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TOWARD A STRUCTURAL COMPREHENSION OF AN 18TH CENTURY SPANISH COLONIAL STONE MASONRY MONUMENT: THE CHURCH OF MISSION SAN JOSE Y MIGUEL DE AGUAYO, TEXAS

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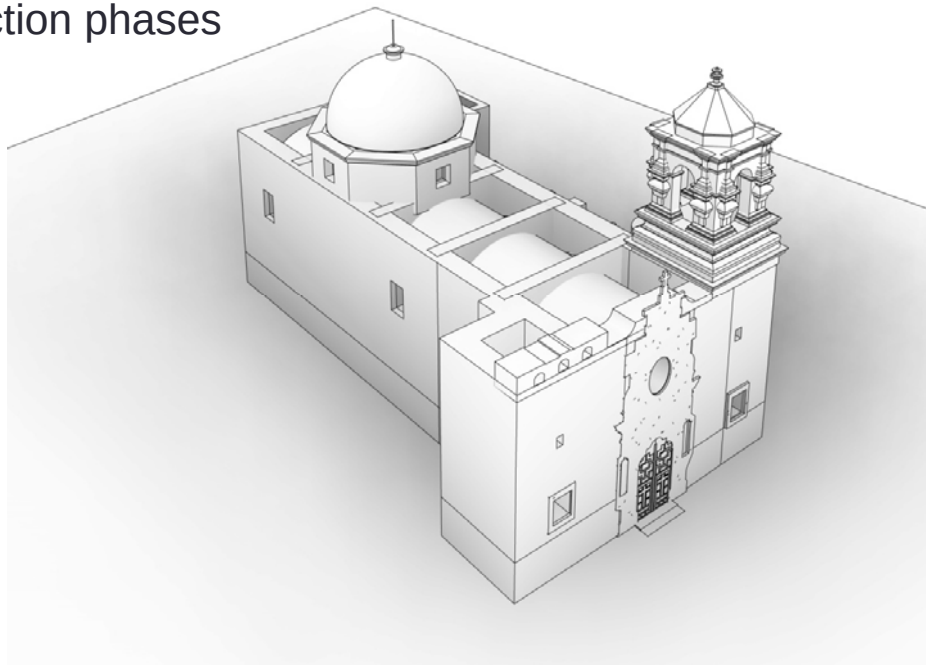
University of Texas at San Antonio

Toward a Structural Comprehension of an 18th Century Spanish Colonial Stone Masonry Monument: **The Church of Mission San Jose y Miguel de Aguayo, Texas**

- INTRODUCTION
- HISTORY OF THE STRUCTURE
- ANALYSIS OF THE CHURCH:
  Architectural survey, design criteria, construction phases and reconstructions
- VISUAL ASSESSMENT
- STRUCTURAL ANALYSIS OF THE CHURCH
- CONCLUSIONS



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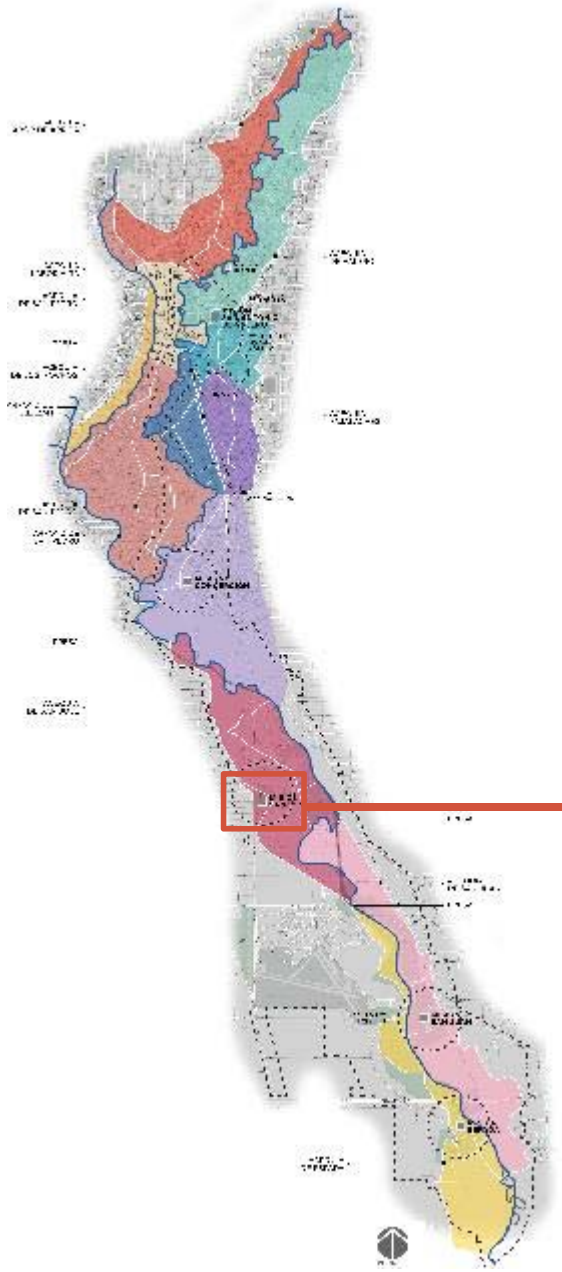
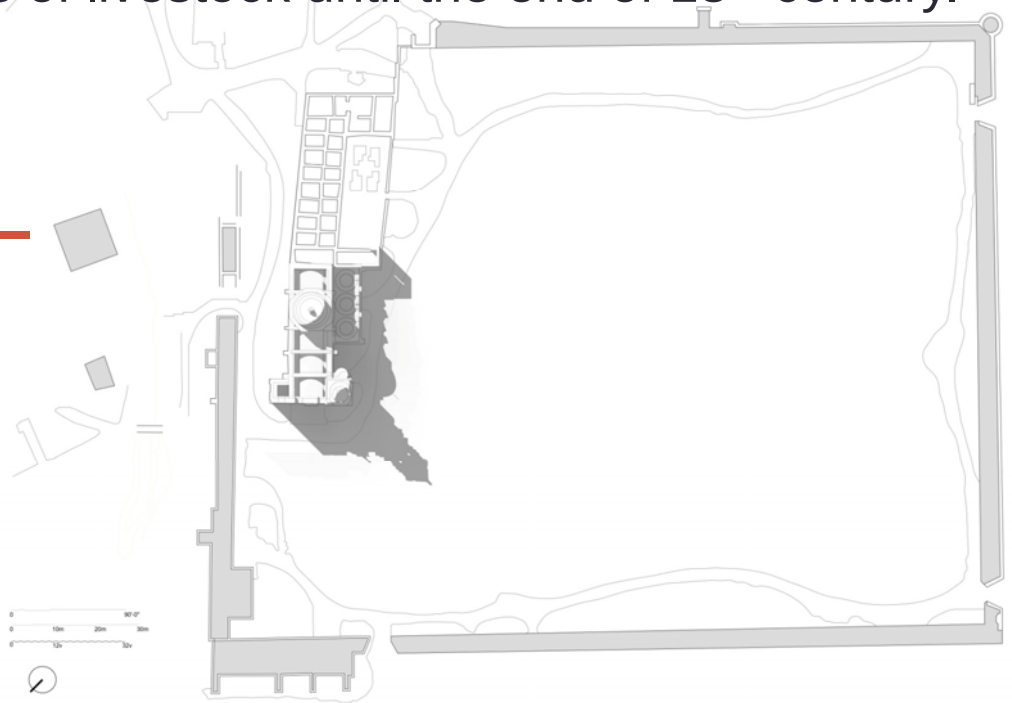
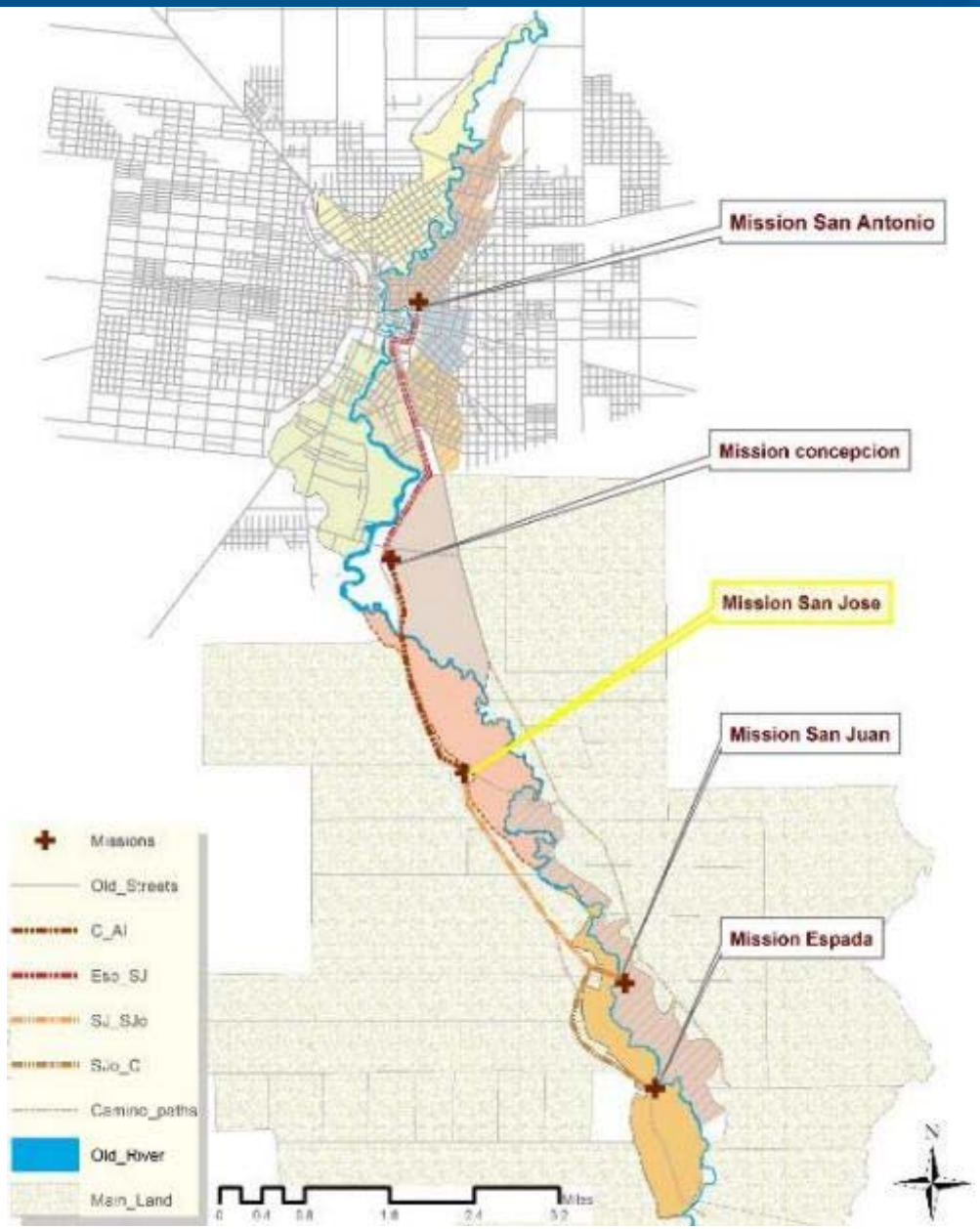
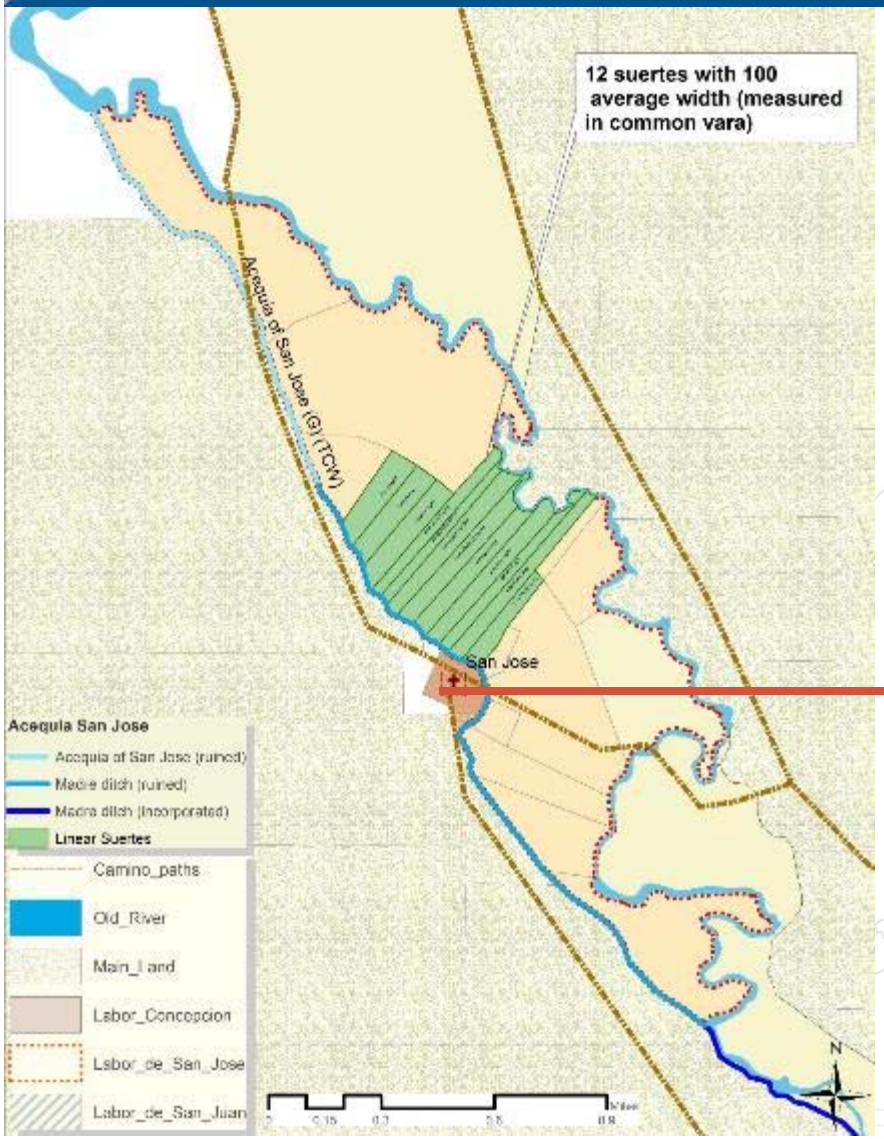


