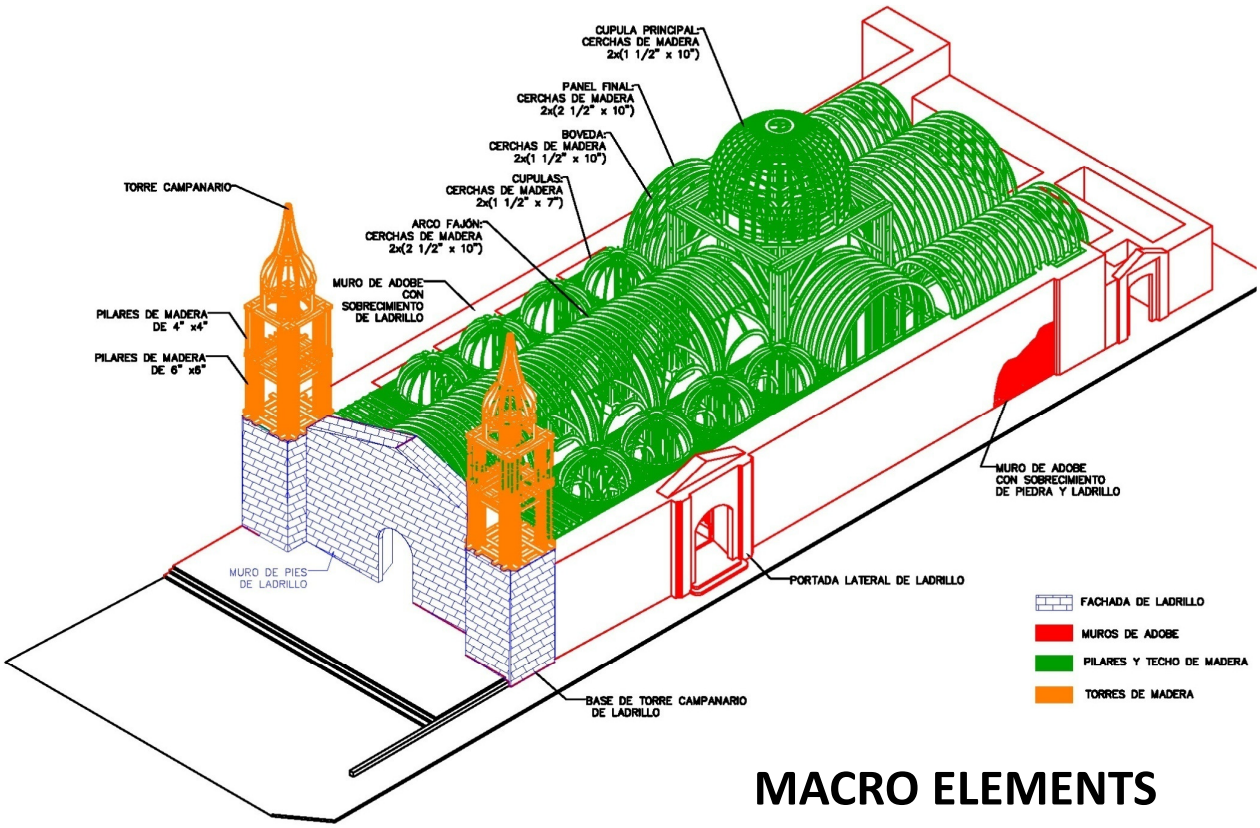
UNIVERSITY OF MINHO
SEMINAR ON HISTORICAL EARTHEN BUILDINGS

STRUCTURAL RESTORATION OF ICA CATHEDRAL

Prof. Daniel Torrealva

Pontifical Catholic University of Peru



MACRO ELEMENTS

MATERIALS – CATEDRAL DE ICA

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

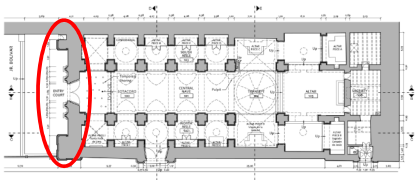
PISCO EARTHQUAKE AUGUST 15TH, 2007

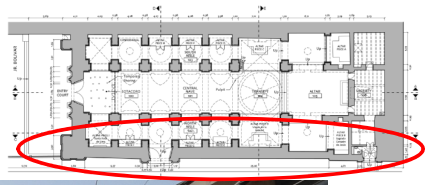
Earthquake Details

This event has been reviewed by a seismologist.

