral of Ica.
Drawing: Base drawing prepared by Mima Soto and edited by the GCI.
MATERIALS – ICA CATHEDRAL

FIGURE 4.5
Floor plan, Cathedral of Ica.
Drawing: Base drawing prepared by Mirna Soto and edited by the GCI.
STRUCTURE OF TRANSEPT

TIMBER CORNER KEY USED IN CUSCO
BUILDING IN CUSCO CITY

METHODOLOGY FOR STRUCTURAL EVALUATION
STEPs FOR A STRUCTURAL RETROFITTING PROJECT ON HISTORIC BUILDINGS

STRUCTURAL EVALUATION
Defining the Structural System

Is the first step in the structural evaluation.

Structural system for vertical loads.
Structural system for horizontal loads.

The structural system can be divided in Macro Elements, and each one them divided in Elements.

Elements can be of a single material (wood) or a combination of materials (masonry).

WHAT IS A MACRO ELEMENT?

Macro Elements are defined as sub-structures that has a particular structural behavior. They may or may not be of different materials and they are capable of interact between them.

Macro Elements are composed of Elements and these are joined by “connections”
CASE STUDY KUÑO TAMBO CHURCH

PLAN LAYOUT OF KUÑO TAMBO CHURCH
(CURRENT STATE)
MACRO ELEMENTS OF A CHURCH

Walls: Longitudinal, Rear and Facade.
Sacrists
Baptistery.
Buttresses.
Roof
MACRO ELEMENTS
WALLS – SACRISTY - BAPTISTRY

MACRO ELEMENT: EXISTING AND PROPOSED BUTTRESSES
MACRO ELEMENTS
WALLS – ROOF
STRUCTURAL SYSTEM OF KUÑO TAMBO CHURCH AND ITS INTERACTION

VARIABLES OF EVALUATION

Five aspects are considered

1. Conception of structural system
2. Interaction between Macro Elements
3. Connections between Elements
4. Quality of Fabric
5. Level of Deterioration
Conception of Structural System

Refers to the ORIGINAL/ACTUAL SYSTEM and how it has performed over the years. Evaluation is qualitative and quantitative.

Qualitative evaluation includes the study of the history of the building.

The quantitative evaluation includes numerical models of the actual structure with actual and future loads.

INTERACTION

STRUCTURAL SYSTEM

MACRO ELEMENT 1

ELEMENT 1

ELEMENT 2

MACRO ELEMENT 2

ELEMENT 1

ELEMENT 2

Constitutive Materials
Interaction between Macro Elements

May be positive or negative

Quantitative evaluation is by means of numerical models.

Qualitative evaluation is by inspection and by studying past performance.
Connections.

How the joints perform their structural function inside a Macro Element.

Evaluation is qualitative by inspection. If needs quantitative evaluation is by experimental testing.

Quality of Fabric.

Is directly related with the quality of original materials and how were they built.

Is evaluated qualitatively by inspection
For masonry: Regularity of joints, etc
In timber: the joints and wood carpentry are evaluated.

Quantitative evaluation include in situ testing.
Level of Deterioration.

Qualitative evaluation is by visual inspection.

Quantitative evaluation is by in situ testing.
CLASSIFICATION SCALE OF VARIABLES OF EVALUATION (except for interaction)

A. High or Very good.

B. Medium high.

C. Medium low.

D. Low or very bad.

SUMMARY OF EVALUATION FOR KUÑO TAMBO

<table>
<thead>
<tr>
<th>MACRO ELEMENT</th>
<th>STRUCTURAL CONCEPTION</th>
<th>CONECTIONS</th>
<th>FABRIC</th>
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<tr>
<td>Facade and Rear Walls</td>
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<td>Longitudinal Walls</td>
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<tr>
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<tr>
<td>Timber Roof</td>
<td>C</td>
<td>D</td>
<td>C</td>
<td>D</td>
</tr>
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RELATIVE IMPORTANCE OF VARIABLES FOR STRUCTURAL EVALUATION

By order of importance:

1. Structural System
2. Interaction between Macro Elements
3. Connections between Elements
4. Quality of Fabric
5. Level of Deterioration
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THANK YOU VERY MUCH FOR YOUR ATTENTION