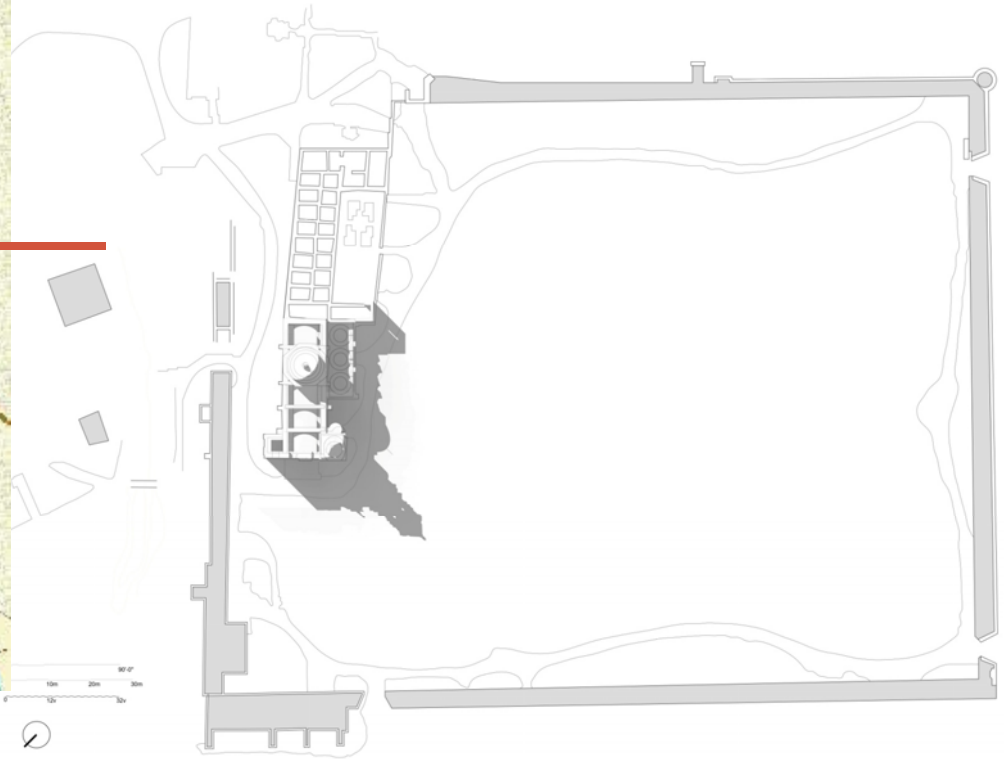
HISTORY OF THE STRUCTURE

- Second mission of a chain of five Franciscan missions established along the San Antonio River, during the first quarter of 18th century;
- Renowned as the ‘Queen of the Missions’
- The community contained about 350 Indian neophytes, sustained by extensive fields and herds of livestock until the end of 18th century.




Mission San Antonio
Mission concepcion
Mission San Jose
Mission San Juan
Mission Espada
Missions
Old_Streets
C_Al
Esp_SJ
SJ_SJo
SJo_C
Camino_paths
Old_River
Main_Land
Miles
N


12 suertes with 100 average width (measured in common vara)
Acequia of San Jose (G) (TCM)
San Jose
Acequia San Jose
Acequia of San Jose (ruined)
Madre ditch (ruined)
Madre ditch (incorporated)
Linear Suertes
Camino_paths
Old_River
Main_Land
Labor_Concepcion
Labor_de_San_Jose
Labor_de_San_Juan
N



HISTORY OF THE CHURCH

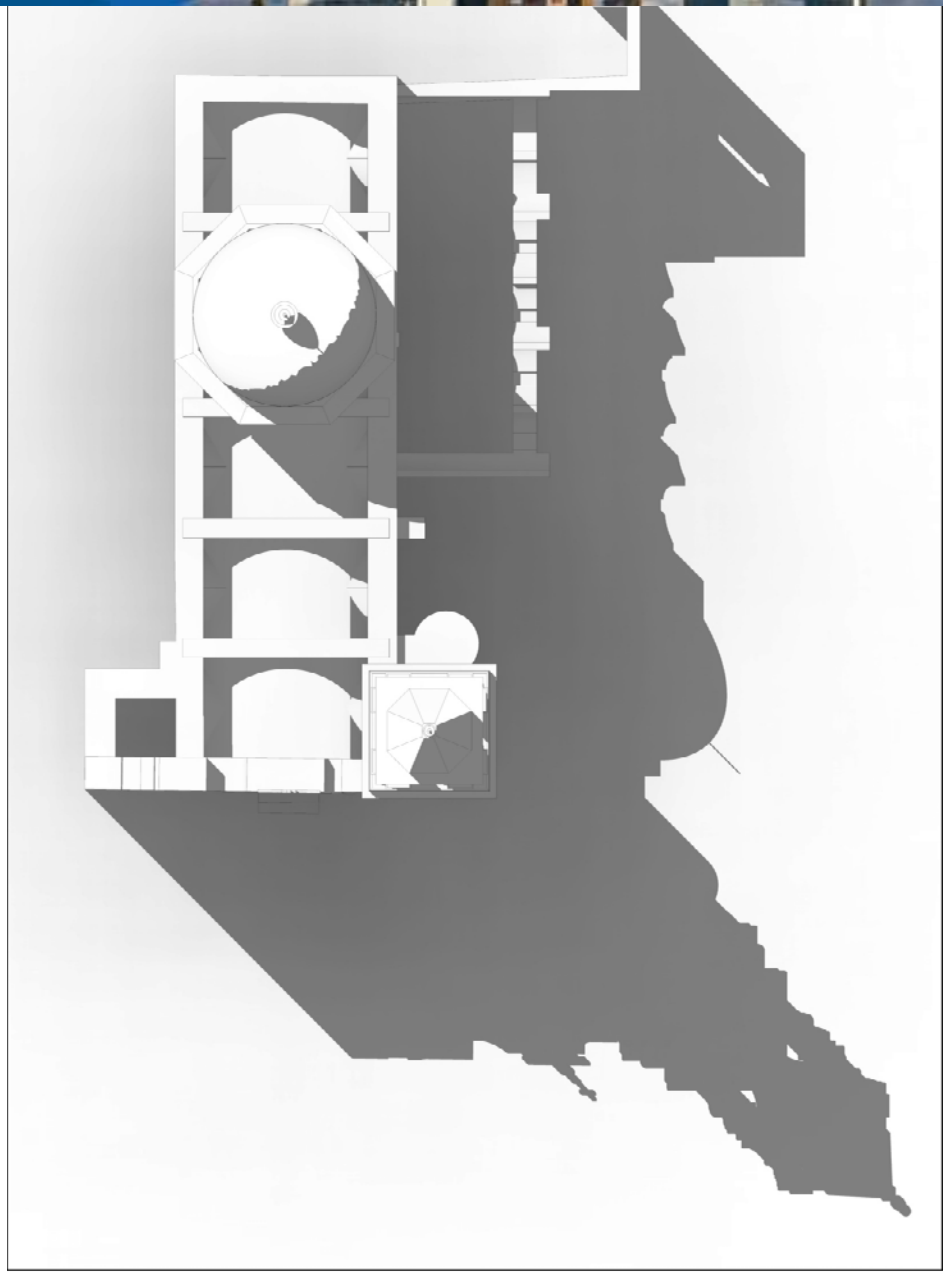
- Construction phases:

1768-1777: Construction period of the present church;

1794: suppression of the missions

19th century: the complex went through several ownerships.

1859: The complex was acquired by the Benedictines, who started to rebuild the convent.



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HISTORY OF THE STRUCTURE

- Construction phases:

1864: Collapse of the north wall

1874, Dec. 25: Collapse of the church roof

1928, March 9, the bell tower also collapsed

- Later modifications:

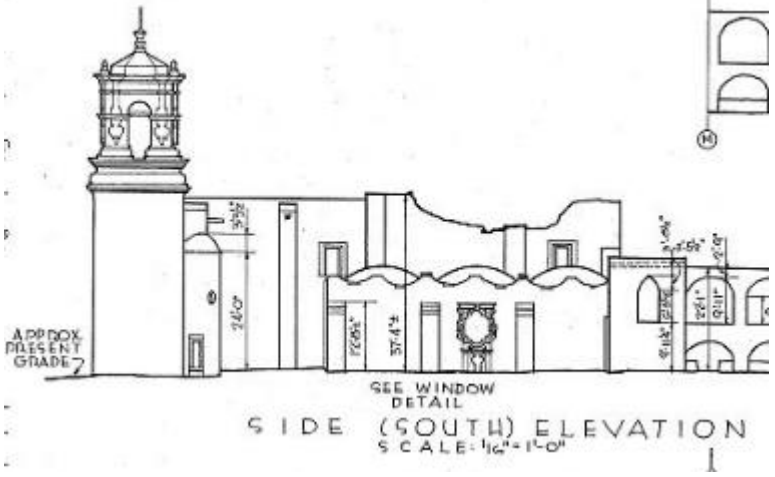
The church restoration

San Antonio Conservation Society and the Federal Government undertook to restore in the 1920s and 1930s, until 1941

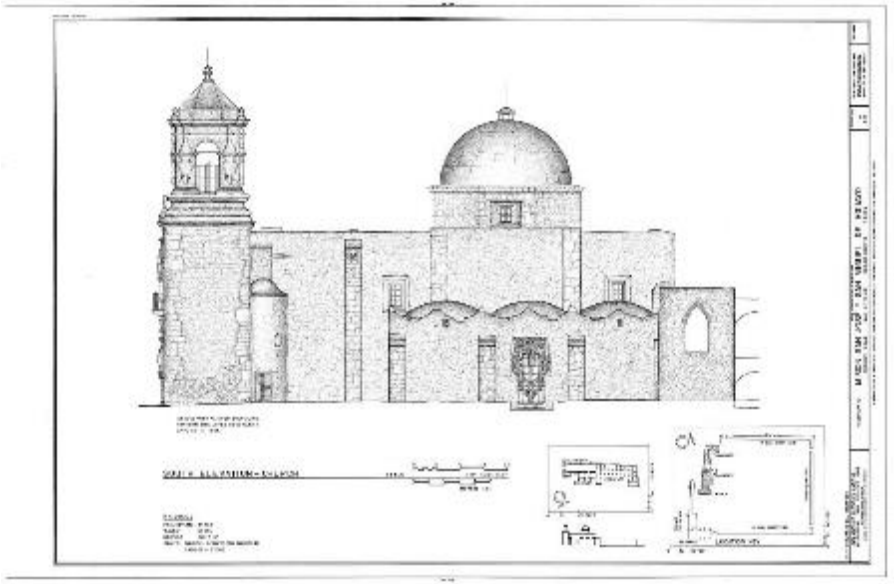
The church with vaults, dome and tower collapsed

ANALYSIS OF THE CHURCH:
Architectural survey

- 1936 and 1983 HABS survey of the site was used as the starting point.
- Measures of the mission church were surveyed with a disto Laser Leika, integrated with tape measures.
- A laser level was used in order to assess the horizontality of the floor inside the church.