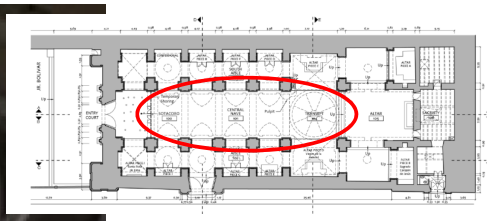
Magnitude	8.0
Date-Time	**Wednesday, August 15, 2007 at 23:40:57 UTC** Wednesday, August 15, 2007 at 06:40:57 PM at epicenter Time of Earthquake in other Time Zones
Location	13.354°S, 76.509°W
Depth	39 km (24.2 miles) set by location program
Region	NEAR THE COAST OF CENTRAL PERU
Distances	50 km (30 miles) W of **Chincha Alta, Peru** 110 km (70 miles) NW of **Ica, Peru** 150 km (95 miles) SSE of **LIMA, Peru** 210 km (130 miles) SW of **Huancayo, Peru**
Location Uncertainty	horizontal +/- 5.2 km (3.2 miles); depth fixed by location program
Parameters	NST=275, Nph=275, Dmin=155 km, Rmss=0.84 sec, Gp= 29°, M-type=centroid moment magnitude (Mw), Version=9
Source	USGS NEIC (WDCS-D)
Event ID	us2007gbcv

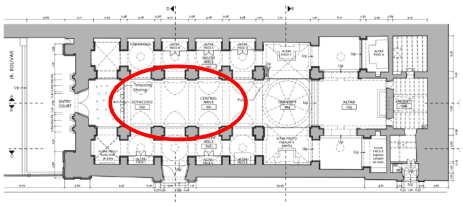
Did you feel it? Report shaking and damage at your location. You can also view a map displaying accumulated data from your report and others.

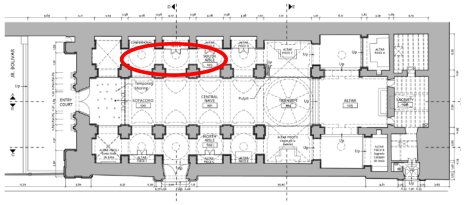


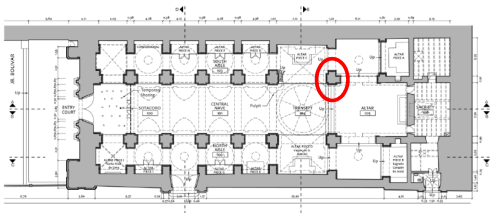


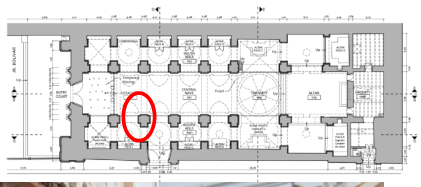
SEÑOR DE LUREN



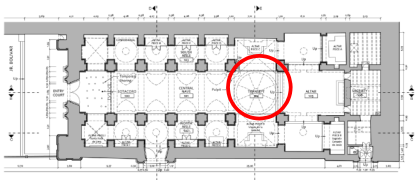


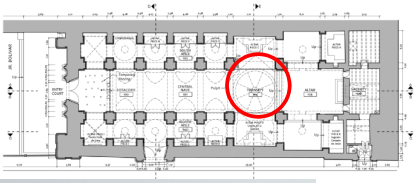


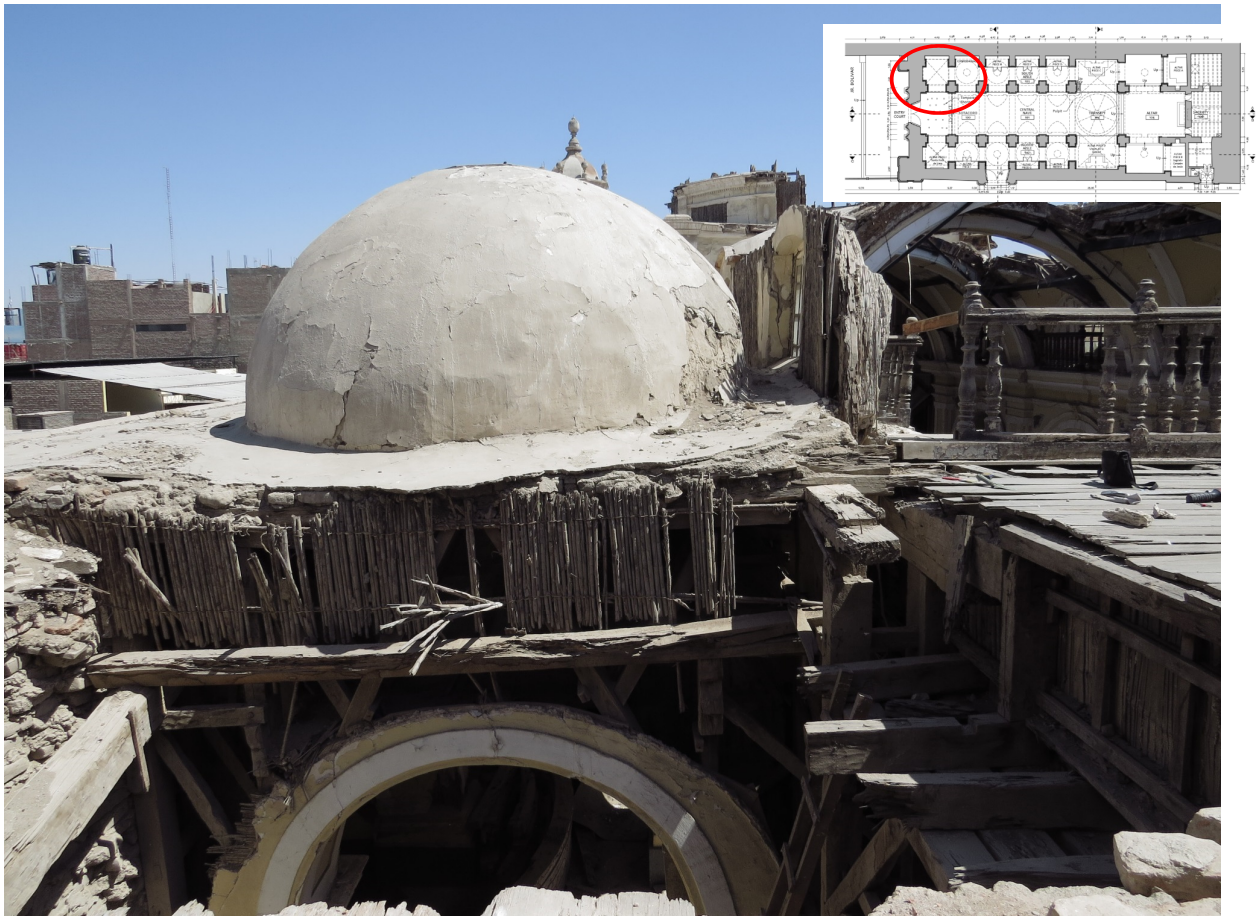




90
B3





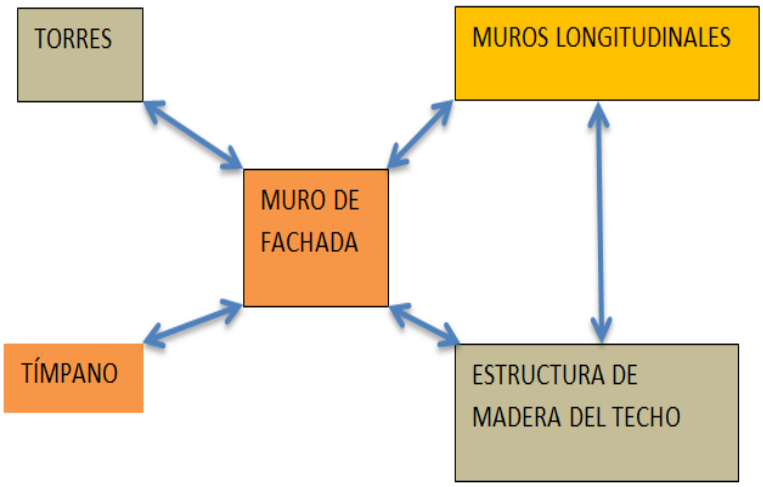


BEAM OVER LUNETT

CONECTION BETWEEN PILLAR AND BEAMS

TORRES

ESTRUCTURAL SYSTEM OF ICA CATHEDRAL AND ITS INTERACTION