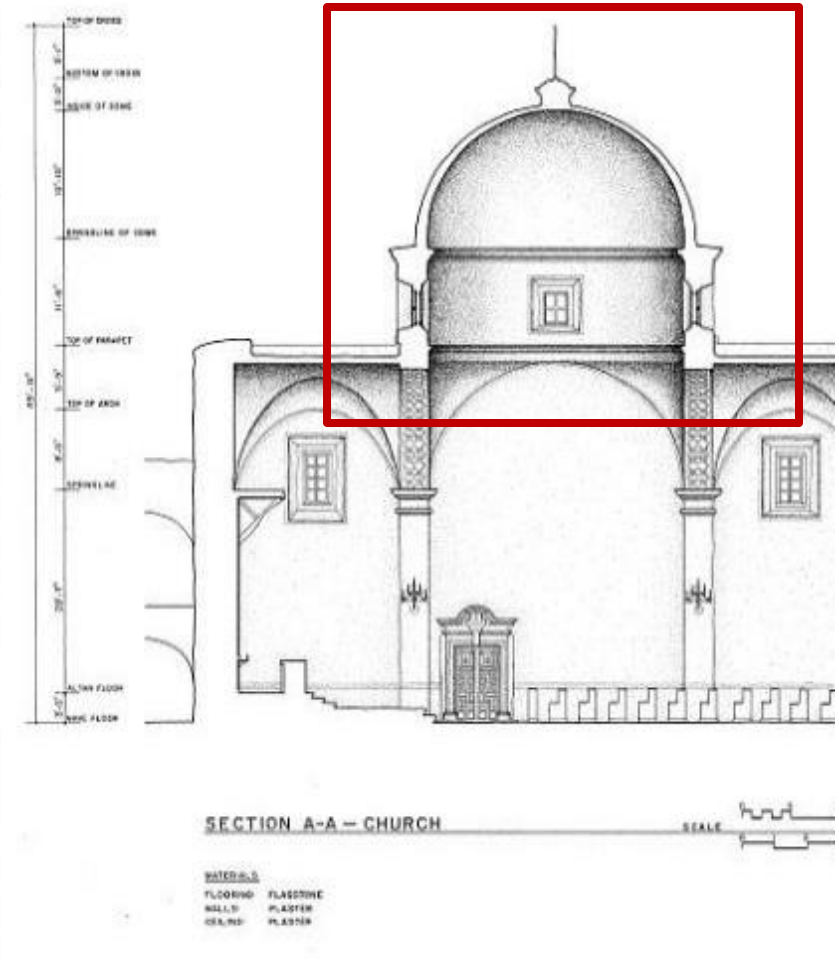
1930 HABS drawings



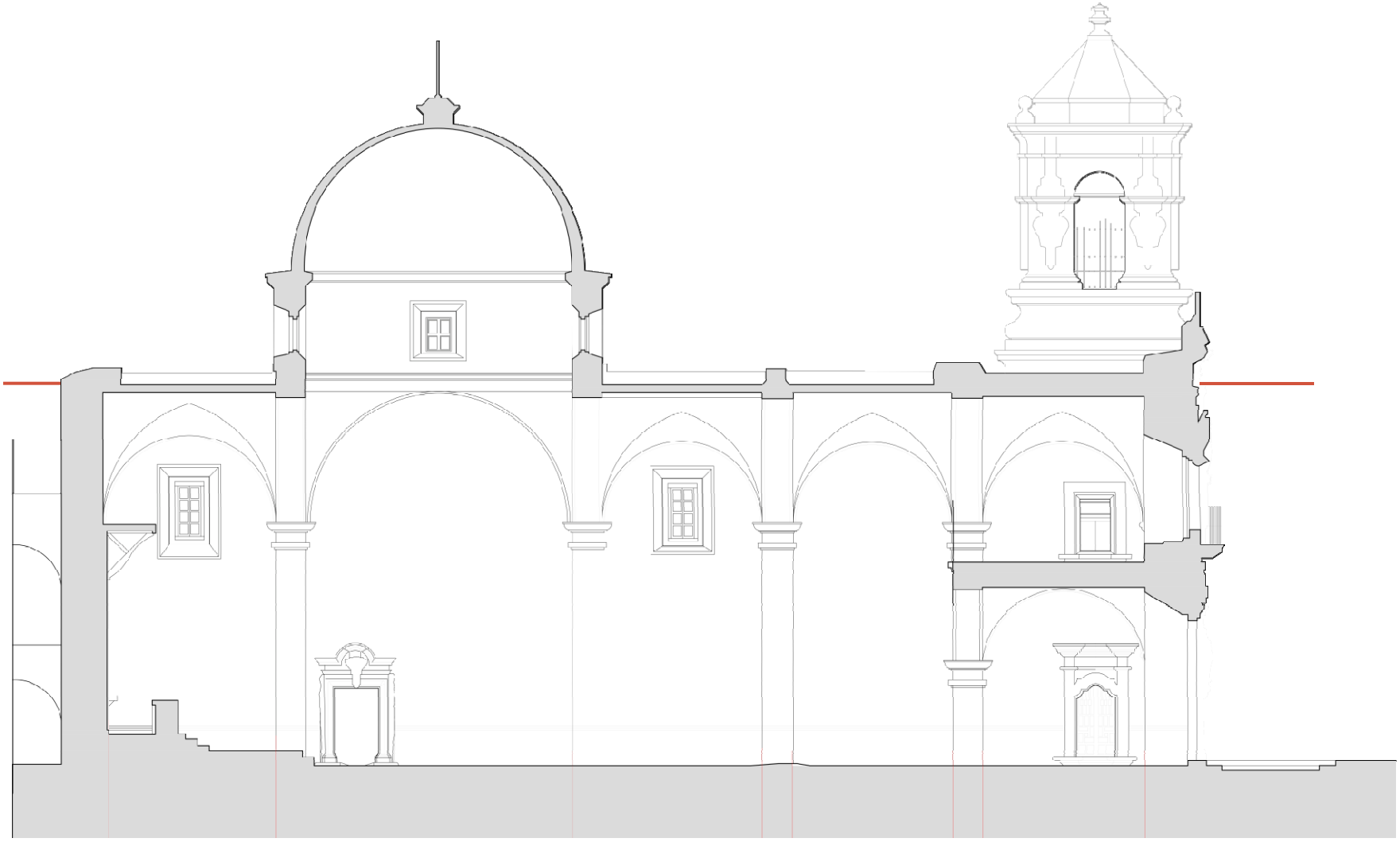
1986 HABS drawings

ANALYSIS OF THE CHURCH: Architectural survey

- CONSTRAINTS
- The survey was not able to verify:
- the longitudinal wall thickness
- the thickness of the dome structures,
- for the main façade, the total height of the bell tower and the dome dimension.



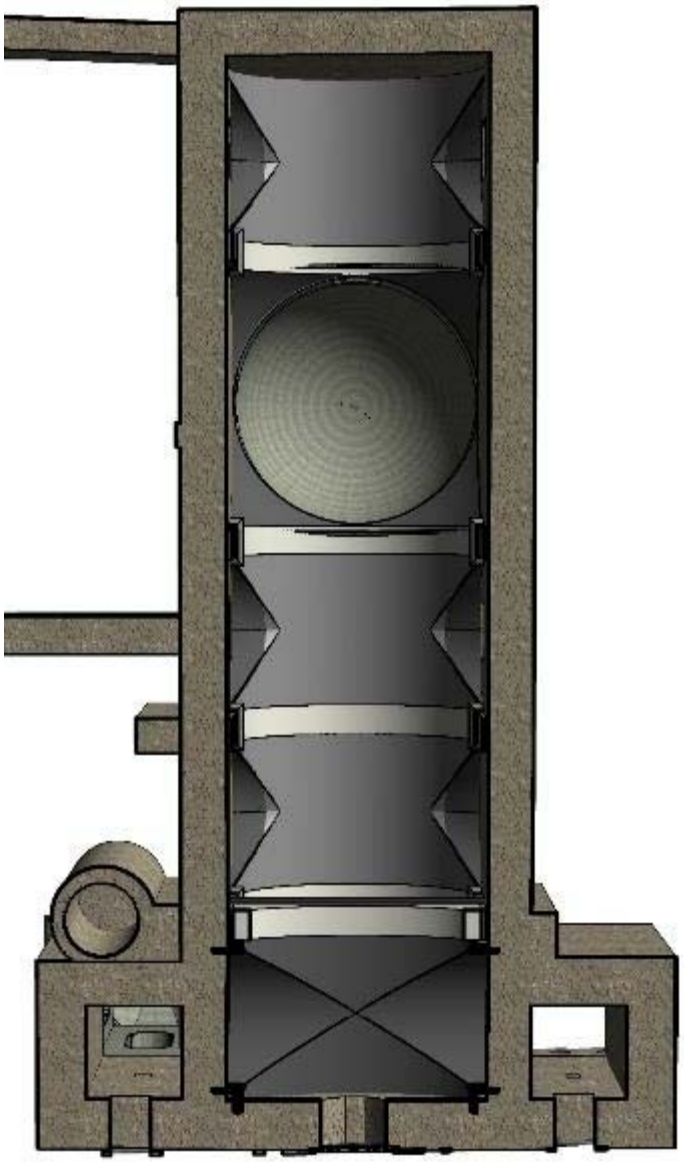
Portion of Longitunal Section (HABS 1986)



Our survey: Longitudinal section facing South

Our survey: Photo-elevation of the Southern Facade

Our survey: 3D model



3D model showing vaulted ceilings:
Bays are covered by barrel vaults with lumettes
Bays are separated by transverse arches
Dome has a circular plan, elevated on a drum.
Pendantifs connect the square base to the round drum