VARIABLES OF EVALUATION

- STRUCTURAL CONCEPTION OF MACRO ELEMENTS
- CONECTIONS
- QUALITY OF FABRIC
- DETERIORATION

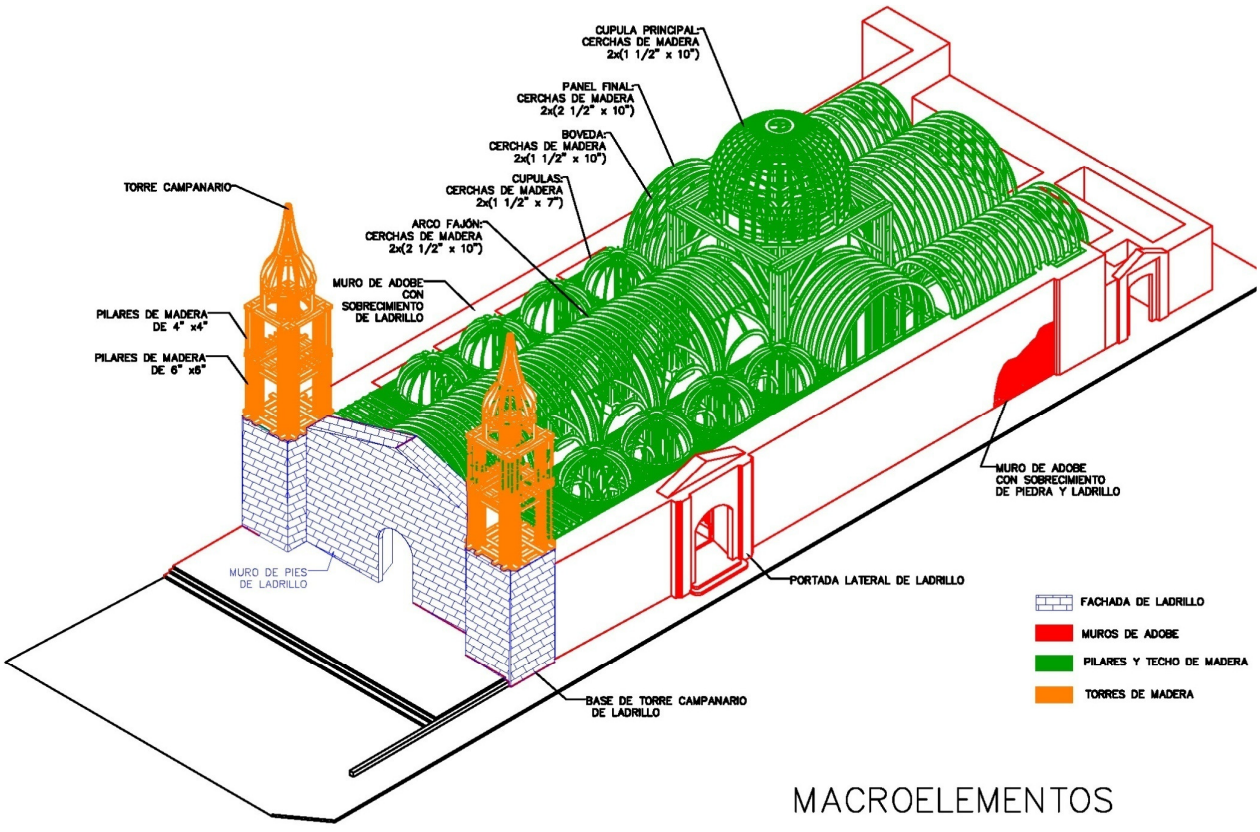
RATING OF VARIABLES

A. VERY GOOD
B. GOOD -MEDIUM
C. MEDIUM - BAD
D. VERY BAD

SUMMARY OF EVALUATION

MACRO ELEMENTS	STRUCTURAL CONCEPTION	CONEXIONS	FABRIC	DETERIORATION
Facade wall	A	N/A	B	B
Gable	C	N/A	B	C
Towers	A	A	A	B
Longitudinal adobe walls	B	N/A	C	D
Timber roof structure	C	C	B	D

DIAGNOSIS OF ICA CATHEDRAL

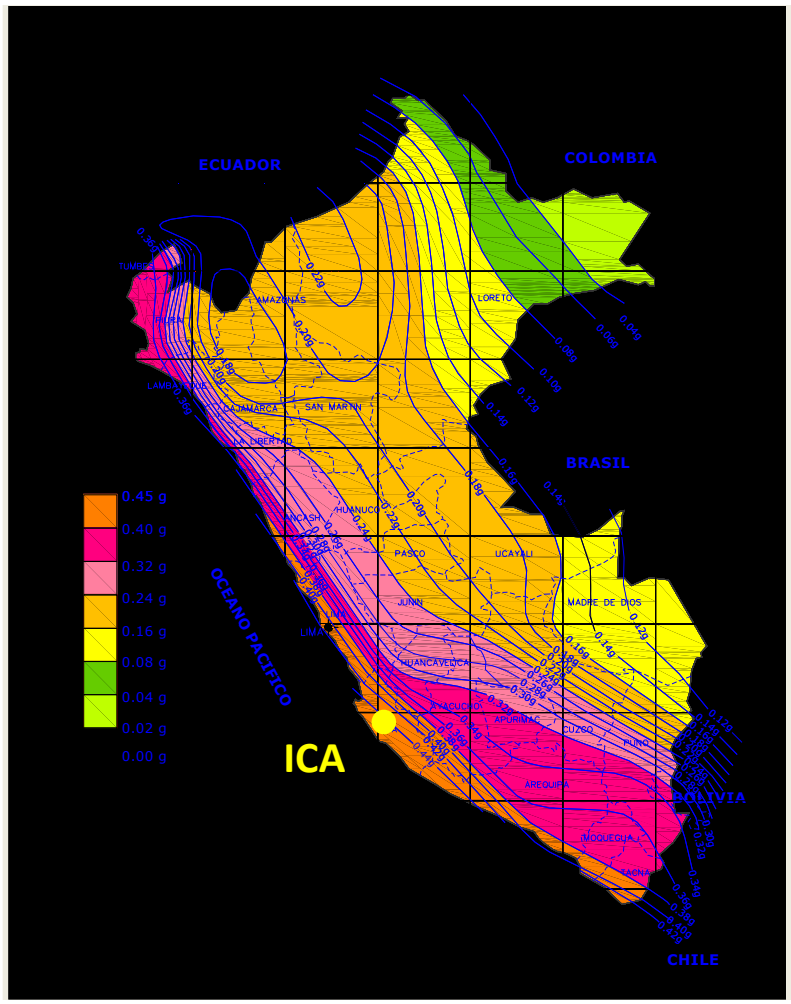


- Most vulnerable parts are longitudinal walls and timber structure because of the deterioration.
- Facade wall and towers present low vulnerability.
- Facade gable has been retrofitted already.
- There is interaction between the adobe walls and the timber structure that has to be taken into account.

- The longitudinal beam over the lunette is the most important timber element and its failure causes the collapse of the vault. Is deficiently designed and maintained.
- Roof cover should be redesigned for impermeability and low weight.
- Plastering of towers should be done with a relatively flexible material.

APPROACH FOR SEISMIC EVALUATION

Distribution of peak acceleration in Peru for a 475 years return period.



Level of threat

Earthquake Classifications

The earthquake intensity is described quantitatively in probabilistic terms as follows:

Earthquake Classification	Recurrence Interval	Probability of Occurence
Frequent	43 years	50% in 30 years
Occasional	72 years	50% in 50 years
Rare	475 years	10% in 50 years
Very Rare	970 years*	10% in 100 years

* need not exceed mean + 1 standard deviation for the maximum deterministic event