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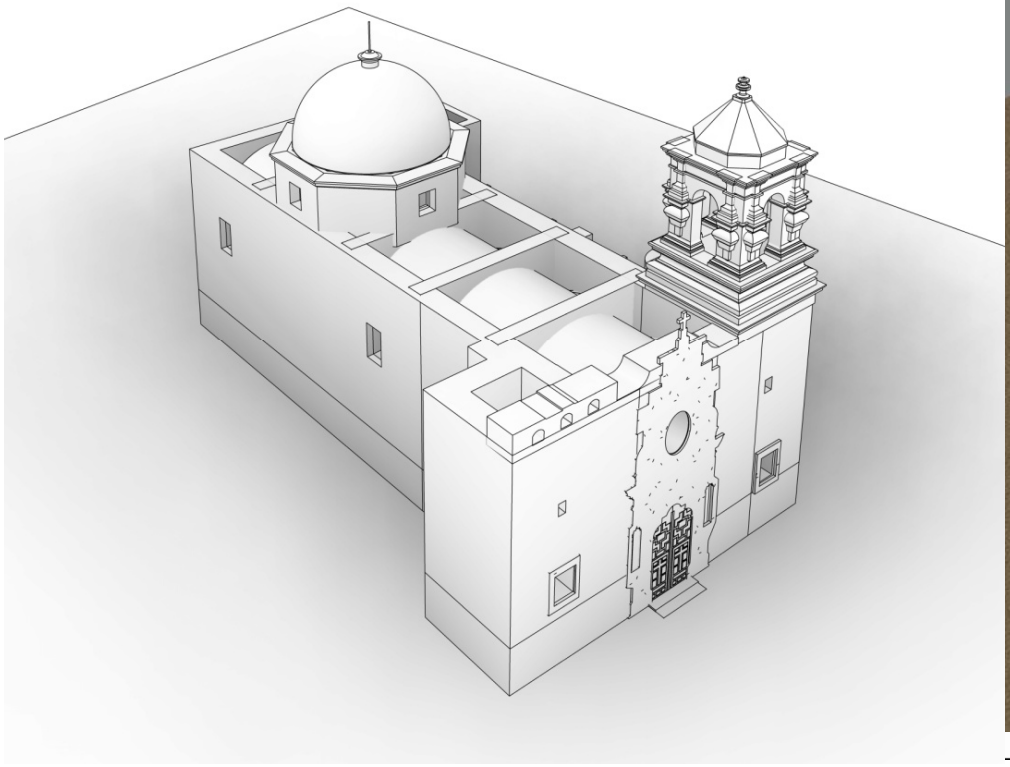
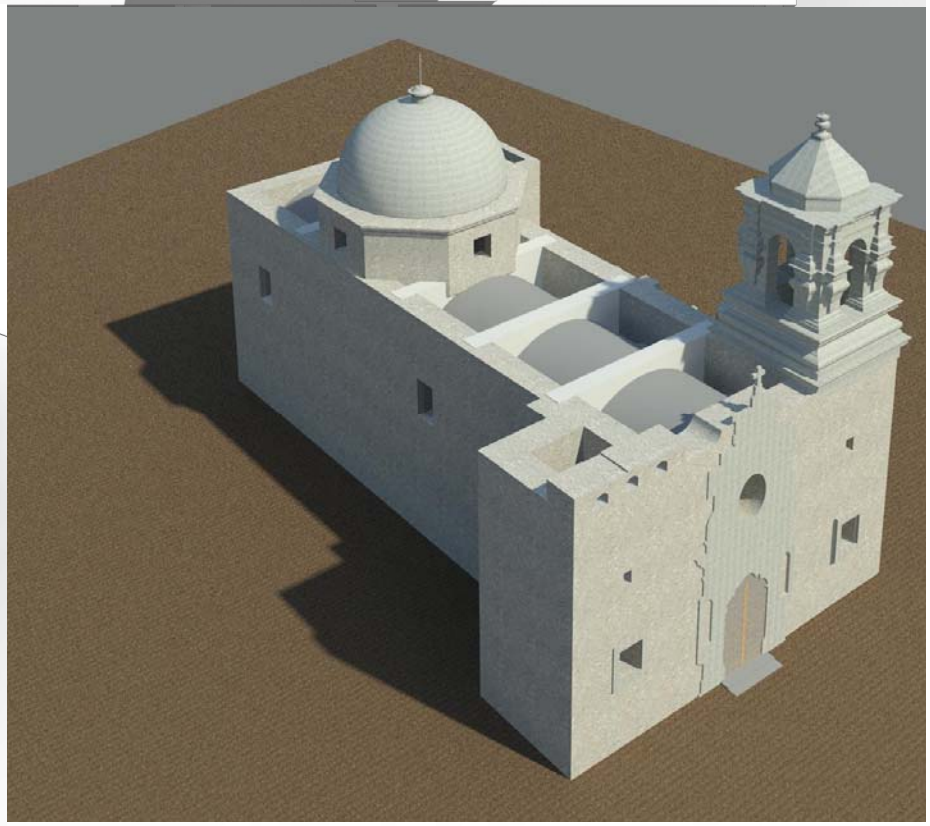
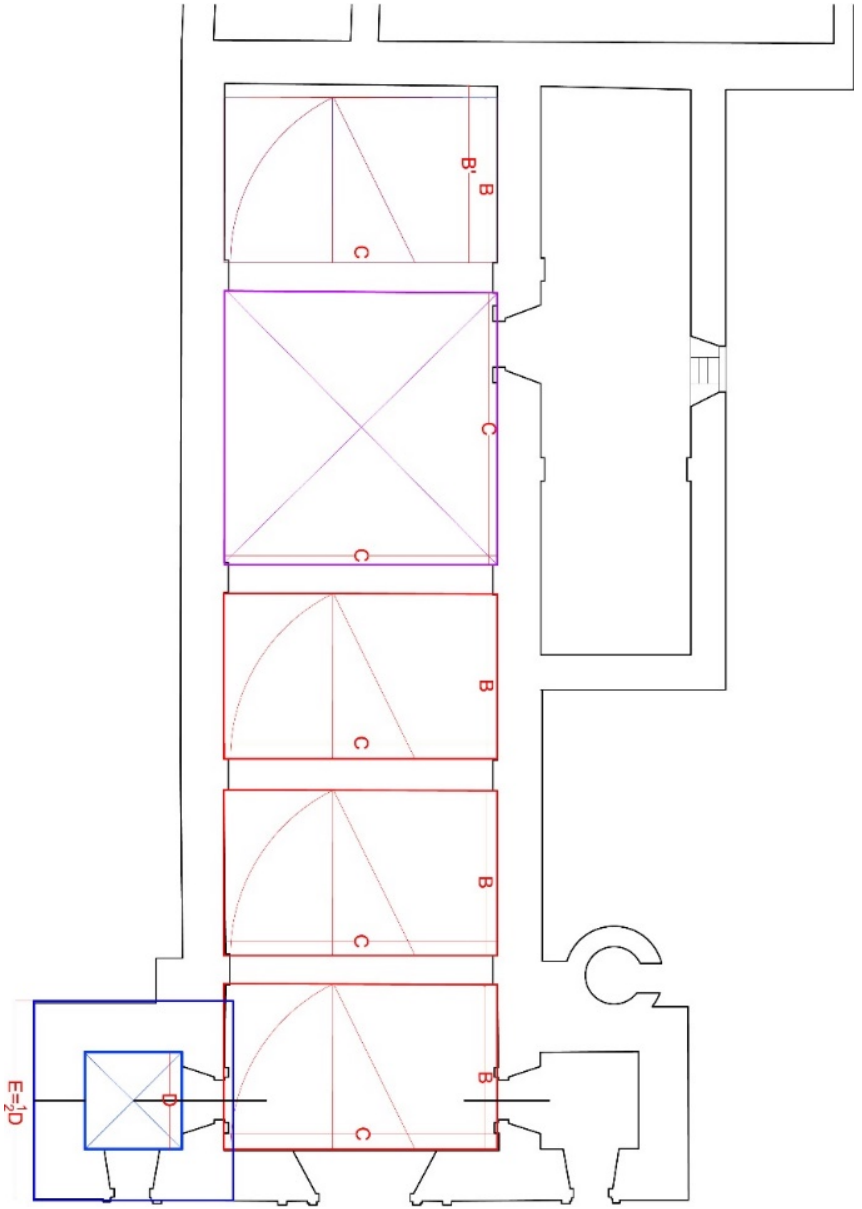


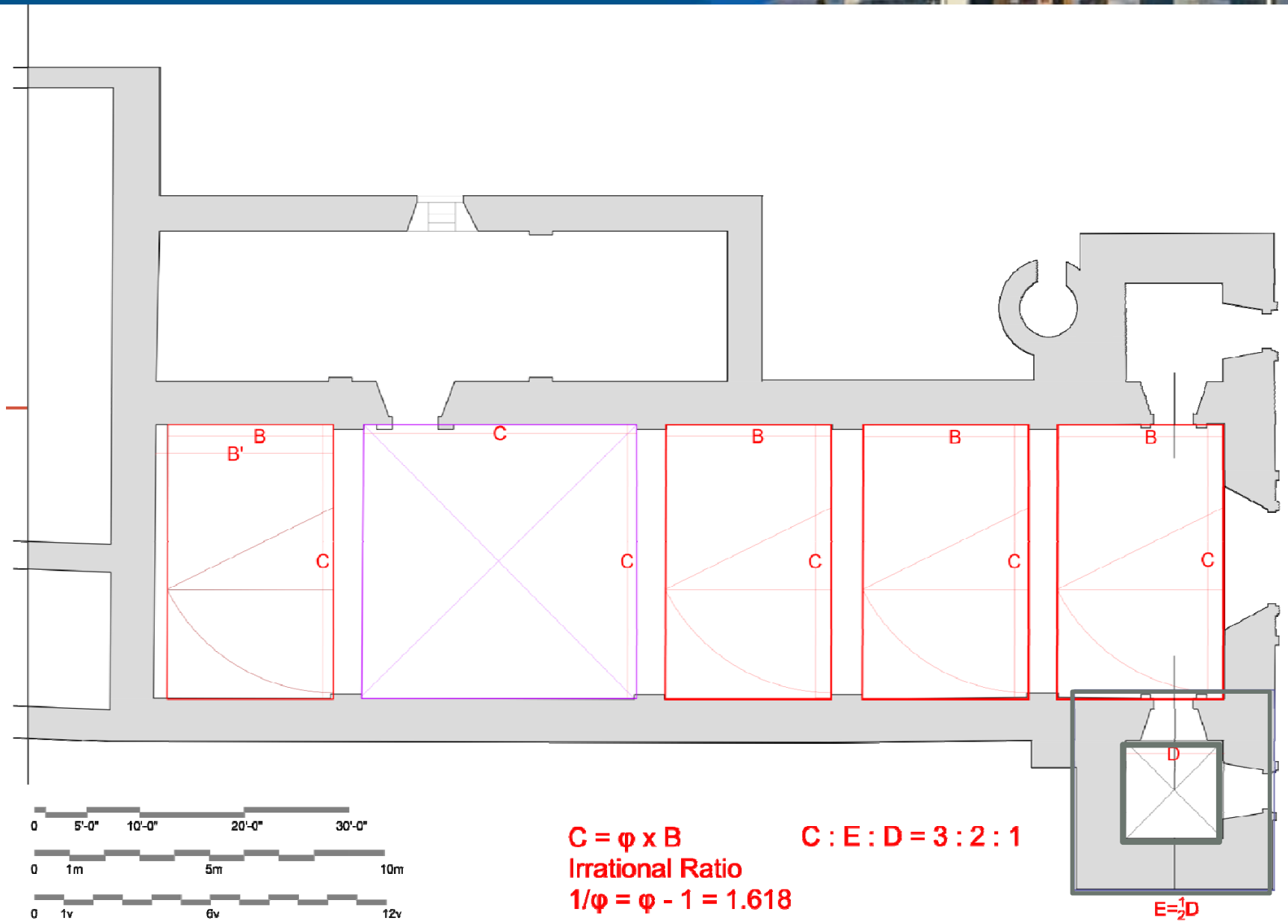


ANALYSIS of the CHURCH DESIGN CRITERIA: METROLOGY and PROPORTIONS

The survey and analysis of the proportioning system show that the simple rectangular form of the church plan has been designed following a rhythmical proportioning system, based on the SQUARE and the GOLDEN SECTION



Our survey: Plan of the church with notes on proportioning

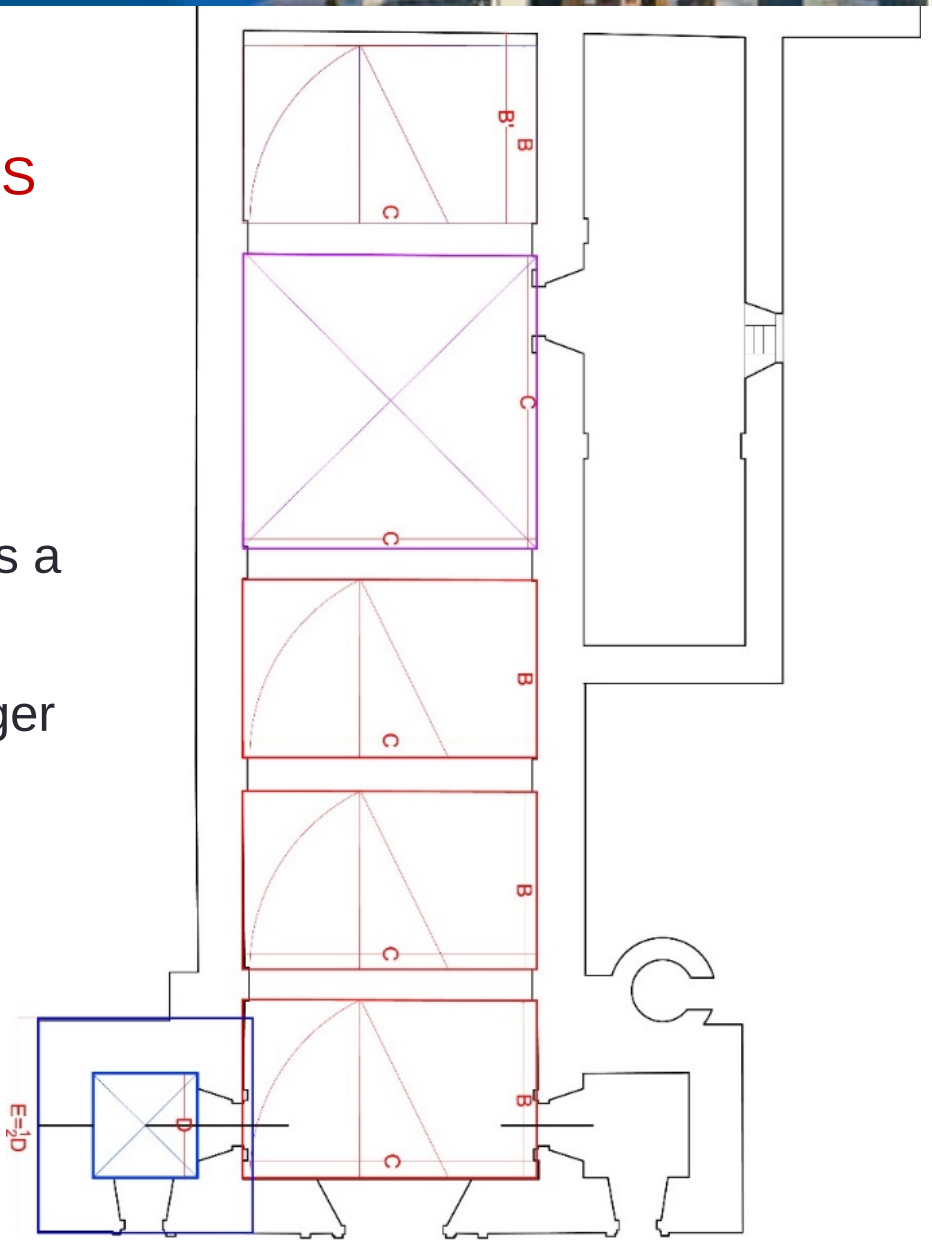

B
B'
C
B
B
B
C
C
C
C
C
D
E=½D
0 5'-0" 10'-0" 20'-0" 30'-0"
0 1m 5m 10m
0 1v 6v 12v
C = φ x B
Irrational Ratio
1/φ = φ - 1 = 1.618
C : E : D = 3 : 2 : 1