PEAK ACCELERATION FOR THE COAST OF PERU

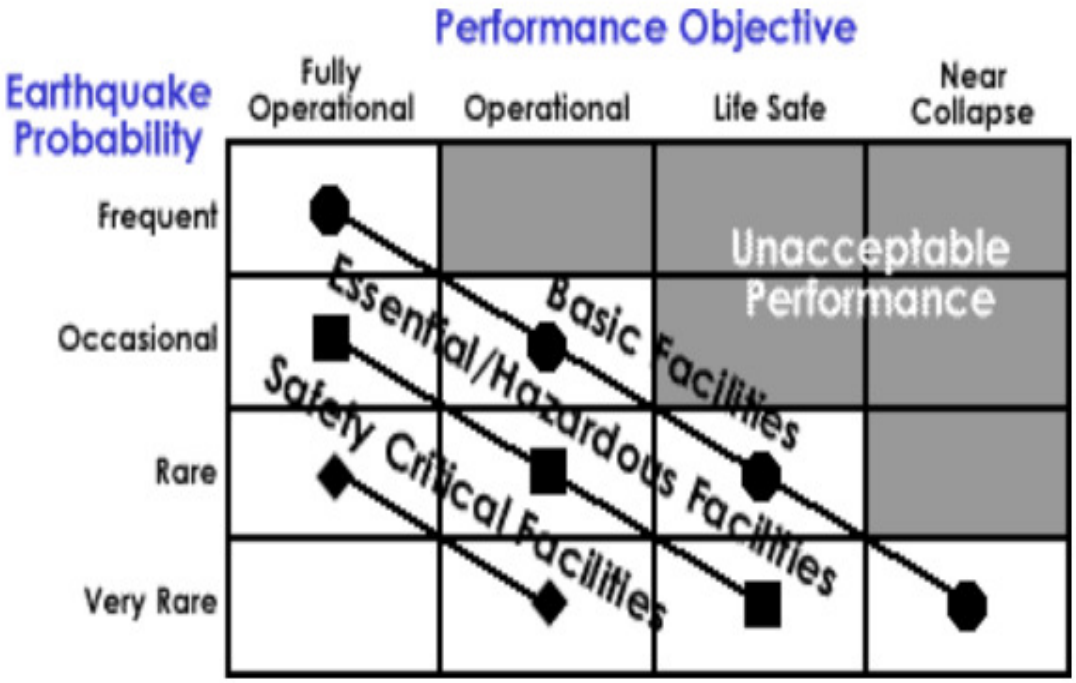
DESIGN EARTHQUAKE	PEAK ACCELERATION FOR THE COAST OF PERU (g)
Frequent earthquake	0.20
Ocasional earthquake	0.25
Rare earthquakes (E.030)	**0.40**
Very rare earthquake	0.50

BASED ON PERUVIAN CODE E.030

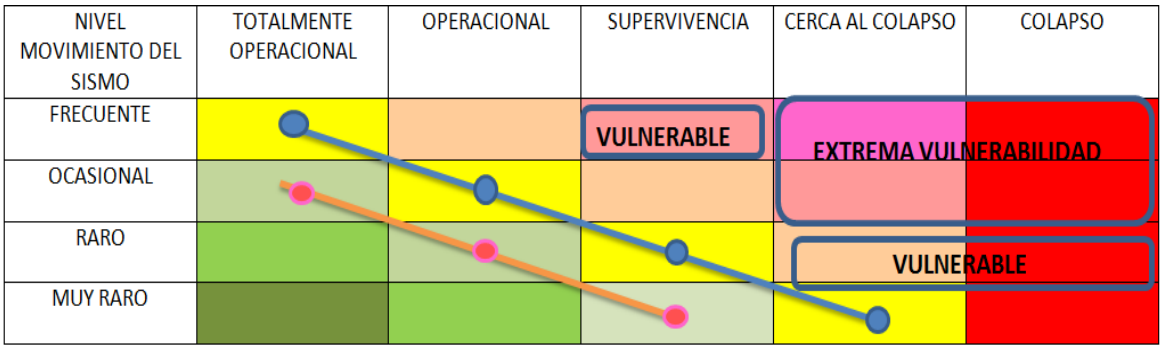
Performance States

Vision 2000 has four performance (i.e. limit) states:

Fully operational	Continuous service. Negligible structural and nonstructural damage.
Operational	Most operations and functions can resume immediately. Structure safe for occupancy. Essential operations protected, non-essential operations disrupted. Repair required to restore some non-essential services. Damage is light.
Life Safe	Damage is moderate, but structure remains stable. Selected building systems, features, or contents may be protected from damage. Life safety is generally protected. Building may be evacuated following earthquake. Repair possible, but may be economically impractical.
Near Collapse	Damage severe, but structural collapse prevented. Nonstructural elements may fall. Repair generally not possible.