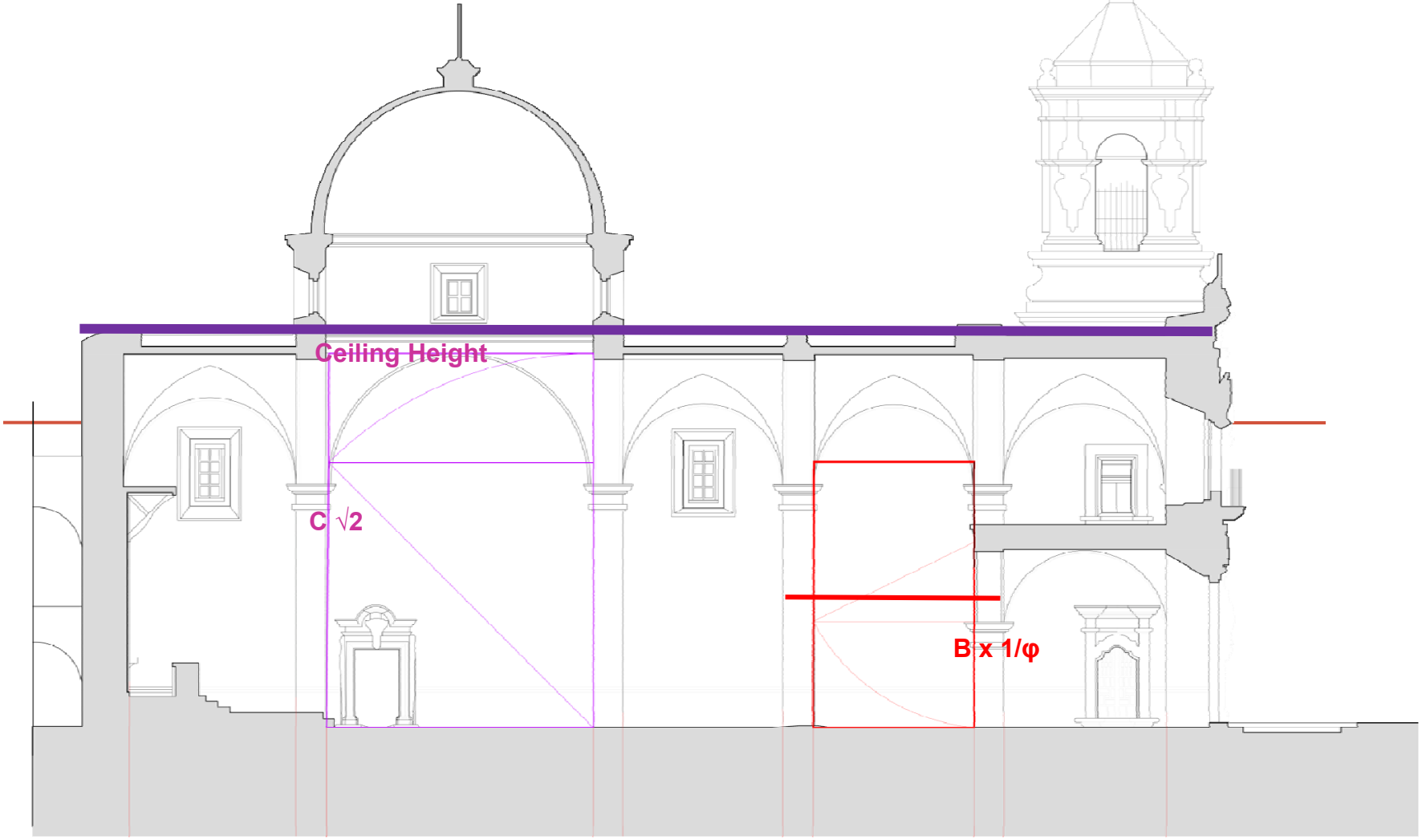
ANALYSIS of the CHURCH:
DESIGN CRITERIA:
METROLOGY and PROPORTIONS

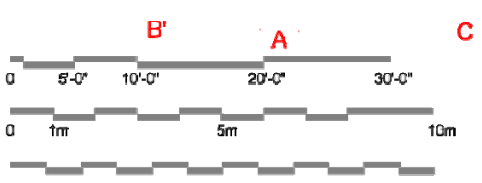
If we designate
the standard bay with the letter B,
the pilaster's width with letter A:

the sequence of bays can be read as a tripartite group,
followed by the center of the whole composition, characterized by a longer bay, C (with the form of a perfect square),
and finally ending with a bay slightly longer than the standard one, here designated as B'.
In combination the whole reads:

B-A – B-A – B-A – C-A – B'.



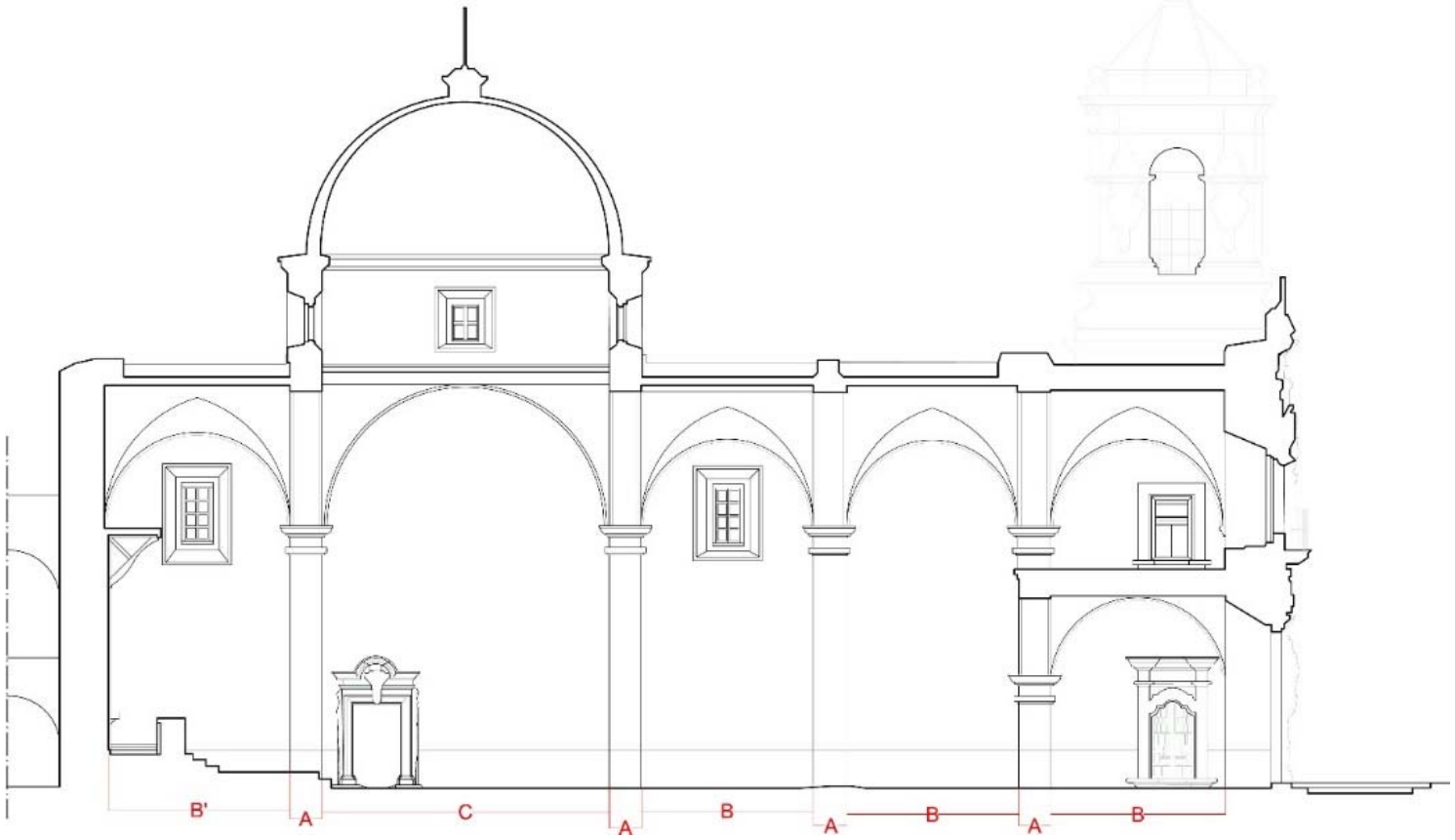




A B A B A B

Our survey: Longitudinal section facing South

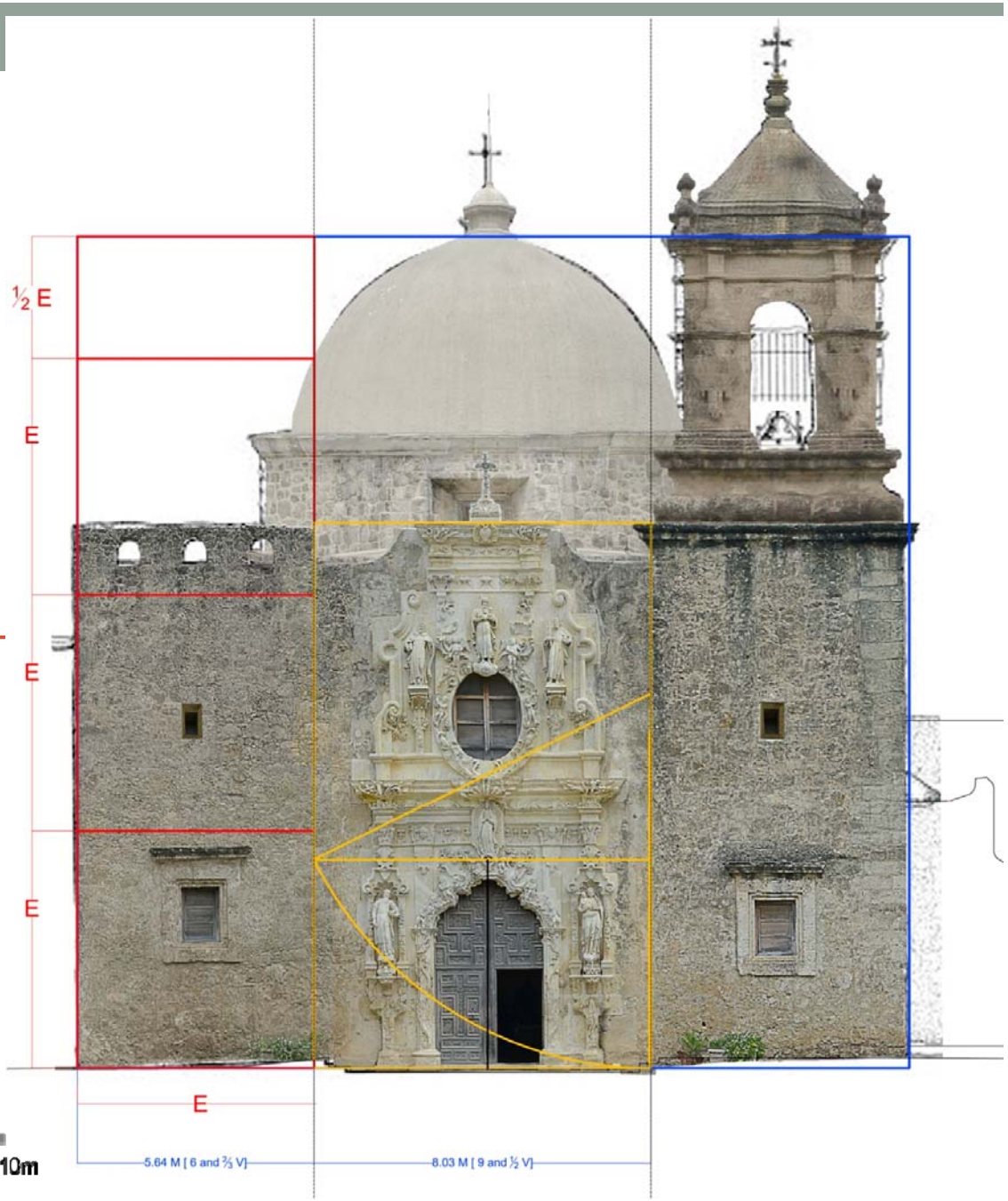
Although bays do not have the same size, there is a clear research of ‘eurithmia’ in the church layout, where the adoption of an even number of bays introduces hierarchy in the rhythmical sequence.

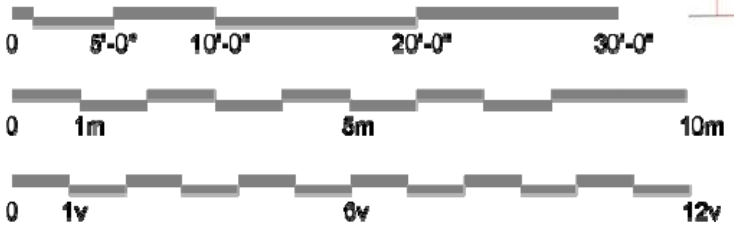


B-A – B-A – B-A – C-A – B’

Eurythmia, *symmetria* and classical geometrical proportioning systems are clearly applied by the church builders.

Our survey:
Photoelevation of the west façade
Showing the proportioning
System based on the square





RECONSTRUCTIONS

- On December 10, 1864, part of the North wall of the church collapsed.
- The roof crashed on December 25, 1874, during Christmas celebrations on a stormy night (Habig, 1958).
- The steps of the spiral staircase beside the tower had laid scattered since 1903, they were put back in 1920 (Habig, 1958).
- The tower had in some way lost its structural integrity. On March 9, 1928, the bell tower also collapsed. The tower reconstruction was the first of a series of projects, which lasted until 1941.

https://utsalibrariestopshelf.wordpress.com/2015/05/15/restoration-of-mission-san-jose/

- Storms are one of the causes of structural damage and can be considered one of the causes of collapse, since internal pressure results when a breach occurs in the windward side of a building.

April 1928

https://utsalibrariestopshelf.wordpress.com/2015/05/15/restoration-of-mission-san-jose/

February 1935

https://utsalibrariestopshelf.wordpress.com/2015/05/15/restoration-of-mission-san-jose/

November 1935

https://utsalibrariestopshelf.wordpress.com/2015/05/15/restoration-of-mission-san-jose/

VISUAL ASSESSMENT OF THE CHURCH

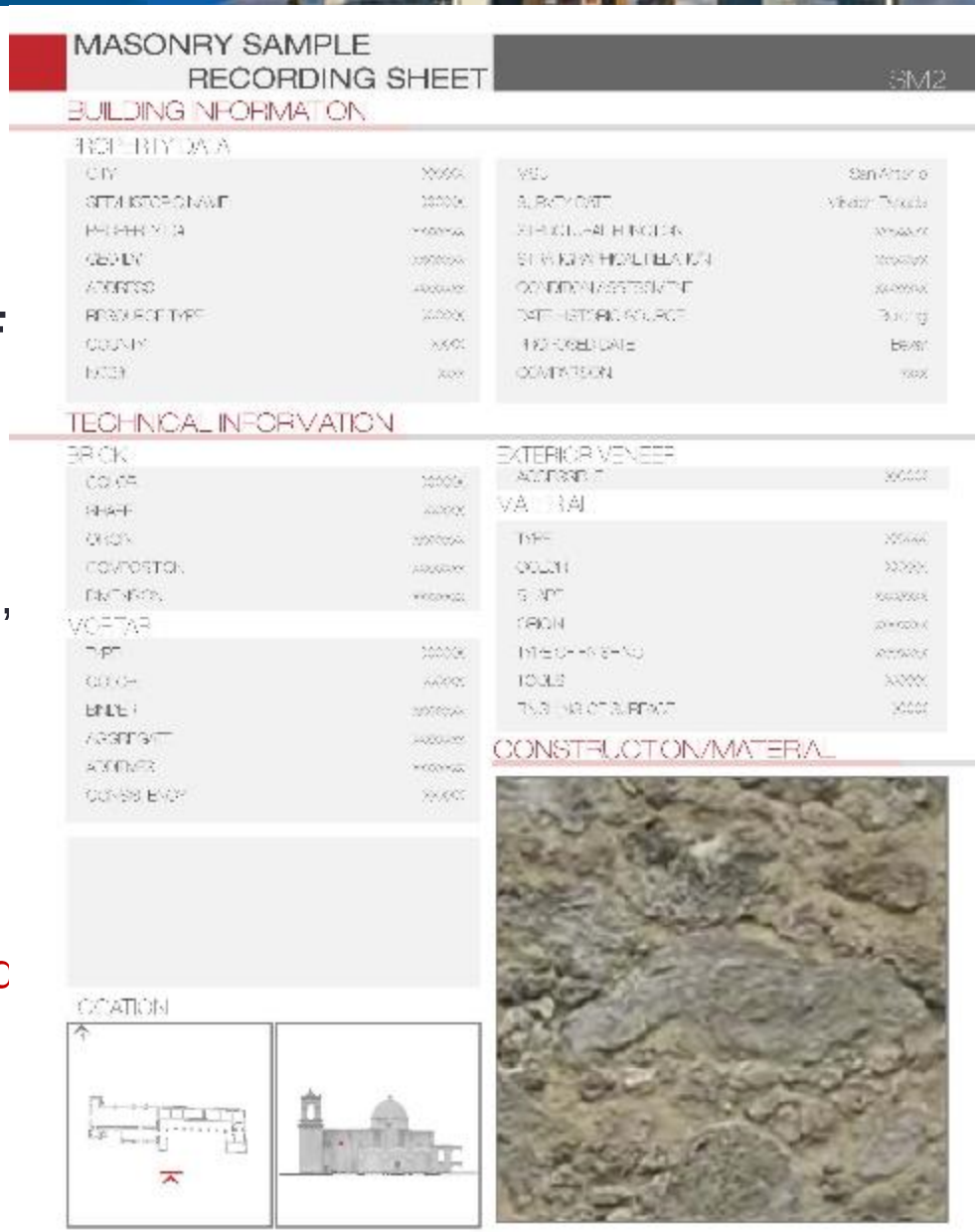
ELEMENTS INFLUENCING MECHANICAL CARACTERISTICS OF THE WALL:

- Type, form and dimensions of the stones:

stones can have different forms i.e. ashlar stones, hammer-dressed stones, cut and roughly squared stones;

- Presence of headers the connecting facing walls;
- Presence of regular horizontal courses, uneven courses, or random courses;
- Effective bonding between stones and regular staggering of mortar joints;
- Mortar type, composition and deterioration.

(Giuffre, 1990).

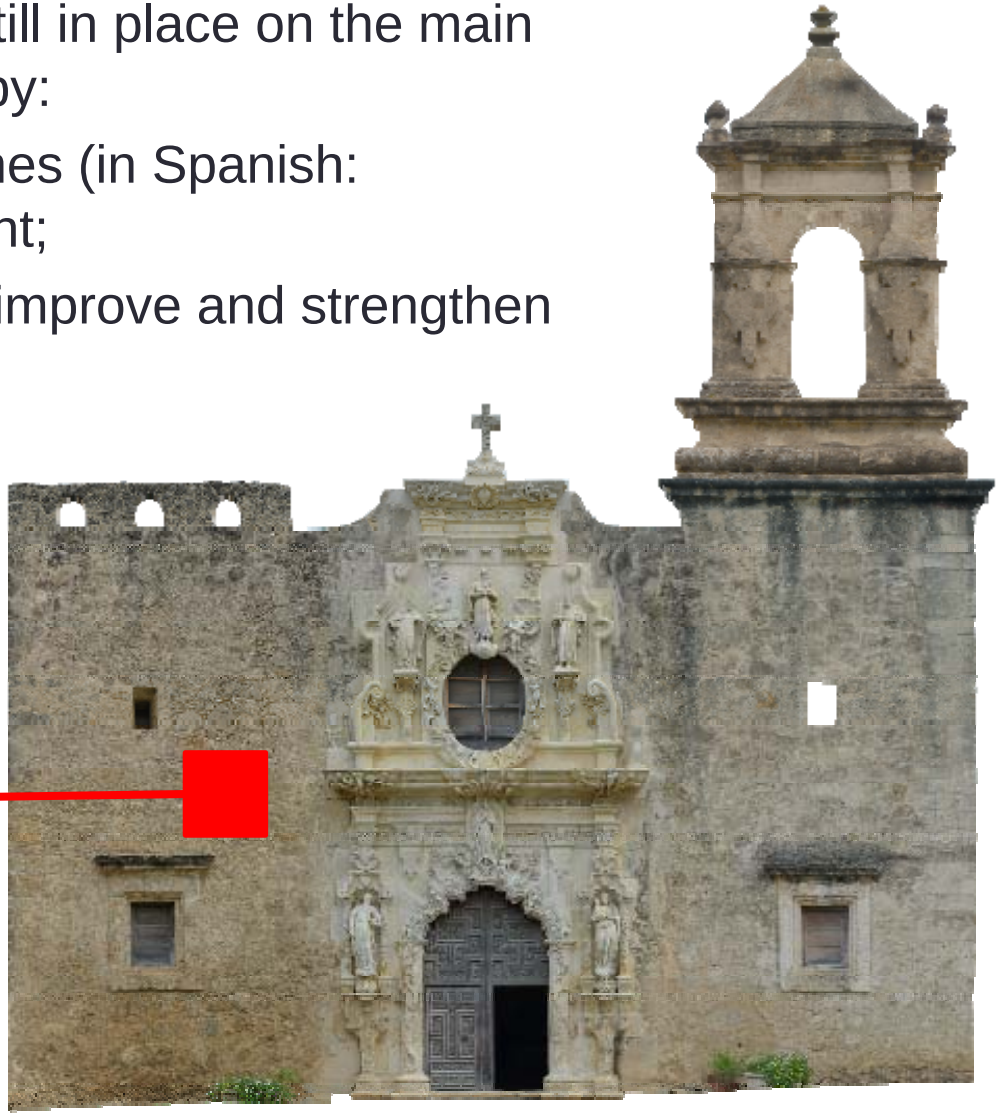


VISUAL ASSESSMENT OF THE CHURCH

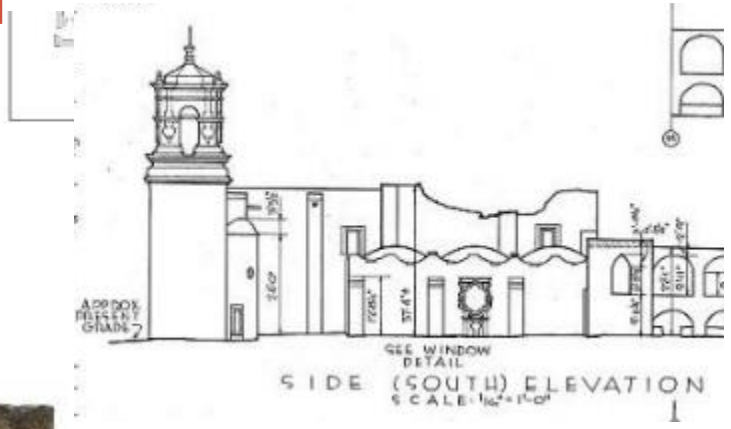
- Original 18th century masonry, still in place on the main façade (west), is characterized by:
- - presence of small livers of stones (in Spanish: *rajuelas*) between the mortar joint;
- - irregular horizontal courses to improve and strengthen the masonry.
- -Original mortar is lime based,
- with yellowish color and friable.

- Façade is finished
- with remnants of stucco.

Masonry samples are 1mt x 1mt



VISUAL ASSESSMENT OF THE CHURCH



View of southern façade with masonry samples units

- Rubble masonry is commonly adopted in 18th century buildings both in Mexico and Europe.

Both mortar and small livers of stones into the mortar joints have key role in improving mechanical characteristics.

In blue: original walls

Visual assessment of the church

In this elevation: In blue: original walls

- RECONSTRUCTED 20TH CENTURY MASONRY IN THE AREA OF THE BELL TOWER:

- Very similar to the original one, with no use of small stone livers.
- Ashlar quoins.