SEISMIC PERFORMANCE OF A BUILDING



ORDINARY BUILDINGS

COMPORTAMIENTO ACEPTADO PARA EDIFICACIONES COMUNES

ESENCIAL BUILDINGS

COMPORTAMIENTO ACEPTADO PARA EDIFICACIONES ESENCIALES

PERFORMANCE OF ICA CATEDRAL

	ACTUAL PERFORMANCE OF ICA CATHEDRAL				
NIVEL MOVIMIENTO DEL SISMO	TOTALMENTE OPERACIONAL	OPERACIONAL	SUPERVIVENCIA	CERCA AL COLAPSO	COLAPSO
FRECUENTE a= 0.20g					
OCASIONAL a=.25g					
RARO a=.40g					
MUY RARO a=.45g					

DESIRED PERFORMANCE LEVEL

	DESIRED PERFORMANCE OF ICA CATHEDRAL				
NIVEL MOVIMIENTO DEL SISMO	TOTALMENTE OPERACIONAL	OPERACIONAL	SUPERVIVENCIA	CERCA AL COLAPSO	COLAPSO
FRECUENTE a= 0.20g					
OCASIONAL a=.25g					
RARO a=.40g					
MUY RARO a=.45g					

PHILOSOPHY OF STRUCTURAL INTERVENTION IN ICA CATHEDRAL

CONSERVATION PRINCIPLES

1. Minimum intervention
2. Reversibility
3. Authenticity
4. Architectural aspect
5. Original materials
6. Traditional techniques
7. Differentiate new and original
8. Maintenance and monitoring

ENGINEERING CRITERIA

1. Safety
2. Durability
3. Technical feasibility
4. Economy

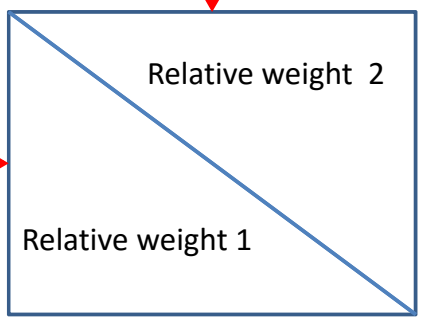
MATRIX OF COMPARISON BETWEEN CONSERVATION PRINCIPLES AND ENGINEERING CRITERIA FOR ICA CATHEDRAL

CONSERVATION PRINCIPLES		ENGINEERING CRITERIA			
		SAFETY (470)	DURABILITY (430)	TECHNICAL FEASIBILITY (410)	ECONOMY (400)
	MINIMUM INTERVENTION (150)	70 / 30	70 / 30	60 / 40	50 / 50
	REVERSIBILITY (160)	60 / 40	60 / 40	60 / 40	60 / 40
	AUTENTICITY (260)	50 / 50	30 / 70	30 / 70	30 / 70
	ARCHITETURAL ASPECT (260)	50 / 50	30 / 70	30 / 70	30 / 70
	ORIGINAL MATERIAL (130)	70 / 30	70 / 30	70 / 30	60 / 40
	TRADITIONAL TECHNIQUES (160)	60 / 40	60 / 40	60 / 40	60 / 40
	DIFERENCIATE NEW AND ORIGINAL (170)	60 / 40	60 / 40	50 / 50	60 / 40
	MAINTENANCE AND MONITORING (200)	50 / 50	50 / 50	50 / 50	50 / 50
		/	/	/	/

(Sum of relative weight of principle or criteria)

DURABILITY

ORIGINAL MATERIAL



Relative weight 1 + Relative weight 2 = 100

RELATIVE IMPORTANCE OF CONSERVATION PRINCIPLES

1. Authenticity (260)
2. Architectural aspect (250)
3. Maintenance and monitoring (200)
4. Differentiate new and original (170)
5. Traditional techniques (160)
6. Reversibility (160)
7. Minimum intervention (150)
8. Original material (130)

RELATIVE IMPORTANCE OF ENGINEERING CRITERIA

1. Safety (470)
2. Durability (430)
3. Technical feasibility (410)
4. Economy (400)

INTERVENTION IN ICA CATHEDRAL

AIMING TO

- Maintaining the timber construction technology.
- Improving the connections between timber elements.
- Replacement of deteriorated timber elements.
- Improving the lateral strength and stiffness of adobe longitudinal wall.

Thank you for your attention