Visual assessment of the church

- Reconstructed 20th century masonry on the northern wall is also made of irregular lime stones.
- - No small slivers of stones or horizontal courses have been observed;
- - Possible adoption of cement-based mortar;

Northern photo elevation:
In blue - original walls

Northern photo elevation with masonry Samples

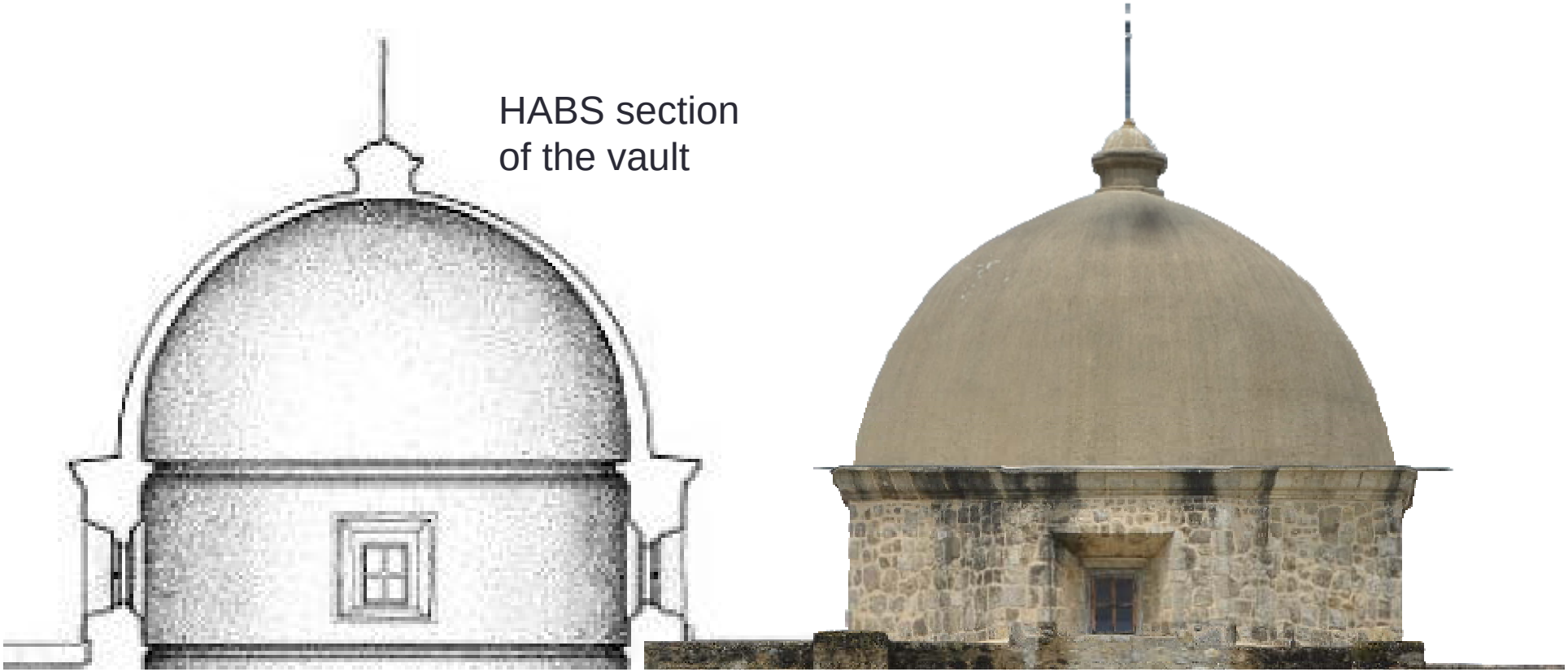
VISUAL ASSESSMENT OF THE CHURCH

- RECONSTRUCTED 20TH CENTURY MASONRY ON THE DRUM:
- quasi squared blocks laid in parallel with horizontal courses;
- for the mortar, possible adoption of cement-based mortar.

View of the dome in the southern facade

Notes on reconstruction

The HABS drawings, drafted by Harvey P. Smith after the church reconstruction, show an extremely thin dome section, the adoption of reinforced concrete.



HABS section
of the vault

VISUAL ASSESSMENT OF THE CHURCH

- From the building survey and analysis,
- it is understood that the northern wall
- was repaired by using rubble stone masonry units, with the adoption of cement based mortar;

Northern photo elevation:
In blue - original walls

Northern photo elevation with masonry Samples

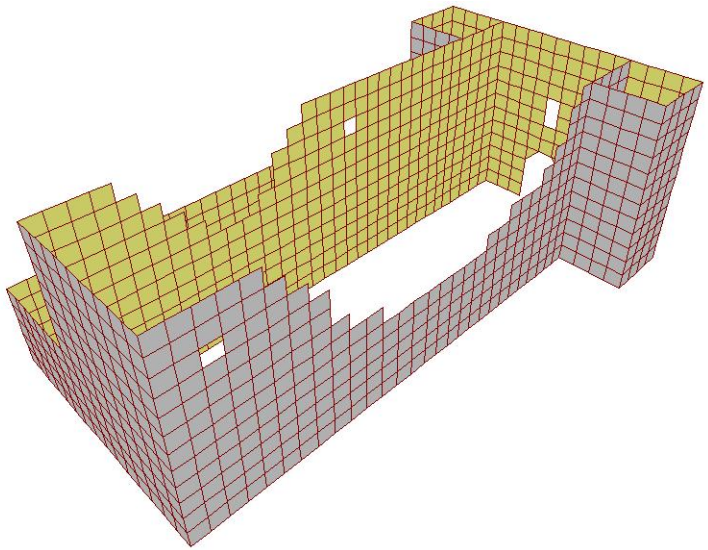
FINITE ELEMENT MODEL AND STRUCTURAL ANALYSIS OF THE CHURCH

- Gravity and wind loads applied.
- Finite element models have been developed to represent the collapsed and repaired conditions of the structure.
- Using the most unfavorable conditions, wind loads have been applied on the structure as a combination of:

  - **1.44 kN/m^2 windward** and

  - **0.86 kN/m^2** leeward pressure (Ochshorn, 2009).

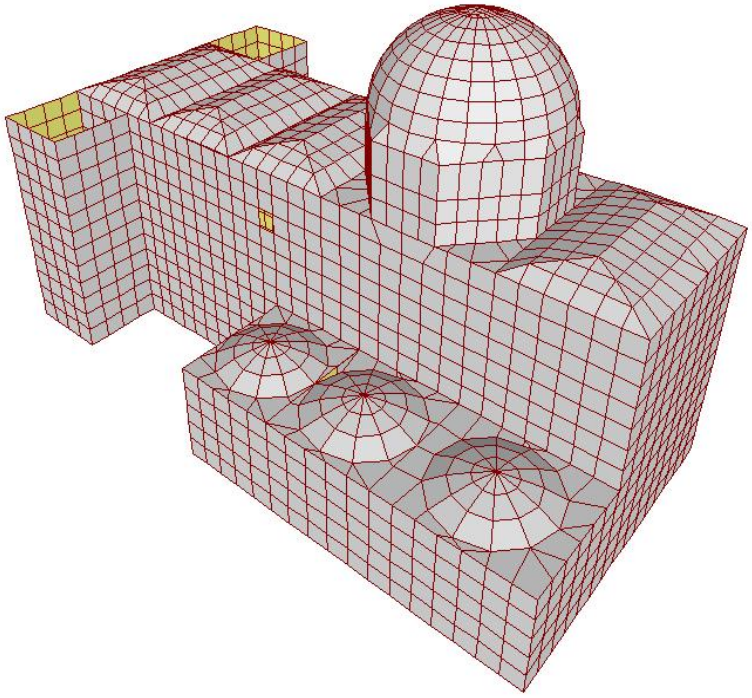
- All the results have been given and discussed as a **combination of gravity loads and wind loads (G + W).**



Finite element model of the collapsed structure

FINITE ELEMENT MODEL AND STRUCTURAL ANALYSIS OF THE CHURCH

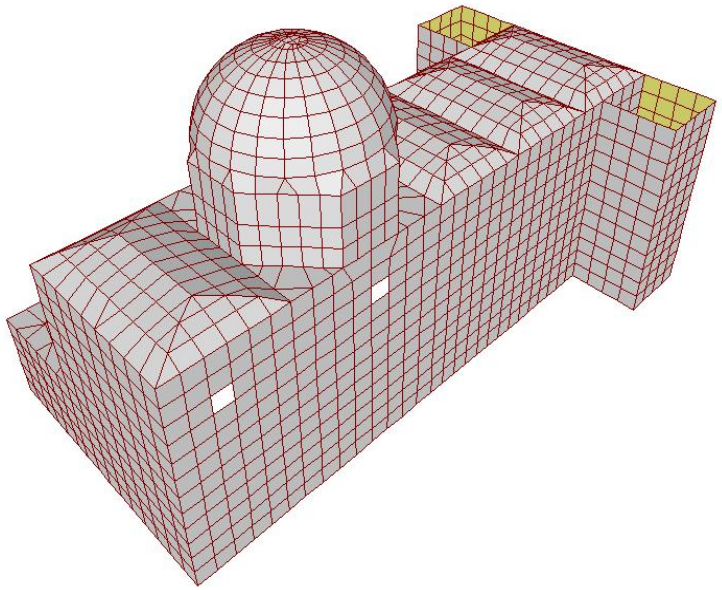
- The majority of the structure, mainly the vaults and walls, have been **modeled by linear elastic SHELL elements**.
- The model has been prepared by using **2,366 nodes and 2,414 SHELL elements**.
- **'Thick shell' option has been chosen for the members** that represent the thick walls. This option enables obtaining more detailed stress values both at the exterior surfaces and within the inner section.



Finite element model
of the recontructed structure

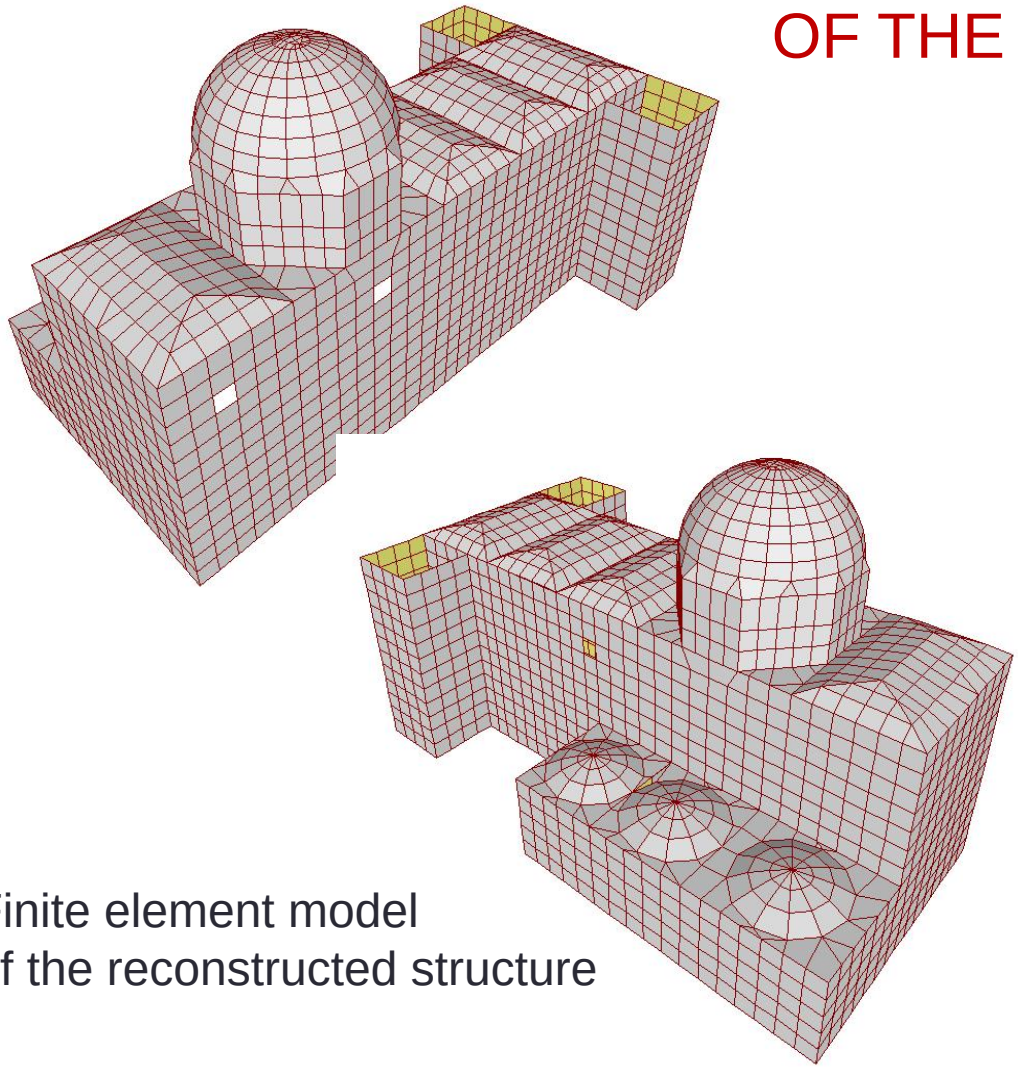
FINITE ELEMENT MODEL AND STRUCTURAL ANALYSIS OF THE CHURCH

- **Boundary conditions** of structural model have been expressed as fixed supports, which demonstrate actual soil conditions.
- **Properties** of the structural materials have been obtained from international literature regarding similar type of structures
  (Borri et al., 2008).
- **Modulus of Elasticity** values and **unit weights** have been specified with the **assumption of perfect unity between mortar and brick or stone masonry units**.
- **450 MPa** for stone masonry vaults and dome
- **28500 MPa** for reinforced concrete dome and vaults

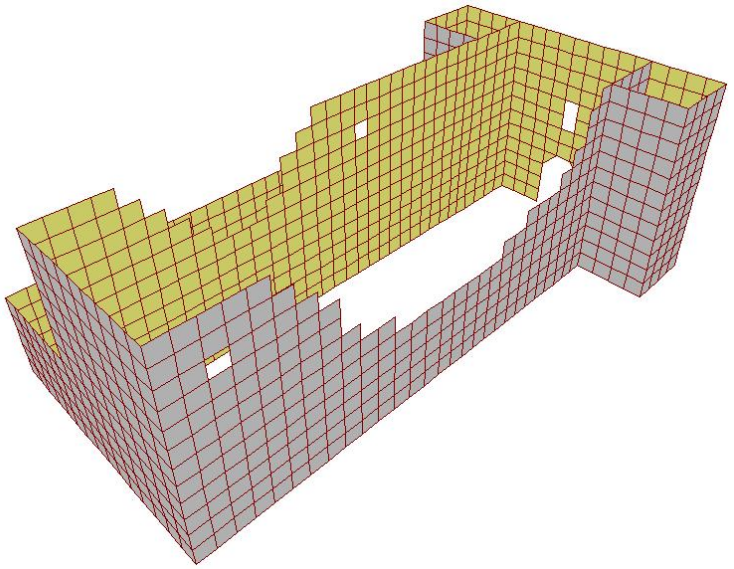


Finite element model
of the reconstructed structure

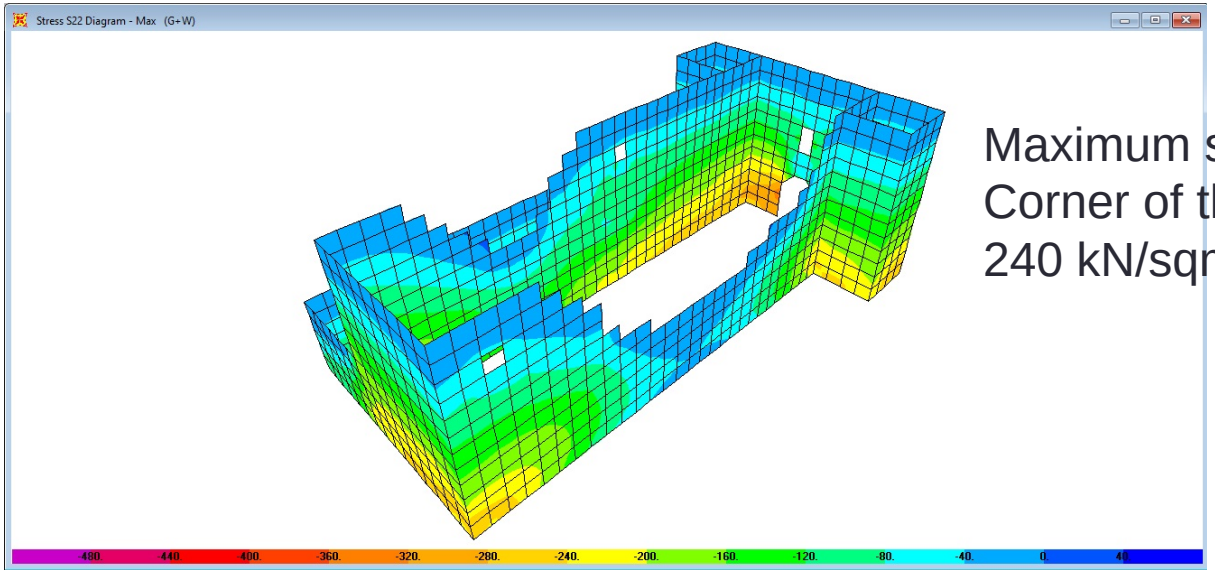
FINITE ELEMENT MODEL AND STRUCTURAL ANALYSIS OF THE CHURCH



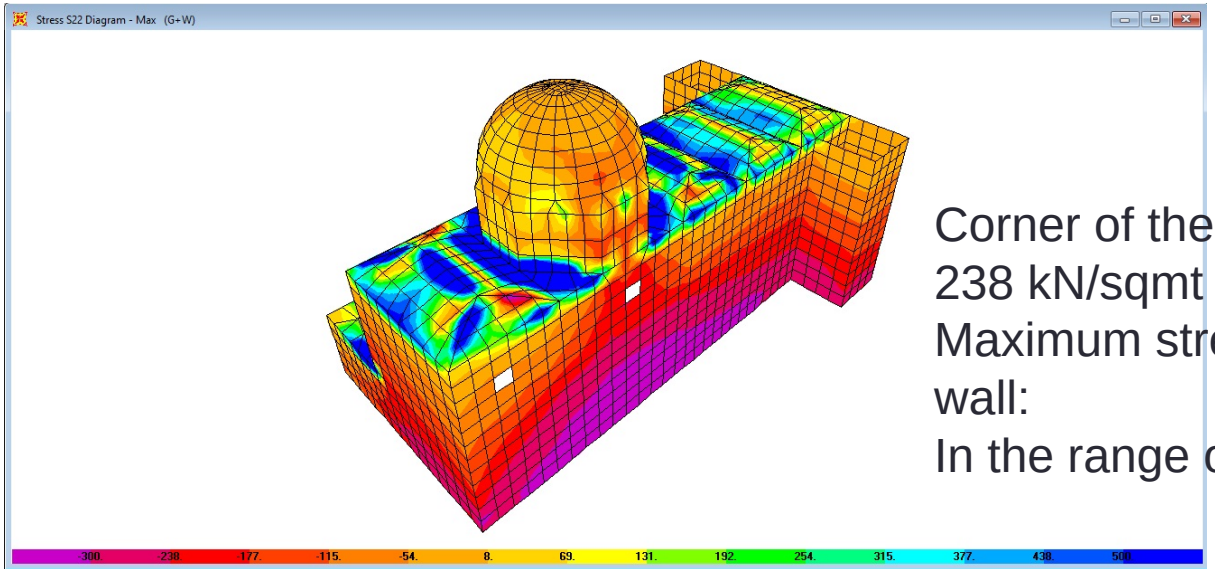
Finite element model
of the reconstructed structure



Finite element model
of the collapsed structure

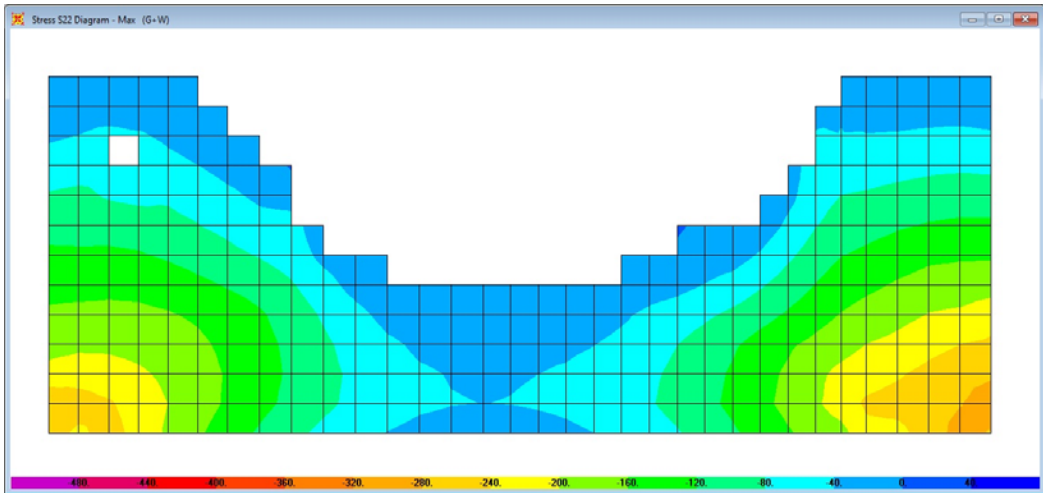


Maximum stress values:
Corner of the bottom of collapsed wall:
240 kN/sqmt – 280 kN/sqmt



Corner of the bottom of collapsed wall:
238 kN/sqmt – 300kN/sqmt
Maximum stress values at the base of the wall:
In the range of 300 kN/sqmt- 362 kN/sqmt

Stress distribution in the collapsed and reconstructed structure



Maximum stress values:
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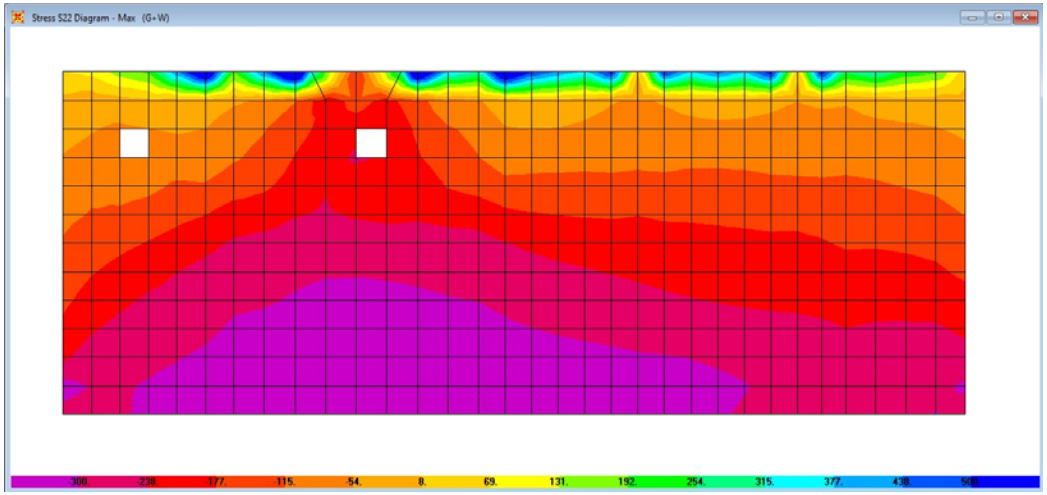
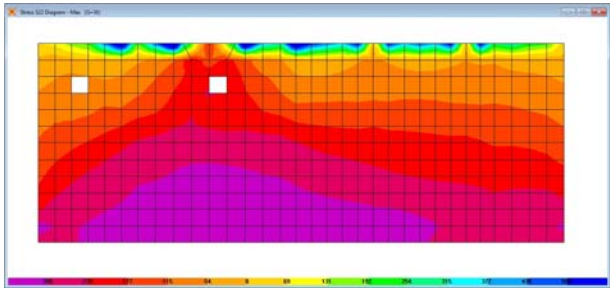


Corner of the bottom of collapsed wall:
238 kN/sqmt – 300kN/sqmt
Maximum stress values at the base of the wall:
In the range of 300 kN/sqmt-362 kN/sqmt

Stress distribution in the collapsed and reconstructed structure

Conclusions

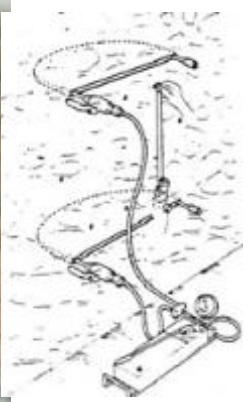
- Due to the lack of seismic incidents in the region, the structure was analyzed only under gravity loads and wind loads.
- For San Jose Mission Church,
- the results of the gravity and wind analysis show that the structure is safe;
- the increase in the compressive stress values at the base of the wall due to the addition of a reinforced concrete dome and vaults do not pose a threat to its overall stability.



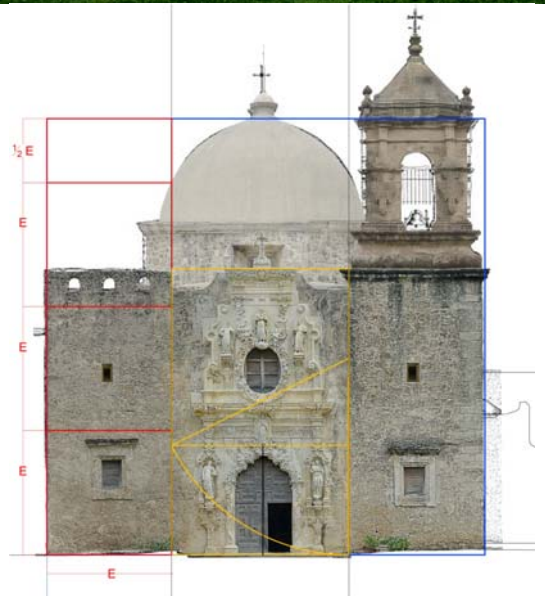
Conclusions

- For the structural performance of the building, any possible deterioration in the structural materials would cause weakening in the overall structural system.

- The mechanical properties that have been taken from literature based on research on similar structures may not reflect the actual performance of the materials. The most accurate results could be obtained by testing the materials. Therefore, further studies on Mission San Jose church could involve material tests for actual mechanical properties of the structural materials.



Thank you



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